European Commission

JRC TECHNICAL REPORTS

Ecodesign and Energy Label for Household Washing machines and washer dryers

Preparatory study
Final report

Boyano A., Cordella M., Espinosa N., Villanueva A. (JRC-EC)
Graulich K., Rüdenauer I. (Öko-Institut),
Alborzi F., Hook I., Stamminger R., (University of Bonn)
(*in alphabetical order)*

2017

Joint Research Centre

EUR 28809 EN

Contact information
Name: Alejandro Villanueva
Email: Alejandro.VILLANUEVA@ec.europa.eu
Tel.: +34 9544-88485

JRC Science Hub
https://ec.europa.eu/jrc

JRC109033

EUR 28809 EN

PDF ISBN 978-92-79-74183-8 ISSN 1831-9424 doi:10.2760/029939

Luxembourg: Publications Office of the European Union, 2017

How to cite this report: Boyano Larriba, A., Cordella, M., Espinosa Martinez, M., Villanueva Krzyzaniak, A., Graulich, K., Rüdinauer, I., Alborzi, F., Hook, I. and Stamminger, R., Ecodesign and Energy Label for household washing machines and washer dryers, EUR 28809 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-74183-8, doi:10.2760/029939, JRC109033

Table of contents

List of tables

List of Figures

Acronyms

ABS	Acrylonitrile butadiene styrene
ADD	Additional (policy options)
AEC	Annual Energy Consumption
Al	Aluminium
BAT	Best available technology
BAU	Business as usual
BC	Base Case
BEC	Base Energy Consumption
BNAT	Best not yet available technology
BoM	Bill of Material
c	rated capacity
CE	European Conformity
CEC	Comparative Energy Consumption
CENELEC	European Committee for Electrotechnical Standardization
CFR	U.S. Code of Federal Regulations
CLP	Classification and packaging of substances and mixtures
Cr	Chromium
Cu	Copper
d	discount rate
DG	Directorate-General
DoC	Declaration of Conformity
DOE	US Department of Energy
e	escalation rate
E	Energy consumption
EC	European Commission
ED	Ecodesign
EEE	Electrical and Electronic Equipment
EEI	Energy Efficiency Index
EMC	Electromagnetic Compatibility
EL	Energy Label
EMC	Electromagnetic Compatibility
EN	European Norm
EoL	End-of-life / costs for end-of-life
EPDM	Ethylene Propylene Diene Monomer

EPS	Expanded polystyrene
ESOs	European Standardisation Organisations
ETSI	European Telecommunications Standards Institute
EU	European Union
FDIS	Final Draft International Standard
FTC	US Federal Trade Commission
GHG	Green-house gases
HFCs	Fluorinated hydrocarbons
HICP	Harmonised Index of Consumer Price
HiNa	High Network Availability
HP	Heat pump
IA	Impact Assessment
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
ISO	International Standardisation Organisation
LB	Label Based
LCC	Life-cycle costs
LLCC	Least life-cycle costs
LVD	Low Voltage Directive
MB	Market Based
MD	Machinery Directive
MEErP	Methodology for the Evaluation of Energy related Products
MRC	Maintenance and repair costs
N	product life (years)
N.A.	Not available / not affected
OC	(Annual) operating costs
OE	Annual operating expense
OEM	Original Equipment Manufacturer
ORP	Observed Retail Price
OLD	old (policy scenario)
ONR	Standard by the Austrian Standards Institute
P	Power
PA	Polyamide
PAS	Publicly Available Specification
PBB	Polybrominated biphenyl
PBDE	Polybrominated diphenylether

PBT	Pay-back time
PC	(Total) product costs
PCB	Printed Circuit Board
PE	Polyethylene
PMMA	Poly(methyl methacrylate)
POM	Polyoxymethylene
PP	Polypropylene
PP	Purchase price (incl. installation costs) (€)
ppm	parts per million
PS	Polystyrene
PU	Polyurethane
PUR	Polyurethane
PVC	Polyvinylchloride
PWB	Printed Wiring Board
PWF	Present worth factor
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	Restriction of Hazardous Substances
rpm	Revolutions per minute
RRP	Recommended Retail Price
RRT	Round Robin Test
SAEC	Standard Annual Energy Consumption
Std	Standard
VAT	Value added tax
T	Time
TC	Technical Committee
TD	Tumble Dryer
TWG	Technical Working Group
TWGM	Technical Working Group Meeting
UK	United Kingdom
US	United States
VA	Voluntary Agreement
WD	Washer-dryer
WEEE	Waste electrical and electronic equipment
WM	Washing machine
Zn	Zinc

Introduction

Background

The Directive 2009/125/EC on Ecodesign establishes a framework for EU Ecodesign requirements for energy-related proiducts with a significant potential for reduction of energy consumption. The implementation of such requirements would contribute to reach the target of saving 20% of primary energy by 2020 as identified in the Commission's Communications on Energy 2020 (European Commission 2010c) and on the Energy Efficiency Plan 2011 (European Commission 2011). Ecodesign measures can be reinforced also through the Directive 2010/30/EU (currently under revision) on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

The European Commission has launched the revision of the Ecodesign and Energy-/Resource label implementing measures for the product group 'household Washing Machines (WM) and Washer-Dryers (WD)'. The revision study is coordinated by the European Commission's DG Environment and DG Energy, and is undertaken by the Commission´s Joint Research Centre (JRC) with technical support from Oeko-Institut and the University of Bonn. The methodology of the revision follows the Commission’s Methodology for the Evaluation of Energy related Products (MEErP) (COWI and VHK 2011), consisting of the following steps:

- Task 1 – Scope definition, standard methods and legislation
- Task 2 – Market analysis
- Task 3 – Analysis of user behaviour and system aspects
- Task 4 – Analysis of technologies
- Task 5 – Environmental and economic assessment of base cases
- Task 6 – Assessment of design options
- Task 7 – Assessment of policy options

The comprehensive analysis of the product group following the steps above is indeed to feed as research evidence basis into the revision of the existing Energy Label Regulation (EC) 1061/2010 (European Commission 2010a) and the Ecodesign Regulation (EC) 1015/2010 on household washing machines (European Commission 2010b), as well as the Energy Label Directive 96/60/EC on household combined washer-dryers (European Commission 1996).

The research has been based on available scientific information and data, following a life-cycle thinking approach and engaging stakeholder experts in order to discuss on key issues and to develop wide consensus.

A set of information of interest included the former preparatory study (the so-called 'ENER Lot 14'), prepared in 2007 (ISIS 2007a) and the resulting regulations on Energy Label and Ecodesign for domestic washing machines. A generic review of the fitness of these policies moreover took place as part of the DG ENER project "Omnibus" (VHK et al. 2014). The Omnibus study identified a number of issues of these regulations where revision is advisable. Against this background, information has been revised, updated and integrated to reflect the current state of play, following the MEErP methodology.

Stakeholder consultation throughout the study

During the preparatory work a continuous stakeholder consultation has taken place. An online communication system BATIS has been set-up for easy exchange of documents between registered stakeholders. A website was also made available to make working documents available in the public domain: http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/index.html.

A Technical Working Group (TWG) has been created in order to support the JRC along the study. This Technical Working Group is composed of experts from Member States, industry, NGOs and academia who have voluntarily requested for being registered as stakeholders of the study through the project website. The TWG has contributed to the study with data, information and written feedback to questionnaires and working documents. In particular, two physical meetings of the TWG have been organised:

- 1st Technical Working Group Meeting (TWGM): Seville, 24 June 2015
- 2nd Technical Working Group Meeting (TWGM): Brussels, 18 November 2015

Questionnaires for gathering information on scope, definitions, and issues of relevance for the revision as well as templates for the collection of data on energy consumption values, the definition of base cases and design options, and the discussion on policy options have been distributed to the TWG along the process. Further, the project team has visited different manufacturers, test labs, recyclers and a trade fair to investigate the product groups in detail and to stay up to date with the latest developments. Input from stakeholders has been integrated in this document to the extent possible.

Objectives and structure of this report

The objective of this report is to:

- Summarise the background information gathered for household washing machines and washer-dryers.
- Identify and investigate on areas which need to be revised, updated and integrated to reflect the current state of play and to align with the MEErP methodology.

The revision study is structured in the following chapters, following Tasks 1 to 7 of MEErP:

- Chapter 1 – Scope, legislation and standardisarion
- Chapter 2 – Markets, presenting economic and EU market data for washing machines and washer-dryers
- Chapter 3 – Users, analysis user behaviour and other system aspects;
- Chapter 4 – Technologies, analysing products from a technical point of view with a special focus on design, technologies, innovation and End-of-Life.
- Chapter 5: Environment and Economics, on definition and environmental and economic assessment of base cases
- Chapter 6: Design Options, on the analysis of design options implementing best available technologies and assessment of environmental and economic impacts;
- Chapter 7: Policy analysis and scenarios, on the analysis of policy options and the preliminary assessment of associated impacts.

As final result, this document represents an updated preparatory study including a comprehensive techno-economic and environmental assessment for this product group. This will provide policy makers with an evidence basis for assessing whether and how revising the existing regulations.

1. Task 1: Scope, legislation and standardisation

The aim of Task 1 is to analyse scope, definitions, standards and assessment methods and other legislation of relevance for the product group and to assess their suitability for the existing Ecodesign and Energy Label Regulations.

1.1. Product Scope

The following sections first provide an analysis of existing definitions of household washing machines and washer-dryers, as used for example in European statistics, EU legislation, standards and other voluntary initiatives such as ecolabels; followed by stakeholder feedback regarding the existing scope and definitions of the current EU Ecodesign and Energy label Regulations.

Based on this information and further research and evidence, a preliminary revised scope and revised definitions are proposed.

1.1.1. Existing definitions

The following section provides an overview of existing definitions of washing machines and washer-dryers given in key legislation, standards and other relevant policy instruments and statistics:

- Commission Regulations 1015/2010 and 1061/2010
- Commission Directive 96/60/EC
- Commission Regulations 932/2012 and 392/2012
- Standards IEC/EN 60456
- Standard EN 50229
- European statistics
- European Ecolabels
- US Energy Star
- Ecodesign Preparatory study Lot 24

The analysis shall support a revision of the scope and definitions of the Ecodesign and Energy Label Regulations of household washing machines and washer-dryers, if necessary.

1.1.1.1. Commission Regulations (EU) 1015/2010 and (EU) 1061/2010

The Commission Regulation 1015/2010 with regard to Ecodesign requirements for household washing machines (European Commission 2010b) and Commission Regulation 1061/2010 with regard to Energy Labelling of household washing machines (European Commission 2010a) apply to

> *'Electric mains-operated household washing machines and electric mains-operated household washing machines that can also be powered by batteries, including those sold for non-household use and built-in household washing machines.'*

For household washing machines and household combined washer-dryers, the following definitions are given, among the others:

> *'Household washing machine' means an automatic washing machine which cleans and rinses textiles using water which also has a spin extraction function and which is designed to be used principally for non-professional purposes.*
>
> *'Built-in household washing machine' means a household washing machine intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing.*
>
> *'Automatic washing machine' means a washing machine where the load is fully treated by the machine without the need for user intervention at any point during the programme.*
>
> *'Household combined washer-drier' means a household washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling.*

Specific Ecodesign requirements for household washing machines are further differentiated by the rated capacity of the appliance, i.e. the maximum mass of dry textiles of a particular type (white cotton items only, clearly defined in the performance measurement standards, cf. section 1.2.2.1) which the manufacturer declares can be treated in the washing machine on the programme selected, expressed in kilograms:

- Requirements regarding the Energy Efficiency Index (EEI):
  - Stricter for household washing machines with a rated capacity equal to or higher than 4 kg;
  - Lower for household washing machines with a rated capacity lower than 4 kg.
- Requirements regarding the Washing Efficiency Index (I_W):
  - Stricter for household washing machines with a rated capacity higher than 3 kg;
  - Lower for household washing machines with a rated capacity equal to or lower than 3 kg.
- Requirements regarding the Water Consumption (W_t):
  - As a linear function of the rated capacity for the standard cotton programmes.

1.1.1.2. Commission Directive 96/60/EC

The scope of Commission Directive 96/60/EC with regard to Energy Labelling of household combined washer-dryers is defined as follows (without providing further definition of 'combined washer-dryers'):

> *'Electric mains operated household combined washer-driers. Appliances that can also use other energy sources are excluded.'*

1.1.1.3. Commission Regulations (EU) 932/2012 and (EU) 392/2012

The Commission Regulation 932/2012 with regard to Ecodesign requirements for household tumble dryers and Commission Regulation 392/2012 with regard to Energy Labelling of household tumble dryers apply to

> *'Electric mains-operated and gas-fired household tumble driers and built-in household tumble driers, including those sold for non-household use. These Regulations shall not apply to household combined washer-dryers and household spin-extractors.'*

The following definitions are given, among the others:

'Household tumble dryer' means an appliance in which textiles are dried by tumbling in a rotating drum through which heated air is passed and which is designed to be used principally for non-professional purposes;

'Household combined washer-dryer' means a household washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling;

'Household spin-extractor', also known commercially as 'spin-dryer', means an appliance in which water is removed from the textiles by centrifugal action in a rotating drum and drained through an automatic pump and which is designed to be used principally for non- professional purposes;

'Air-vented tumble dryer' means a tumble dryer that draws in fresh air, passes it over the textiles and vents the resulting moist air into the room or outside;

'Condenser tumble dryer' means a tumble dryer which includes a device (either using condensation or any other means) for removing moisture from the air used for the drying process;

'Automatic tumble dryer' means a tumble dryer which switches off the drying process when a certain moisture content of the load is detected, for example through conductivity or temperature sensing;

'Non-automatic tumble dryer' means a tumble dryer which switches off the drying process after a predefined period, usually controlled by a timer, but which may also be manually switched off.

1.1.1.4. Standards IEC/EN 60456

The standards IEC 60456 (edition 5.0 from February 2010), and EN 60456:2011 'Clothes washing machines for household use – Methods for measuring the performance' apply to *clothes washing machines for household use, with or without heating devices utilising cold and / or hot water supply*. They also deal with appliances for water extraction by centrifugal force (spin extractors) and are applicable to appliances for both washing and drying textiles (washer-dryers) with respect to their washing related functions. The standards define household washing machines as follows:

<u>Washing machine</u>*: appliance for cleaning and rinsing of textiles using water which may also have a means of extracting excess water from the textiles.*

Further, sub-categories of washing machines are defined in the standards IEC / EN 60456:

<u>Washer-dryer</u>*: washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling*

<u>Spin extractor</u>*: separate water-extracting appliance in which water is removed from textiles by centrifugal action (spin extraction)*

<u>Standard extractor</u>*: spin extractor used to remove water remaining in the base load at the completion of the programme where a rinse performance measurement is required*

<u>Vertical axis washing machine</u>*: washing machine in which the load is placed in a drum which rotates around an axis which is vertical or close to vertical. For the purposes of this document, vertical axis is where the angle of the axis of rotation is more than 45 degrees to horizontal. Where the drum does not rotate, the washing machine shall be classified as a vertical axis washing machine.*

Horizontal axis washing machine: washing machine in which the load is placed in a drum which rotates around an axis which is horizontal or close to horizontal. For the purposes of this document, horizontal axis is where the angle of the axis is less than or equal to 45 degrees to horizontal.

NOTE: The classification of vertical axis or horizontal axis in this document is only used to define the placement of the load into the drum.

Automatic machine: washing machine where the load is fully treated by the machine without the need for user intervention at any point during the programme prior to its completion

Manual washing machine: washing machine where the machine requires user intervention at one or more points during the programme to enable the machine to proceed to the next operation.

NOTE: Examples of user intervention could include manual fill (non-automatic water level), transfer of the load between a washing drum and a spin extractor drum or manual draining. Manual washing machines have special requirements regarding the programme which is tested for this document.

1.1.1.5. Standard EN 50229

The standard EN 50229:2007 ''Electric clothes washer-dryers for household use - Methods of measuring the performance' specifies the test methods which shall be applied in accordance with the Commission Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to Energy Labelling of household combined washer-dryers. Regarding terms and definitions of appliance types, however, standard EN 50229 refers to the definitions provided by EN 60456, see above.

1.1.1.6. European statistics

The European statistical database for manufactured goods PRODCOM (Eurostat [n.d.]) , classifies washing machines and washer-dryers under the following NACE Rev. 2 code:

2751.13.00 – Cloth washing and drying machines, of the household type

In 2002, a major revision of NACE was launched. The Regulation establishing NACE Rev. 2 was adopted in December 2006. It includes provisions for the implementation of NACE Rev. 2 and coordinated transition from NACE Rev. 1.1 to NACE Rev. 2 in various statistical domains. NACE Rev. 2 is to be used, in general, for statistics referring to economic activities performed as from 1 January 2008 onwards. For washing machines and washer-dryers, the NACE Rev. 1.1 code used in the Preparatory Study Lot 14 of 2007 was 2971.13.00 – Cloth washing and drying machines, of the household type.

1.1.1.7. European Ecolabels

The scope of the Nordic Ecolabelling of white goods (Nordic Ecolabelling 2014) covers inter alia household washing machines; a further definition is not provided. The requirements for spinning performance are further differentiated by capacity:

- Household washing machines ≤ 3.5 kg capacity
- Household washing machines > 3.5 kg capacity

The scope of the German Ecolabel Blue Angel RAL-UZ 137 for Household Washing machines (Ral gGmbH 2013a) is given as follows – a further definition of 'electric mains operated household washing machines' is not provided:

The Basic Criteria apply to electric mains operated household washing machines.

The calculation of specific requirements on water consumption of household washing machines is further differentiated by capacity:

- Household washing machines < 7 kg rated capacity
- Household washing machines ≥ 7 kg rated capacity

Washer-dryers are not covered by the scope of European Ecolabels.

1.1.1.8. US Energy Star

The scope of the US ENERGY STAR Program Requirements for Clothes Washers – Eligibility Criteria 7.0 (US EPA 2015) covers following products:

A. Included Products: Products that meet the definition of a Residential Clothes Washer or Commercial Clothes Washer as specified herein are eligible for ENERGY STAR qualification, with the exception of excluded products.

B. Excluded Products: The following products are not eligible for ENERGY STAR qualification:

i) products with a clothes container volume of less than 1.6 cubic feet (about 45 litres),

ii) products configured in any way other than a front- or top-loading design,

iii) Combination All-in-One Washer-Dryers,

iv) Residential Clothes Washers with an Optional Dry Cycle, and

v) Commercial Clothes Washers with a clothes container volume larger than 6.0 cubic feet (about 170 litres).

Further, the US Energy Star Program Requirements Version 7.0 for Clothes washers provides definitions for "clothes washers" and the following sub-categories:

A1. Residential Clothes Washer: A consumer product (cf. 10 CFR 430 Subpart A, Section 430.2) designed to clean clothes, utilizing a water solution of soap and/or detergent and mechanical agitation or other movement, and must be one of the following classes: automatic clothes washers, semi-automatic clothes washers, and other clothes washers.

A2. Residential Clothes Washer with Optional Dry Cycle: A Residential Clothes Washer that has an optional add-on dry cycle, where drying is accomplished through use of electricity or gas as a heat source and forced air circulation; drying cannot be selected independently from a wash cycle (this is interpreted as if the machine cannot used as dryer only).

B. Commercial Clothes Washer: A soft-mounted front-loading or soft-mounted top-loading clothes washer that is designed for use in applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas and coin laundries.

C. Combination All-in-One Washer-Dryer: A consumer product designed to clean and dry fabrics in a single drum, where a separate drying cycle uses electricity or gas as a heat source and forced air circulation.

Specific US ENERGY Star requirements for clothes washers are further differentiated by capacity (cubic feet), design format (top- or front-loading) and intended use (residential or commercial):

- Residential Clothes Washers, Front-loading (> 2.5 cu-ft)
- Residential Clothes Washers, Top-loading (> 2.5 cu-ft)

- Residential Clothes Washers (≤ 2.5 cu-ft)
- Commercial Clothes Washers.

The US Energy Star Program refers to the US standards mentioned in section 1.2.4.3 and to the definition of consumer product given in the U.S. Code of Federal Regulations (CFR). The cited U.S. Code of Federal Regulations (CFR), Title 10 / Part 430 (Energy Conversation Program for Consumer Products), § 430.2 provides the following definition of “Consumer products” (U.S. Government 2014a):

> *Consumer product means any article (other than an automobile, as defined in Section 501(1) of the Motor Vehicle Information and Cost Savings Act): (1) Of a type— (i) Which in operation consumes, or is designed to consume, energy or, with respect to showerheads, faucets, water closets, and urinals, water; and (ii) Which, to any significant extent, is distributed in commerce for personal use or consumption by individuals; (2) Without regard to whether such article of such type is in fact distributed in commerce for personal use or consumption by an individual.*

The U.S. Code of Federal Regulations (CFR), Title 10 / Part 431 (Energy Efficiency Program for Certain Commercial and Industrial Equipment), § 431.152 provides the following definition of Commercial Clothes Washers (U.S. Government 2014b):

> *Commercial clothes washer means a soft-mounted front-loading or soft-mounted top-loading clothes washer that—*
>
> *(1) Has a clothes container compartment that—*
>
> *(i) For horizontal-axis clothes washers, is not more than 3.5 cubic feet (about 99 litres); and*
>
> *(ii) For vertical-axis clothes washers, is not more than 4.0 cubic feet (about 113 litres); and*
>
> *(2) Is designed for use in—*
>
> *(i) Applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas and coin laundries; or*
>
> *(ii) Other commercial applications.*

The ENERGY STAR definition of a commercial clothes washer differs from the CFR definition of commercial clothes washers by: 1) not specifying a maximum capacity; and 2) not covering “other commercial applications.”

1.1.1.9. Ecodesign Preparatory study Lot 24

The Preparatory study for Eco-design Requirements of Energy-using Products, Lot 24: Professional Washing Machines, Dryers and Dishwashers, Part Washing Machines and Dryers, Task 1 (Scope), defines professional washing machines as follows (Graulich et al. 2011):

> *‘<u>Professional washing machine</u>’ means a machine which cleans and rinses laundry like clothes, tablecloths, bedclothes, towels, and other textiles or items by using water, chemical, mechanical, and thermal means; which might also have a spin extraction or drying function and which is designed to be used principally for commercial and industrial purposes as stated by the manufacturer in the Declaration of Conformity (DoC).*

Within the preparatory study, seven sub-categories of professional washing machines were defined. The following categories seem to be closest comparable to household washing machines and washer-dryers (whereas the other 4 categories are either larger or rather industrial appliances):

- semi-professional washer-extractor (up to 7 kg),
- professional washer extractor < 15 kg and

- professional washer dryer.

Compared to household washing machines and washer-dryers, however, the main aspect considered in the design of semi-professional appliances is to provide satisfactory levels of performance quickly and continuously to meet exigencies of commercial users. As a result, semi-professional appliances present different characteristics, e.g. higher input of water and energy and recycle of these resources, shorter programme durations and larger capacities, different components and longer durability in terms of cycles, customised and partial programmability, possible heating of water by means of steam.

The delimitation of professional washing machines to washing machines for household use is defined through the Machinery Directive 2006/42/EC, that explicitly exclude washing machines intended for household use and which defines essential health and safety requirements for washing machines which are intended for professional use. Professional and semi-professional appliances have to comply with the machinery directive: they either need higher voltage or different safety requirements. According to the Machinery Directive, manufacturers have to determine the ‘intended use’ (domestic or commercial / industrial use) and state this in the product information or the so called Declaration of Conformity. “Household appliances intended for domestic use”, on the other hand, must fulfil the safety objectives of the Low Voltage Directive 2006/95/EC (note: meanwhile revised, LVD 2014/35/EU) (European Parliament 2006b).

The term “domestic use” is defined as “use by private persons (consumers) in the home environment”. While it is possible for a consumer to acquire an appliance intended for professional use or for a professional to acquire an appliance intended for domestic use, the criterion to be taken into account for determining the intended use is the use intended and stated by the manufacturer of the appliance in his product information or his Declaration of Conformity. Evidently, this statement must accurately reflect the foreseeable use of the product, as indicated in the Guide to application of the Machinery Directive 2006/42/EC (European Commission 2010d).

Currently, semi-professional washing machines, professional washer extractors and professional washer-dryers are excluded from the scope of the Ecodesign and Energy Label Regulations on household washing machines.

Table 1.1: Main differences between household and semi-professional washing machines

	Household washing machines (in-house elaboration)	Semi-professional washing machines and washer extractor; source: Graulich et al. (2011)
	220 cycles per year	1,800 cycles per year
Typical cycle times (depending on the chosen programme)	30-200 minutes	35-55 minutes
Safety requirements	Low Voltage Directive	Machinery Directive

1.1.1.10. Summary of existing definitions

The following Table 1.2 provides a summarized overview of existing definitions for household washing machines.

For washer-dryers, only the definitions provided in the EU Ecodesign and Energy Label Regulations 1015/2010, 1061/2010, 932/2012 and 392/2012, and in the IEC / EN 60456 standards apply (which are almost identical), as well as the US Energy Star definition.

Table 1.2: Systematic of existing definitions for household washing machines

Table header	EU Ecodesign / Energy Label Regulations	IEC / EN standards	EU Prodcom statistics	German Blue Angel / Nordic Swan ecolabels	US Energy Star label (based on CFR definitions)
Function	"Machine which cleans and rinses textiles using water which also has a spin extraction function and which is designed to be used principally for non-professional purposes."	"Appliance for cleaning and rinsing of textiles using water which may also have a means of extracting excess water from the textiles."	"Clothes washing and drying"	---	"Product designed to clean clothes, utilizing a water solution of soap and / or detergent and mechanical agitation or other movement"
Operation	Automatic	• Automatic • Manual	---	---	• Automatic • Semi-automatic • Other
Intended use	• "Household washing machine", • including "those sold for non-household use"	"for household use"	"of the household type"	"household"	• "Residential / Consumer product: means any product which to any significant extent, is distributed in commerce for personal use or consumption by individuals." • "Commercial: designed for use in applications in which the occupants of more than one household will be using the clothes washer, such as multi-family housing common areas and coin laundries."
Design format	Including "Built-in, i.e. intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing"	• Vertical axis • Horizontal axis • With or without heating devices utilising cold and / or hot water supply	---	---	Front-loading Top-loading

Table header	EU Ecodesign / Energy Label Regulations	IEC / EN standards	EU Prodcom statistics	German Blue Angel / Nordic Swan ecolabels	US Energy Star label (based on CFR definitions)
Capacity and / or dimen-sions	Energy Efficiency Index requirements: <4 kg / ≥ 4 kg Water Efficiency Index requirements: ≤ 3 kg / > 3 kg Water con-sumption: function of the rated capacity	---	---	• Blue Angel (water con-sumption): < 7 kg / ≥ 7 kg • Nordic Swan (spinning performan ce): ≤ 3.5 kg / > 3.5 kg	• Scope: • < 1.6 cubic feet (excluded) • Specific re-quirements on energy / water consumption: • > 2.5 cu-ft • ≤ 2.5 cu-ft
Power supply	"Electric mains-operated" and "Electric mains-operated that can also be powered by batteries"	---	---	---	---

1.1.2. Feedback from stakeholders with regard to the existing scope and definitions

In March 2015, a questionnaire has been circulated to gather input from stakeholders for the revision of the Ecodesign and Energy Label regulations for household washing machines and washer-dryers (JRC IPTS 2015b). With respect to scope and definitions of the current regulations, stakeholders were in particular asked:

- To describe washing machines and washer-dryers from a functional point of view,
- To indicate if the existing definitions are comprehensive and clear or should be modified,
- To indicate if reference to devices that can also be powered by batteries and to built-in household appliances was needed or not,
- To indicate if an exclusion of semi-professional appliances from the scope was appropriate or not,
- To provide examples of niche or special purpose types of household washing machines.

Based on this input, a draft revised scope and definitions were presented and discussed at the 1st TWG meeting (24 June 2015, Seville). Based on the further input received, a slight adaption of scope and definition was presented to stakeholders at the 2nd TWG meeting (18 November 2015, Brussels).

All recommendations provided by stakeholders are summarised in the following, leading to the final draft revised scope and definitions used for this study (cf. section 1.1.3).

1.1.2.1. Functional parameters

The following functional parameters have been defined for household washing machines and household washer-dryers also based on the stakeholders' feedback:

- Primary functions:
  - Washing machines: Washing / cleaning; rinsing; spin extraction

  - Washer-dryers: Washing / cleaning; rinsing; spin extraction; the drying (only) or continuous washing-drying function is seen either as primary function by some stakeholders or as secondary function by others.

- Secondary functions: Automatic detergent dosage; possibility of adapting the spin speed or capability to be remotely controlled (Demand Response (DR) functionality) are seen as secondary functions of washing machines and washer-dryers by some stakeholders. Also, some stakeholders see the drying (only) function as secondary function of washer-dryers. One argument provided for the drying function of a washer-dryer being considered as a secondary function, at least as stand-alone function, is that results from household testing and user surveys demonstrate washer-dryers being mainly used as a washing machine and only occasionally as a dryer.

Two stakeholders explain that the separation of spinning function from washing and rinsing is historical: automatic washing machines were able to wash and rinse only and additional spin extractors were used. Currently, the spinning function has become a primary function of the so-called "fully automatic washing machines" (cf. section 1.1.2.2). Moreover, for households not equipped with a dryer or a separate laundry room with external ventilation, spinning is essential to prevent excess humidity and consequently formation of mould.

1.1.2.2. Operation: ”automatic” vs. ”semi-automatic”

It was discussed if the reference to "automatic" from the definition of household WM might be removed as only automatic ones are sold in the European market. This would reduce the number of necessary definitions in the regulations.

- Automatic (also ‘fully automatic’) washing machines have only one tub in which all functions (washing, rinsing, and spinning) are performed without the need of user intervention to shift clothes. This "automatic" feature of the appliance must not be confused with the “automatic programmes” that a machine may offer.
- In contrast to that, semi-automatic washing machines have two tubs, one for washing and the other for the spinning cycle which needs user intervention after the washing cycle to shift the clothes manually from one tub to the other (or to a separate spin extractor).

According to initial stakeholders' feedback it did not seem necessary to provide a separate definition for automatic washing machines. At the 1st TWG meeting (24 June 2015, Seville), however, it was clarified, that the removal of the word "automatic" would open to possibility for the inclusion of both automatic and semi-automatic machines in the scope.

Semi-automatic WM are still produced and sold internationally outside the EU. For this kind of WM, the evaluation of the washing and the spinning performance would have to be done separately. However, it was pointed-out by stakeholders that defining the spinning performance alone may be difficult, that the market of semi-automatic machines is small and that no problem with the current definition has been registered so far.

A stakeholder recommended to reference to automatic appliances in the scope (not necessarily in the definitions). Semi-automatic machines sold on extra-EU markets would not be covered by the ED / EL regulations anyway, as the regulations only apply to products sold in the EU.

1.1.2.3. Intended use: semi-professional appliances

The current regulations apply to “household” washing machines and washer-dryers. There was a discussion on the following two questions:

- Scope: Should semi-professional appliances (which at first glance seem to be possibly comparable to household washing machines and washer-dryers) be additionally included in the revised regulations?
- Definitions: Are the current definition of “household” sufficient to delimit these products from (semi-) professional appliances?

Scope

Although few stakeholders argued that semi-professional washing machines and washer-dryers should have Ecodesign and Energy Label requirements since their use of resources is more intensive, most stakeholders agreed not to handle semi-professional and professional appliances under the scope of this revision on household appliances as the professional ones are currently covered under Lot 24, which is currently ongoing.

Several of the stakeholders answering to the first question explained that semi-professional appliances are different from household appliances: They either need higher voltage or different safety requirements. They cannot be compared with household washing machines and washer-dryers as they have different types of use and cannot be evaluated as single machines without consideration of external water and energy recycling systems installed in professional laundry shops. Further, industry stakeholders inform that to meet the requirement of high productivity, resources (water, energy) are used typically in higher amounts and will be centrally recycled, which also require to take local infrastructure and system aspects into account. In summary, such appliances need different Ecodesign and Energy label requirements compared to household appliances because of their different technical characteristics.

Based on this, it was recommended to stick to household appliances in this revision.

Definition

The current definition states that household washing machine means an automatic washing machine, which is ‘designed to be used principally for non-professional purposes’.

It seems that this current definition might not be clear enough, as it is in general possible for a private consumer to acquire and use an appliance designed and intended for professional use or for a professional user to acquire and use a household appliance. Besides the design, also the way household and professional products are marketed to and accessible for consumers is relevant.

In general, for household appliances the requirements of the “Low Voltage” Directive LVD 2014/35/EU (European Parliament 2014b) apply, whereas professional appliances fall under the scope of the “Machinery” Directive MD 2006/42/EC (European Parliament 2006a).

In order to provide greater legal certainty for manufacturers and to avoid potential misinterpretations, the “Guidelines on the application of the Low Voltage Directive 2006/95/EC” (European Commission 2007 / modif. 2012) clarify the borderline between the scope of these two Directives. The criterion to be taken into account for determining the intended use is the use intended and stated by the manufacturer of the concerned appliance in the so called “Declaration of Conformity (DoC)” and in the product information / instructions / advertising concerning the product. This statement determines the intended use of the appliance and which Directive (Low Voltage Directive or Machinery Directive) applies accordingly. Evidently this must accurately reflect the reasonably foreseeable use of the product. The definitions provided by the guidelines are “Household appliances intended for domestic use” and a description of “domestic use”.

In this sense, the reference to the Low Voltage Directive was confirmed by stakeholders to appear the most objective mean to differentiate between household and non-household use of the appliance.

1.1.2.4. Product format: Built-in appliances

It was discussed if the separate reference to "built-in appliances" in the current scope and definitions might be removed as in the performance requirements of the regulations there is no further differentiation between stand-alone and built-in appliances.

Most stakeholders stated that generally there is no need for a separate category because they are basically same appliances and there is no difference, in terms of efficiency and performance, between built-in and not built-in machines. “Built-in” was in the past used as one of the differentiation criteria for professional appliances.

At the 2nd TWG meeting on 18 November in Brussels, stakeholders were however informed that there is explicit reference made to built-in appliances in the Energy Label Directive 2010/30/EU ((European Parliament 2010), currently under revision), where §4 “Information requirements” states

> *Member States shall ensure that:*
>
> *(a) information relating to the consumption of electric energy, other forms of energy and where relevant other essential resources during use, and supplementary information is, in accordance with delegated acts under this Directive, brought to the attention of end-users by means of a fiche and a label related to products offered for sale, hire, hire-purchase or displayed to end-users directly or indirectly by any means of distance selling, including the Internet;*
>
> *(b) the information referred to in point (a) is provided in respect of built-in or installed products only where required by the applicable delegated act.*

Based on this explicit reference it was proposed and agreed by stakeholders to keep ‘built-in’ appliances mentioned in the current scope of the revised regulations on washing machines and washer-dryers just for the purpose of aligning to the horizontal Energy Label Directive 2010/30/EU.

In case of the future revised Energy Label Directive 2010/30/EU not including this reference any more, the explicit reference to built-in appliances might also be removed from the revised scope of the WM / WD regulations.

1.1.2.5. Power supply: Battery-powered washing machines and washer-dryers

Input from stakeholders on this topic was initially rather indifferent.

On the one hand, some stakeholders informed that the market relevance of this kind of machines is very low (production volume is estimated to be lower than 200,000 pieces per year), thus they should be excluded from the scope. On the other hand, few stakeholders argued that they may become relevant in the future in the framework of smart grids and demand-response and renewable energy management. Theoretically, battery powered household appliances might work as capacity storage in a smart-grid network; however, it is assumed that such power storage would rather be implemented as a central storage system for the whole household with the single appliances still being electric-mains operated.

Further, one stakeholder argued that battery powered appliances would need a different amount of energy in case of battery usage as compared to being operated by electric mains. It is also recommended to consider such products separately as they may not reach the same performance levels as traditional machines.

Finally, several industry stakeholders informed that the current test standard does not explicitly describe a test procedure for battery driven appliances, i.e. if included inside the scope, standards should be improved accordingly.

At the 1st TWG meeting, stakeholders generally welcomed the proposal of excluding batteries-operated WM and WD from the scope due to the lack of market relevance of this type of machines. However, it was recommended by stakeholders that the exclusion of batteries-operated appliances should apply only to those that are solely operated by batteries and not to those appliances that either have a battery as one of their components to operate auxiliaries or those that can be both mains-operated and operated by batteries (e.g. battery back-up). This differentiation shall be clarified in the definitions.

1.1.2.6. Niche or special purpose products

The following niche products or special purpose equipments are proposed by stakeholders to be excluded from the scope:

- Micro-washing machines, i.e. washing machines with a capacity of 1 kg or less, as the test standard is suitable only for 1 kg and above. According to stakeholder feedback, they have no market relevance in Europe. One stakeholder even indicates that this is also valid for 2 kg appliances.
- Water-heated washing machines and washer-dryers; these are appliances with no own heating element that rely on an external heater exchanger fed by e.g. district heating. They use external sources of water for heating and cooling the process water used for washing the laundry (not to be confused with appliances with hot / cold fill), cf. also section 4.4.2.4. According to stakeholder information, this product was available on the market before 2010, and then was phased out from the current Ecodesign regulation because it could not reach A class washing performance. Also no test method is available that is independent from the water heating / cooling system. According to stakeholder feedback, there are currently no such appliances available on the market.
- Waterless washing machines (which are excluded by the current definition) as they have a different technology concept that has not evolved into a feasible market phase and shall thus still be excluded. According to stakeholder feedback, these appliances have no market relevance in Europe.

On the other hand, the following niche products or special purpose equipment are proposed by stakeholders to be explicitly included in the scope:

- Alternatively heated appliances, as potentially 'green' technologies. It was recommended to add definitions for “hot fill”, “solar heated”, “renewable energy heated” and similar on the basis that a system approach would be needed to identify the additional energy saving potential achievable beyond that inherently associated to the appliance. Some stakeholders, however, argued that these appliances have no market relevance today and thus might be excluded from the scope. On the other hand, one stakeholder is in favour of the principle that consumers should always be able to choose among all types of products available on the market. Therefore, both cold fill and hot cold fill washing machines are necessary on the market in order to satisfy consumer expectations.
- Smart-grid ready appliances, as upcoming technology where the time of use of the appliance can be adjusted depending on the needs of the energy system. Although this technology does not offer direct energy savings, it can allow for saving of resources at system level (see section 4.4.2.9). Whereas one stakeholder commented that ‘smart-grid ready’ is mainly a marketing topic, as reason for inclusion into the scope, another stakeholder argued that they will shortly stop being a niche market and any washing machine might / will have this function. Further, it was proposed that the energy efficiency of the wireless LAN modules of these appliances should be evaluated / rated separately for instance in relation to networked standby. In case of inclusion, a stakeholder invited to uptake as much as possible from the Ecodesign preparatory study on smart appliances, which is currently ongoing and will provide additional information, also from a more systematic point of view (cf. section 1.2.1.1). One stakeholder disagreed with including these products into the scope as there are no standards and many different protocols, thus being too

early to include them. Another stakeholder argued besides a currently low market relevance, that they should be included as the basic function of the appliance is still a WM or a WD.

- Multi-drum washing machines. A stakeholder requested further investigations on if / how to include in the regulations the new WM models equipped with more than one washing compartment (twin tub / drum). Recently, such appliances have been introduced into the market. The appliances have two washing drums, which can either work together or separately. It is considered that this kind of appliance would also be covered by the term 'automatic' washing machine, as each drum could finish a complete washing process (cf. Chapter 4.1.3.1). However, further analysis might be needed with regard to testing and labelling of performance.

1.1.2.7. Inclusion of washer-dryers into the scope of the washing machine regulations

The existing Energy labelling and Ecodesign Regulations for washing machines explicitly exclude washer-dryers (defined as *'household combined washer-dryers'*) from their scope. One of the targets of this study is to analyse the feasibility of including household washer-dryers into the revised Ecodesign and Energy label measures for household washing machines. Considering that washer-dryers offer three different functions (i.e. washing only, drying only, combined wash&dry function – either interrupted or continuous), there are three different ways of handling this appliance:

a) Separate ED / EL regulation for washer-dryers (revision and update of the existing EL Directive plus additional ED requirements)

b) Inclusion of ED and EL requirements for washer-dryers in the ED / EL regulations for washing machines

c) Inclusion of ED and EL requirements for washer-dryers in the ED / EL regulations for tumble dryers

At the beginning of this study stakeholders generally agreed on the need of updating the Energy label for washer-dryers and implementing Ecodesign requirements as market shares of this product group are increasing. Washer-dryers are in general less efficient than single washing machines and tumble dryers although there are also high efficient design options (with heat pump) available on the European market.

At the 1st TWG Meeting it was stated by industry stakeholders that WM and WD should be treated separately in the revision of the ED / EL regulations, due to the technical and usage differences that the two products present. It was argued that only the washing part of these two products is similar, whereas the drying part needs to be tackled in a different way. Handling and maintenance of requirements for WM and WD might have different needs and this would be easier with separate regulations. Future regulations should in any case take into account the specificity of each product and, if separate, be aligned as much as possible.

On the other hand, some MS indicated that if the regulations for WM and WD are split, there is a risk that the WD regulation will be delayed or not passed due to the so far small market of WD. If the two products are formally included in the same regulation (even if with different requirements for WM and WD), there is a higher chance that there will be ED and EL regulations also for WD.

Different policy strategies are analysed in more detail in Task 7.

1.1.2.8. Further amendments to existing definitions

At the 1st TWG meeting, the project team introduced an addition to the definition of household washing machines to align with the definitions currently proposed in Lot 24 for professional washing appliances (cf. section 1.1.1.9) and to reflect the influence factors of the washing process according to the so called Sinner's Circle (cf. section 4.1.1.1):

'Household washing machine' means an automatic washing machine which cleans and rinses textiles by using water, chemical, mechanical and thermal means […].

Industry stakeholders recommend modifying the definition of "household combined washer-dryer" by deleting the word "usually" of the definition as the washer-dryer needs to have a device to heat the process air based on different technologies.

'Household combined washer-dryer' means a household washing machine which includes both a spin extraction function and also a means for drying the textiles~~, usually~~ by heating and tumbling.

One stakeholder further suggested adding "heat pump systems" after "thermal means" both for WM and WD which is, however, expected to be included by the description of the definition.

1.1.3. Draft final product scope and definitions

Based on the previous analysis of existing scopes and definitions, stakeholder feedback related to the scope during the course of the preparatory study (cf. section 1.1.2) as well as the analysis of market data and trends (cf. Task 2), the following draft final product scope and definitions are proposed for the revision of the Ecodesign and Energy label Regulations for household washing machines and washer-dryers.

1.1.3.1. Draft final proposal for a product scope

Current scope of the Ecodesign Regulation 1015/2010 for household washing machines:

This Regulation establishes ecodesign requirements for the placing on the market of electric mains-operated household washing machines and electric mains-operated household washing machines that can also be powered by batteries, including those sold for non-household use and built-in household washing machines.

The Energy Label Regulation 1061/2010 has the same scope.

Proposal for a revised scope of the Ecodesign Regulation for household washing machines and washer-dryers:

This Regulation establishes Ecodesign requirements for the placing on the market of electric mains-operated household washing machines and household washer-dryers including those which are electric mains-operated but can also be powered by batteries, and including built-in household washing machines and washer-dryers.

The Energy labelling Regulation would have the same scope, as follows:

This Regulation establishes requirements for the labelling of and the provision of supplementary product information on electric mains-operated household washing machines and household washer-dryers including those which are electric mains-operated but can also be powered by batteries, and including built-in household washing machines and washer-dryers.

1.1.3.2. Draft final proposal for definitions

Current definitions for household washing machines and washer-dryers in the Ecodesign Regulation 1015/2010 and the Energy Label Regulation 1061/2010:

'Household washing machine' means an automatic washing machine which cleans and rinses textiles using water which also has a spin extraction function and which is designed to be used principally for non-professional purposes.

'Built-in household washing machine' means a household washing machine intended to be installed in a cabinet, a prepared recess in a wall or a similar location, requiring furniture finishing.

'Automatic washing machine' means a washing machine where the load is fully treated by the machine without the need for user intervention at any point during the programme.

'Household combined washer-dryer' means a household washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling.

Proposal for revised definitions of the Ecodesign and Energy Label Regulations for household washing machines and washer-dryers:

'Household washing machine' means an automatic washing machine which cleans and rinses textiles by using water, chemical, mechanical and thermal means; which also has a spin extraction function and which is designed in a way principally intended for domestic use complying with the Low Voltage Directive 2014/35/EU as stated by the manufacturer in the Declaration of Conformity (DoC).

'Household ~~combined~~ washer-dryer' means a household washing machine which includes both a spin extraction function and also means for drying the textiles by heating and tumbling.

The definitions of built-in household washing machines and automatic washing machines are kept unchanged. Depending on the techno-economic elements gathered along the elaboration of the study and the consequent proposal of policy measures, further types of appliances and / or definitions might be added during the course of the study (e.g. special purpose products, system approach like 'renewable energy heated', 'smart grid ready (SG ready)' or others.

1.2. Legislation and standards for ecodesign, energy efficiency and other performance characteristics

In the following sections of chapter 1.2, the EU legislation (section 1.2.1), test standards (section 1.2.2) and ecolabels (section 1.2.3) of relevance for ecodesign, energy efficiency and other performance criteria are described, followed by a compilation of *international and third-country* legislation and standards (section 1.2.5).

1.2.1. European legislation on ecodesign, energy efficiency and other performance characteristics

1.2.1.1. Ecodesign regulations relevant for washing machines and washer dryers

Ecodesign Regulation 1015/2010 on washing machines

Commission Regulation (EU) No 1015/2010 of 10 November 2010 is implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for household washing machines. At the present time (December 2015), the following EU generic and specific Ecodesign requirements apply for washing machines sold on the EU market (Commission Regulation (EU) No 1015/2010 and Corrigendum) on the basis of the testing framework set with the standard EN 60456:2011:

- Energy Efficiency Index (EEI): Since 2011, for all household washing machines, the Energy Efficiency Index (EEI) shall be less than 68 (i.e. Energy Label class A or better); further, since 1 December 2013, for all washing machines ≥ 4 kg the EEI has to be < 59 (Energy Label class A+ or better).
- Water consumption (W_t): has to be ≤ 5 x $c_{1/2}$ + 35, where $c_{1/2}$ is the washing machine's rated capacity for the standard 60 °C cotton programme at partial load or for the standard 40 °C cotton programme at partial load, whichever is the lower.
- Washing Efficiency Index (I_w): for household washing machines with a rated capacity > 3 kg it must be greater than 1.03, which corresponds to the class A according to the former Energy Label (Commission Directive 95/12/EC). For household washing machines with a rated capacity equal to or lower than 3 kg, the Washing Efficiency Index (I_w) shall be greater than 1.00, however, according to the market research, these small appliances are not provided on the market any more (cf. Figure 2.21)
- Availability of a cold wash programme (max. 20 °C): Washing machines shall offer to end-users a cycle at 20 °C. This programme shall be clearly identifiable on the programme selection device and / or the display.

Further requirements are related on the calculation of the energy consumption and other parameters as well as on the booklet of instructions

- Standard 60 °C and 40 °C cotton programmes:
  - According to Regulation 1015/2010, for the calculation of the energy consumption and the other parameters for household washing machines, the *cycles which clean normally soiled cotton laundry (hereafter standard cotton programmes) at 40 °C and 60 °C* shall be used. These cycles shall be clearly identifiable on the programme selection device of the household washing machines or the household washing machines display, if any, or both, and indicated as 'standard 60 °C cotton programme' and 'standard 40 °C cotton programme'.

  - Regarding these programmes, the booklet of instructions provided by the manufacturer shall specify that they are suitable to clean normally soiled cotton laundry and that *they are the most efficient programmes in terms of combined energy and water consumptions for washing that type of cotton laundry*; in addition, they shall provide an indication that the actual water temperature may differ from the declared cycle temperature;
- The booklet of instructions shall further provide
  - power consumption of the off-mode and of the left-on mode;
  - indicative information on the programme time, remaining moisture content, energy and water consumption for the main washing programmes at full or partial load, or both; and
  - recommendation on the type of detergents to use.

Ecodesign Regulation (EU) No 932/2012 on tumble dryers

No separate Ecodesign regulation applies so far to washer-dryers. However, as washer-dryers offer also drying functions (i.e. drying only and wash&dry) besides the washing function, the current Ecodesign requirements for tumble dryers are presented for comparison. Compatibility and applicability of its elements for washer-dryers will be analysed throughout this study.

Commission Regulation (EU) No 932/2012 of 3 October 2012 is implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for household tumble dryers.

Currently (December 2015), the following EU Ecodesign requirements apply for tumble dryers sold on the EU market (Commission Regulation (EU) No 932/2012 and Corrigendum):

- Specific ecodesign requirements: Since 2013, for household tumble dryers, the Energy Efficiency Index (EEI) shall be less than 85 (i.e. Energy Label class C or better). Since November 2015, for condenser household tumble dryers the energy efficiency index (EEI) shall be less than 76 (i.e. Energy Label class B or better) and the weighted condensation efficiency shall be not lower than 70%.
- Standard programme:
  - For the calculation of the energy consumption and other parameters for household tumble dryers, the cycle which dries cotton laundry (with an initial moisture content of the load of 60%) up to a remaining moisture content of the load of 0% (hereinafter the ‘standard cotton programme’) shall be used. That cycle shall be clearly identifiable on the programme selection device(s) of the household tumble dryer or the household tumble dryer display, if any, or both, and indicated as ‘standard cotton programme’ or by a uniform symbol or an appropriate combination thereof, and shall be set as the default cycle for household tumble dryers equipped with automatic programme selection or any function for automatically selecting a drying programme or maintaining the selection of a programme. If the tumble dryer is automatic tumble dryer the ‘standard cotton programme’ shall be automatic.
  - The booklet of instructions shall provide information about the ‘standard cotton programme’ and shall specify that it is suitable to dry normal wet cotton laundry and that it is the most efficient programme in terms of energy consumption for drying wet cotton laundry;
- Information to provide in the booklet of instructions of the appliance:

- the power consumption of the off-mode and the left-on mode;
- indicative information on the programme time and energy consumption for the main drying programmes at both full, and, if applicable, partial load.

Ecodesign Regulation 1275/2008 for standby and off mode

Commission Regulation (EC) No 1275/2008 of 17 December 2008 is implementing the Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment (European Commission 2008).

According to the Regulation 1275/2008,

- 'standby' is a condition where the equipment is connected to the mains power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for an indefinite time: reactivation function, or reactivation function and only an indication of enabled reactivation function, and/or information or status display.
- 'off mode' means a condition in which the equipment is connected to the mains power source and is not providing any function; the following shall also be considered as off mode:

d) conditions providing only an indication of off-mode condition;

e) conditions providing only functionalities intended to ensure electromagnetic compatibility pursuant to Directive 2004/108/EC of the European Parliament and of the Council.

According to Annex I of the regulation, washing machines as household appliances are falling under the scope of this regulation, as well as washer-dryers, which are not listed separately, but under the category 'Other appliances for cooking and other processing of food, cleaning, and maintenance of clothes'.

Currently, stage 2 is applicable for products placed on the market from 7 January 2013, with the following requirements regarding power consumption for standby- and off-mode, as well as power management or similar functions:

- Power consumption in 'standby mode(s)':
  - The power consumption of equipment in any condition providing only a reactivation function, or providing only a reactivation function and a mere indication of enabled reactivation function, shall not exceed 0.50 W.
  - The power consumption of equipment in any condition providing only information or status display, or providing only a combination of reactivation function and information or status display shall not exceed 1.00 W.
- Power consumption in 'off mode':
  - Power consumption of equipment in any off-mode condition shall not exceed 0.50 W.
- Availability of off mode and/or standby mode: Equipment shall, except where this is inappropriate for the intended use, provide off mode and/or standby mode, and/or another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source.
- Power management: When an equipment is not providing the main function, or when other energy-using products are not dependent on its functions, equipment shall, unless inappropriate for the intended use, offer a power management function, or a similar

function, that switches the equipment after the shortest possible period of time appropriate for the intended use of the equipment, automatically into:

- standby mode, or
- off mode, or
- another condition which does not exceed the applicable power consumption requirements for off mode and/or standby mode when the equipment is connected to the mains power source. The power management function shall be activated before delivery.

Washing machines and washer-dryers usually have “delayed start” and “left-on mode” functions. According to the Ecodesign Regulation 1015/2010 for washing machines, ‘left-on mode’ means the lowest power consumption mode that *may* persist for an *indefinite* time after completion of the programme without any further intervention by the end-user besides unloading of the household washing machine. A definition for delayed start mode is not provided by 1015/2010. According to stakeholders, both left-on-mode and delayed start mode do not fall under the definition of a standby-mode under regulation 1275/2008. In the Commission guidelines for this Regulation (European Commission 2014b), in the answer to one of the questions it is stated that a “delayed start” function is not to be considered as standby because it does not last for an indefinite time. Also, since introduction of a power management in 2013 (see above), left-on mode does not fall under the definition of a standby-mode under regulation 1275/2008 anymore, as it is switched into off-mode after a certain time. This means that currently the requirements of regulation 1275/2008 with regard to power consumption in standby modes do not apply to household washing machines and washer-dryers.

Nevertheless, the time and power in left-on mode has to be measured according to the Ecodesign and Energy Label Regulations 1015/2010 and 1061/2010 for washing machines to determine the annual energy consumption (AE_C) being the basis for the Energy Efficiency Index (EEI).

For washer-dryers, the Energy Label Directive 96/60/EC does not include standby and off-mode consumption. For washing machines and washer-dryers, this means that all appliances placed on the market after January 2013 have a power management system requiring the appliances to automatically switch from left-on-mode into off-mode (not exceeding 0.50 W) after each cycle after a certain time. The timeframe has not been further specified; according to stakeholder feedback, this is for example realised after 30 minutes. The power management for networked appliances is preset at 20 minutes, cf. next section.

Currently (December 2015), the Commission Regulation (EC) 1275/2008 is under review with focus on analysing:

- the inclusion of products currently not in scope, like inter alia, professional equipment and products equipped with electric motors operated by remote control (e.g. adjustable beds or desks) and other relevant products (e.g. paper shredders);
- the appropriateness and level of the requirements for standby/off mode: according to the revision study (Viegand Maagøe 2015), market surveillance indicate a downward trend from the standby/off limit of 0.5 W as being required in the Regulation 1275/2008 since 2013. Current benchmarks are:
  - Off mode: 0-0.3 W
  - Standby of reactivation functions: 0.1 W
  - Standby of simple displays and low power LEDs: 0.1 W (larger displays require more power)

- the appropriateness and level of networked standby requirements from the third stage of implementation for non HiNA-equipment (2019);
- whether the exemption for products placed on the market with low voltage power supplies is still valid and justified.

Other aspects that will be reviewed are ambiguous definitions, interfaces with Vertical Regulations, and other important products currently not included in Annex I of the Regulation.

Further, at the stakeholder meeting of the revision study which has taken place on 21 October 2015, the following issues were addressed specifically to household washing machines and might also be applicable to washer-dryers (Viegand Maagøe 2015):

- Main function of washing machines. An example from a Market Surveillance Authority (MSA) showed that it is debatable whether a networked washing machine has a networked standby or not. It is argued that the equipment is providing safety function as the main function during the time (left-on or similar mode) when the door is locked. Some MSAs argue that the main function of a washing machine is to wash, whereas safety is the main function only for the door lock. According to MSA, manufacturers argue that the left-on or similar mode after the end of a washing cycle is not a standby mode as defined in the standby regulation due to lack of a reactivation function. MSA on the other hand argue that the standby regulation requires the machine to go into a mode (standby or similar ≤ 0.5 or 1 W) when not providing the main function (i.e. washing), so any mode after the end of the washing cycle should be standby or similar that does not exceed the standby limit.
- There might be a savings potential e.g. if a networked washing machine would be going to product standby (instead of networked standby) when no longer in use.

These issues will be further evaluated within the standby revision study with results expected to be published in the final report in June 2016.

Ecodesign Regulation 801/2013 on networked standby

The Commission Regulation 801/2013 on Networked Standby amended the Commission Regulation (EC) No 1275/2008 with regard to Ecodesign requirements for standby, off mode electric power consumption of electrical and electronic household and office equipment by adding definitions and Ecodesign requirements with regard to networked appliances (European Commission 2013b).

The Regulation establishes Ecodesign requirements related to standby and off mode, and networked standby, electric power consumption for the placing on the market of electrical and electronic household and office equipment. In this context, “networked standby” means a condition in which the equipment is able to resume a function by way of a remotely initiated trigger from a network connection, i.e. a signal that comes from outside the equipment via a network. Thus, the Regulation 801/2013 applies to all washing machines and washer-dryers being connected to a network (“smart appliances”).

While Ecodesign Regulation 1275/2008 for standby and off mode requires a power management for all equipment other than networked equipment since 2013 (see section above), the following requirements apply to networked equipment (i.e. equipment that can connect to a network and has one or more network ports) since 1 January 2015:

- <u>Possibility of deactivating wireless network connection(s)</u>: Any networked equipment that can be connected to a wireless network shall offer the user the possibility to deactivate the wireless network connection(s). This requirement does not apply to products which rely on a single wireless network connection for intended use and have no wired network connection.
- <u>Power management for networked equipment</u>: Equipment shall, unless inappropriate for the intended use, offer a power management function or a similar function. When equipment is

not providing a main function, and other energy-using product(s) are not dependent on its functions, the power management function shall switch equipment after the shortest possible period of time appropriate for the intended use of the equipment, automatically into a condition having networked standby. In a condition providing networked standby, the power management function may switch equipment automatically into standby mode or off mode or another condition which does not exceed the applicable power consumption requirements for standby and/or off mode. The power management function, or a similar function, shall be available for all network ports of the networked equipment. The power management function, or a similar function, shall be activated, unless all network ports are deactivated. In that latter case the power management function, or a similar function, shall be activated if any of the network ports is activated. The **default period of time** after which the power management function, or a similar function, switches the equipment automatically into a condition providing networked standby **shall not exceed 20 minutes**.

- Networked equipment that has one or more standby modes shall comply with the requirements for these standby mode(s)
  - When all network ports are deactivated (since 1 January 2015)
  - When all wired network ports are disconnected and when all wireless network ports are deactivated (from 1 January 2017).
- Networked equipment other than High Network Availability (HiNA) equipment shall comply with the provisions of 'power management for all equipment other than networked equipment'
  - When all network ports are deactivated (since 1 January 2015)
  - When all wired network ports are disconnected and when all wireless network ports are deactivated (from 1 January 2017).
- The power consumption of 'other' networked equipment (i.e. not HiNA equipment or equipment with HiNA functionality) in a condition providing networked standby into which the equipment is switched by the power management function, or a similar function,
  - Shall not exceed 6 W (since 1 January 2015);
  - Shall not exceed 3 W (from 1 January 2017);
  - Shall not exceed 2 W (from 1 January 2019).

For household washing machines and washer-dryers which are connected to a network, the latter requirements for non-HiNA equipment apply.

Ecodesign Regulation 640/2009 for electric motors

Commission Regulation (EC) No 640/2009 of 22 July 2009 is implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to Ecodesign requirements for electric motors, including where integrated in other products. The Regulation, however, does not cover all motor types being on the market. Therefore, the preparatory study for Lot 30, finished in 2014 (cf. http://www.eco-motors-drives.eu/Eco/Home.html) aimed at identifying the environmental improvement potential of products outside the scope of Regulation 640/2009 on electric motors, such as:

- Motors below 750 W and above 375 kW;
- special-purpose inverter duty motors (asynchronous servo motors);
- permanent magnet motors;
- motors cooled by their load (fans),

- drives, such as soft starters, torque or variable speed drives (VSD) from 200W–1 000kW.

Motors are also integral part of household washing machines and washer-dryers. With the extension of the Ecodesign Regulation 640/2009 to motors below 750 W, asynchronous inverter motors and permanent magnet motors, these household appliances would indirectly also be affected (cf. also section 4.4.2.2).

On 29 April 2015, there has been an Ecodesign horizontal matters consultation forum meeting in Brussels, inter alia dealing with a discussion paper on Ecodesign for energy-related products integrated into other energy-related products, concerning inter alia Regulation 640/2009 with regard to Ecodesign requirements for electric motors which either may be sold as "stand alone" products, or integrated in other energy-related products such as washing machines and washer-dryers.

The discussion paper informs that

- It has been claimed by some manufacturers of final products incorporating other energy-related products that setting minimum requirements for components might have a negative impact on the LCC of the final products and that it is necessary to allow manufacturers flexibility in deciding the best combination of 'measures' to meet the Ecodesign requirements for the final product (or to achieve a higher energy efficiency class).
- It has to be noted that from a technical point of view, so far no evidence has been presented showing that the use of more efficient components leads to a lower energy efficiency of the final product. In reality, most of the time very efficient products are combinations of very efficient components put together in an appropriate way.
- In fact, Ecodesign requirements only remove the worst performing products from the market, leaving enough choice for final equipment manufacturers to integrate components allowing them to meet their design requirements including the minimum energy efficiency requirements set by a specific ecodesign measure.
- The results of a LCC analysis depend on the underlying assumptions regarding production costs, energy use, cost and hours of operation. If the assumptions regarding these parameters are set appropriately, the use of a more efficient component 'automatically' leads to a more efficient final product .Nevertheless, as “base cases” are abstractions of reality, not all the specific uses of equipment can be captured. For instance, the assumptions regarding the use of small motors need to reflect the “typical” use of a motor in different products (ranging from domestic washing machines and fridges to commercial chillers or industrial machine tools), the operating hours of which are all different .Moreover, the same applies to the different ways in which a final consumer may operate a (fairly homogeneous) product such as a washing machine, resulting in different LCC in reality. As an example, the preparatory study on the review of the motor Regulation assumed 400 running hours per year for small single phase motors which is line with the assumptions usually made regarding the use of domestic appliances. In reality, these running hours may differ for certain products and use patterns.

The discussion paper concludes that

- It may also lead to higher cost of the final product but if the requirements are correctly set, they will still be at the point of least LCC. Manufacturers may have less flexibility to decide what design measures to take.

The general aspect of components which are falling under the scope of other Ecodesign Regulations and which are integrated into other regulated products, such as washing machines and washer-dryers, might be relevant for instance also for:

- directional lamps, light emitting diode lamps and related equipment (Regulation 1194/2012)

- displays
- fans (Regulation 327/2011)
- water pumps (Regulation 547/2012).

Ecodesign preparatory study on smart appliances (ENER Lot 33, ongoing)

This study is aimed to provide the European Commission with an analysis of all technical, economic, environmental, market and societal aspects that are relevant for a broad market introduction of smart appliances. The study team started effectively in the autumn of 2014 and is expected to be finished in September 2016. A first discussion note had been published, presented and discussed at the first stakeholder meeting of the study in March 2015, providing initial information on the expected scope of the study, standardisation activities at EU level (cf. section 1.2.2.8), interoperability (i.e. the link between the individual appliance and the supply side) and options to reduce the interoperability gaps. By November 2015, Tasks 1 to 4 have been published and on 19 November 2015 a second stakeholder meeting has taken place.

According to VITO et al. (2015), the overall idea of a smart grid with smart appliances is to achieve a better balancing of energy supply and energy demand while accommodating more renewable energy and reducing peak load power generation. Flexibility of the energy demand is obtained through smart appliances for which the energy consumption load patterns can be shifted with acceptable user impact. The load shifting can take place when needed – typically at power peaks and times with renewable energy power surplus – and in accordance with the agreements with the consumers. Shifting of the energy consumption load patterns take typically place through VITO et al. (2015):

- Control signals from the power system as direct appliance control (start, stop, modulate load etc.) after an agreement with the consumer.
- Price signals that the appliance can react on according to consumer settings.
- Appliances with internal voltage and/or frequency measurement and control, where the appliances switch on/off or modulate the consumption in function of those measurements and according to consumer settings.

In the framework of the horizontal study, a smart appliance is defined by means of the following characteristics:

- It is an appliance as defined and within the scope of the Ecodesign and Energy labelling framework;
- It is an appliance that is able to automatically respond to external stimuli such as price information, direct control signals, and power line quality (mainly voltage and frequency);
- The response should result in a change of the appliance's electricity consumption pattern;
- The smart capability must be able to function all over the EU;
- The specific technical smart capabilities do not need to be activated when the product is placed on the market; the activation can be done at a later point of time by the consumer or a service provider.

As example of periodical household appliances, in the study dishwashers, washing machines, tumble dryers and washer dryers are analysed in more detail. According to the study, their higher power during operation, the larger delay windows (higher flexibility) compared to other product categories and the high market penetration in Europe, especially in the case of washing machines and dishwashers, results in a significant demand response potential. (Vanthournout, Ectors, Claessens et al. 2015)

The study provides information on the implementation potential of these household appliances for ‘remote activation’ (i.e. the user selected program is remotely activated before the user deadline is reached) or ‘altered electricity consumption patterns’ (i.e. while the appliance is activated, the consumption patterns are changed through pausing the operation, changing the temperatures, etc.), as well as information on the consumer acceptance.

For example, for remote activation consumer’s acceptance is expected to be high. However, there can be concerns regarding safety (especially in periods of absence) and noise (during the night). On the other hand, altered consumption mode operation may have an impact on the quality of the appliance’s operation (e.g. changes in cleaning performance or colour fading due to pausing and prolonging the operation) and on its energy consumption. If a process, for example, is interrupted during a critical heating phase, the process temperature will decrease due to heat losses and additional energy is needed after the pause to compensate for this lost heat.

One of the case studies chosen in the preparatory study is a washing machine. According to VITO et al. (2015), in this use case, the user has an electricity contract based on variable prices, e.g., prices based on the day ahead energy market. Those prices are directly downloaded to the washing machine, which has a communication interface that supports the used pricing scheme and which is equipped with dynamic pricing scheduling logic. When the user configures the machine, he/she sets a deadline when the laundry should be finished the latest, and the washing machine then automatically starts the washing program such, that the total energy price for the programme is cheapest, while the laundry is still finished in time. The washing machine may also give indications via its user interface to the user on when the cheapest and/or highest prices occur, such that the user can take this into account during configuration. The same principle might also apply to household washer-dryers.

- For further details, please refer to the dedicated website http://www.eco-smartappliances.eu.

1.2.1.2. Legislation on energy efficiency and other performance characteristics for washing machines and washer-dryers

EU Regulation 1061/2010 with regard to Energy Labelling of household washing machines

Commission Delegated Regulation (EU) No 1061/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to Energy Labelling of household washing machines (European Commission 2010a) introduces new energy efficiency classes (A+, A++ and A+++), in addition to A-G ratings. This Delegated Regulation replaces the Energy Labelling of household washing machines as established by Commission Directive 95/12/EC of 23 May 1995 implementing Council Directive 92/75/EEC with regard to Energy Labelling of household electric washing machines (OJ L 47, 24.2.1996, p. 35).

The regulation requires for all washing machines placed on the European market to present following information to the customer:

- 7 classes maximum: from A+++ to D
- Coloured arrows are used to differentiate energy efficient from lower energy efficient products: dark green indicates a highly efficient product and red a low efficient product.
- The label for washing machines no longer includes a washing performance class as A class washing performance is mandatory for all washing machines with a rated capacity greater than 3 kg.

- Annual energy consumption in kWh (assuming 220 cycles per year and including standby consumption)
- Pictograms highlighting selected performances and characteristics:
- Noise emissions in decibels
- Spin-drying efficiency class
- Capacity in kilograms
- Annual water consumption in litres

The annual energy and water consumptions, and the spin-drying efficiency class indicated on the label, are calculated, in accordance with the technical specifications set in the standard EN 60456:2011, on the basis of:

- 60 °C cotton programme at full and partial load
- 40 °C cotton programme at partial load
- Left-on mode and off-mode

Values for the annual water consumption and the spin-drying efficiency class are based on the same set of washing cycles as the energy consumption data.

The classification of individual machines to the efficiency classes A^{+++} to D is done in accordance with the given ranking criteria (Table 1.3)

Table 1.3: Energy efficiency classes for household washing machines

Energy efficiency class	Energy Efficiency Index (EEI)
A^{+++}	EEI < 46
A^{++}	46 ≤ EEI < 52
A^{+}	52 ≤ EEI < 59
A	59 ≤ EEI < 68
B	68 ≤ EEI < 77
C	77 ≤ EEI < 87
D	EEI ≥ 87
(European Commission 2010a)	

In order to classify an appliance, the **energy efficiency index (EEI)** is calculated according to Equation 1.1:

Equation 1.1:

$$EEI = \frac{AE_C}{SAE_C} \times 100$$

where: AE_C = annual energy consumption of the household washing machine

SAE_C = standard annual energy consumption of the household washing machine

The **standard annual energy consumption (SAE_C)** is calculated in kWh/year as indicated in Equation 1.2: and rounded to two decimal places. SAE_C was calculated in ENER Lot 14, reflecting the market situation before the introduction of the EU regulations 1015/2010 and 1061/2010.

Equation 1.2:

$SAE_C = 47.0 \times c + 51.7$

where:

c = rated capacity of the household washing machine for the standard 60 °C cotton programme at full load or the standard 40 °C cotton programme at full load, whichever is the lower.

As shown in Equation 1.3:, the **Annual Energy Consumption AE_C** results from the energy consumption of the standard test programme and the power consumption of left-on mode and off mode, each of them taken into account to 50% percent where no power management is present. A usage frequency of 220 cycles per year is assumed for the calculation of EEI and annual consumption of energy and water for household washing machines.

Equation 1.3:

$$AE_C = E_t \times 220 + \frac{\left[P_o \times \frac{525600 - (T_t \times 220)}{2} + P_l \times \frac{525600 - (T_t \times 220)}{2} \right]}{60 \times 1000}$$

Where

E_t = weighted energy consumption for the standard cycle, in kWh

P_l = weighted power in 'left-on mode' for the standard cycle, in W

P_o = weighted power in 'off mode' for the standard cycle, in W

T_t = weighted programme time for the standard cycle, in minutes

Since January 2013, according to the second tier of the Regulation 1275/2008 for standby and off-mode, all household washing machines have to be equipped with a power management system, with the household washing machine reverting automatically to 'off-mode' after the end of the programme. Therefore, another equation is applied for calculating the **Annual Energy Consumption**, taking into consideration the effective duration of 'left-on mode'.

Equation 1.4:

$$AE_C = E_t \times 220 + \frac{\{P_l \times T_l \times 220 + P_o \times [525600 - (T_t \times 220) - (T_l \times 220)]\}}{60 \times 1000}$$

Where

T_l = measured time in 'left-on mode' for the standard washing cycle, in minutes.

The weighted **energy consumption (E_t)** is calculated in kWh as follows and rounded to three decimal places:

Equation 1.5:

$$E_t = 3 \times E_{t,60} + 2 \times E_{t,60\frac{1}{2}} + 2 \times E_{t,40\frac{1}{2}}$$

where:

$E_{t,60}$ = energy consumption of the standard 60 °C cotton programme;

$E_{t,60½}$ = energy consumption of the standard 60 °C cotton programme at partial load;

$E_{t,40½}$ = energy consumption of the standard 40 °C cotton programme at partial load.

The **weighted power in 'off-mode' (P_o)** is calculated in W, as follows and rounded to two decimal places:

Equation 1.6:

$$P_O = 3 \times P_{O,60} + 2 \times P_{O,60\frac{1}{2}} + 2 \times P_{O,40\frac{1}{2}}$$

where:

$P_{o,60}$ = power in 'off-mode' of the standard 60 °C cotton programme at full load;

$P_{o,60½}$ = power in 'off-mode' of the standard 60 °C cotton programme at partial load;

$P_{o,40½}$ = power in 'off-mode' of the standard 40 °C cotton programme at partial load.

The **weighted power in the 'left-on mode' (P_l)** is calculated in W, as follows and rounded to two decimal places:

Equation 1.7:

$$P_l = 3 \times P_{l,60} + 2 \times P_{l,60\frac{1}{2}} + 2 \times P_{l,40\frac{1}{2}}$$

where:

$P_{l,60}$ = power in 'left-on mode' of the standard 60 °C cotton programme at full load;

$P_{l,60½}$ = power in 'left-on mode' of the standard 60 °C cotton programme at partial load;

$P_{l,40½}$ = power in 'left-on mode' of the standard 40 °C cotton programme at partial load.

The **weighted programme time (T_t)** is calculated in minutes as follows and rounded to the nearest minute:

Equation 1.8:

$$T_t = 3 \times T_{t,60} + 2 \times T_{t,60\frac{1}{2}} + 2 \times T_{t,40\frac{1}{2}}$$

where:

$T_{t,60}$ = programme time of the standard 60 °C cotton programme at full load;

$T_{t,60½}$ = programme time of the standard 60 °C cotton programme at partial load;

$T_{t,40½}$ = programme time of the standard 40 °C cotton programme at partial load.

The **weighted time in 'left-on mode' (T_l)** is calculated in minutes as follows and rounded to the nearest minute:

Equation 1.9:

$$T_l = 3 \times T_{l,60} + 2 \times T_{l,60\frac{1}{2}} + 2 \times T_{l,40\frac{1}{2}}$$

where:

$T_{l,60}$ = time in ‘left-on mode’ of the standard 60 °C cotton programme at full load;

$T_{l,60½}$ = time in ‘left-on mode’ of the standard 60 °C cotton programme at partial load;

$T_{l,40½}$ = time in ‘left-on mode’ of the standard 40 °C cotton programme at partial load.

Further, calculation methods for the washing efficiency index, spin-drying efficiency, annual water consumption, remaining moisture content and the maximum allowed verification tolerances are provided by Regulation 1061/2010/EU (European Commission 2010a), on the basis of the testing framework set with the standard EN 60456:2011.

Recently, the Regulation 1061/2010/EU was amended by the Commission Delegated Regulation (EU) No 518/2014, providing indications for the labelling of energy-related products on the internet.

EU Directive 96/60/EC with regard to Energy Labelling of washer-dryers

Household combined washer-dryers are addressed in Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to Energy Labelling of household combined washer-dryers. They are explicitly exempted from the scope of the current Regulations 1061/2010 (Energy Labelling of washing machines) and 392/2012 (Energy Labelling of tumble dryers).

The Energy label for washer-dryers contains:

- The energy consumption per cycle (washing and drying)
- The energy consumption per cycle – washing only
- Washing performance – with a class from A to G
- The maximum spin speed
- The total cotton capacity (washing and drying separately)
- Water consumption for a full load washed and dried – note that condenser dryers may use significant amounts of water on the drying cycle
- Noise in dB (A) (separately for washing, spinning and drying)

For combined washer-dryers the energy efficiency scale is based on the energy consumption 'C' in kWh per kg of load for a complete operating cycle (washing, spinning and drying) using the standard 60 °C cotton cycle, and 'dry cotton' drying cycle.

The allocation of individual machines to the efficiency classes A to G is done in accordance with the given scheme (Table 1.4)

Table 1.4: Energy efficiency classes for household washer-dryers

Energy efficiency class	Energy Consumption (C)
A	C ≤ 0.68
B	0.68 < C ≤ 0.81
C	0.81 < C ≤ 0.93
D	0.93 < C ≤ 1.05
E	1.05 < C ≤ 1.17
F	1.17 < C ≤ 1.29
G	1.29 < C

Energy efficiency class	Energy Consumption (C)
(European Commission 1996)	

The washing performance class of an appliance is measured based on using a standard 60 °C cotton cycle and shall be determined in accordance with Table 1.5.

Table 1.5: Washing performance classes for household washer-dryers

Washing performance class	Washing Performance Index (P)
A	P > 1.03
B	1.03 ≥ P > 1.00
C	1.00 ≥ P > 0.97
D	0.97 ≥ P > 0.94
E	0.94 ≥ P > 0.91
F	0.91 ≥ P > 0.88
(European Commission 1996)	

EU Regulation 392/2012 with regard to Energy Labelling of household tumble dryers

Household combined washer-dryers are explicitly addressed in the Commission Directive 96/60/EC, concerning the energy labelling of such appliance, cf. section above. However, for the sake of comparison, the current Energy label regulation 392/2012 for tumble dryers is presented and applicability of its elements for the drying function(s) of washer-dryers will be analysed throughout the study.

Commission Delegated Regulation (EU) No 392/2012 of 1 March 2012 (European Commission 2012b) establishes requirements for the labelling of and the provision of supplementary product information on electric mains-operated and gas-fired household tumble dryers and built-in household tumble dryers, including those sold for non-household use. Further, the regulation differs between 'air-vented' (i.e. a tumble dryer that draws in fresh air, passes it over the textiles and vents the resulting moist air into the room or outside) and 'condenser tumble dryer' (i.e. a tumble dryer which includes a device either using condensation or any other means for removing moisture from the air used for the drying process). As the drying process of washer-dryers is solely based on the condensing principle (cf. section 4.3.2), in the following only the requirements for this drying type are listed.

The following information is included in the label for household condenser tumble dryers:

- the energy efficiency class indicated by an arrow
- weighted annual energy consumption (AE_C) in kWh/year, rounded up to the nearest integer
- information on the type of household tumble dryer;
- cycle time corresponding to the standard cotton programme at full load in minutes and rounded to the nearest minute;
- rated capacity, in kg, for the standard cotton programme at full load;
- the sound power level (weighted average value — L_{WA}), during the drying phase, for the standard cotton programme at full load, expressed in dB, rounded to the nearest integer;
- the condensation efficiency class.

Table 1.6: Energy efficiency classes for household tumble driers

Energy efficiency class	Energy Efficiency Index (EEI)
A^{+++}	EEI < 24
A^{++}	24 ≤ EEI < 32
A^{+}	32 ≤ EEI < 42
A	42 ≤ EEI < 65
B	65 ≤ EEI < 76
C	76 ≤ EEI < 85
D	EEI ≥ 85
(European Commission 2012b)	

In order to classify an appliance, the **energy efficiency index (EEI)** is calculated according to Equation 1.10:

Equation 1.10:

$$EEI = \frac{AE_C}{SAE_C} \times 100$$

where: AE_C = weighted annual energy consumption of the household tumble dryer

SAE_C = standard annual energy consumption of the household tumble dryer

For all household tumble dryers that are not air-vented, the **standard annual energy consumption (SAE_C)** is calculated in kWh/year as indicated in Equation 1.11 and rounded to two decimal places.

Equation 1.11:

$SAE_C = 140 \times c^{0.8}$

where:

c = rated capacity of the household tumble dryer for the standard cotton programme.

Since January 2013, according to the second tier of the Regulation 1275/2008 for standby and off-mode, all household tumble dryers have to be equipped with a power management system, with the machine reverting automatically to 'off-mode' after the end of the programme. Therefore, the following equation is applied for calculating the **Annual Energy Consumption**, taking into consideration the effective duration of 'left-on mode'.

Equation 1.12:

$$AE_C = E_t \times 160 + \frac{\{P_l \times T_l \times 160 + P_o \times [525600 - (T_t \times 160) - (T_l \times 160)]\}}{60 \times 1000}$$

where:

E_t = weighted energy consumption, in kWh and rounded to two decimal places

P_l = power in 'left-on mode' for the standard cotton programme at full load, in W and rounded to two decimal places

P_o = power in 'off mode' for the standard cotton programme at full load, in W and rounded to two decimal places

T_t = weighted programme time, in minutes and rounded to the nearest minute

T_l = duration of the 'left-on mode' for the standard cotton programme at full load, in minutes and rounded to the nearest minute.

160 = total number of drying cycles per year.

The **weighted programme time (T_t)** for the standard cotton programme is calculated in minutes as follows and rounded to the nearest minute:

Equation 1.13:

$$T_t = (3 \times T_{dry} + 4 \times T_{dry\frac{1}{2}})/7$$

where:

T_{dry} = programme time for the standard cotton programme at full load; in minutes and rounded to the nearest minute.

$T_{dry½}$ = programme time for the standard cotton programme at partial load; in minutes and rounded to the nearest minute.

The weighted **energy consumption (E_t)** is calculated in kWh as follows and rounded to two decimal places:

Equation 1.14:

$$E_t = (3 \times E_{dry} + 4 \times E_{dry\frac{1}{2}})/7$$

where:

E_{dry} = energy consumption of the standard cotton programme at full load; in kWh and rounded to two decimal places

$E_{dry½}$ = energy consumption of the standard cotton programme at partial load; in kWh and rounded to two decimal places

In case of condenser tumble dryers, the product fiche must report also the weighted condensation efficiency (C_t) for the 'standard cotton programme at full and partial load', as a percentage and rounded to the nearest whole percent.

The condensation efficiency of a programme is the ratio between the mass of moisture condensed and collected in the container of a condenser household tumble drier and the mass of moisture removed from the load by the programme, the latter being the difference between the mass of the wet test load before drying and the mass of the test load after drying. For calculating the weighted condensation efficiency, the average condensation efficiency for the standard cotton programme at both full and partial load is considered.

Table 1.7: Condensation efficiency classes for household tumble driers

Energy efficiency class	Weighted condensation efficiency
A	$C_t > 90$
B	$80 < C_t \leq 90$
C	$70 < C_t \leq 80$
D	$60 < C_t \leq 70$
E	$50 < C_t \leq 60$
F	$40 < C_t \leq 50$
G	$40 \geq C_t$
(European Commission 2012b)	

The weighted condensation efficiency (C_t) of a programme is calculated as a percentage and rounded to the nearest whole percent as:

Equation 1.15:

$$C_t = (3 \times C_{dry} + 4 \times C_{dry\frac{1}{2}})/7$$

where:

C_{dry} = average condensation efficiency of the standard cotton programme at full load

$C_{dry½}$ = average condensation efficiency of the standard cotton programme at partial load.

The average condensation efficiency C is calculated from the condensation efficiencies of test runs and expressed as a percentage:

Equation 1.16:

$$C = \frac{1}{(n-1)} \sum_{j=2}^{n} \left(\frac{W_{wj}}{W_i - W_f} x100 \right)$$

where:

n = number of test runs, comprising at least four valid test runs for the selected programme.

j = test run number.

W_{wj} = mass of water collected in the condenser reservoir during test run j.

W_i = mass of the wet test load before drying.

W_f = mass of the test load after drying.

The standard programme to measure the energy consumption of tumble dryers is the standard cotton programme which dries cotton laundry with an initial moisture content of the load of 60% up to a remaining moisture content of the load of 0% (cupboard dry). The calculation of the weighted annual energy consumption value is based on 160 drying cycles of the standard cotton programmes at full and partial load, and the consumption of the low-power modes

A stakeholder informed that it is difficult to fully dry cotton clothes with the standard programme due to the fixed target of 0% remaining moisture content. The reason is that the moisture is not distributed evenly within the laundry and therefore slightly moist areas always remain. To achieve fully cupboard dry clothes the target moisture content has to be set slightly below 0% (i.e. -2%). Based on this, it is suggested that different levels of residual moisture content should be selectable by the users in the standard programme.

1.2.1.3. Legislation on safety and other aspects of potential relevance for washing machines and washer dryers

LVD Directive 2014/35/EU

Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 is on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (European Parliament 2014b).

The purpose of this Directive is to ensure that electrical equipment on the market fulfils the requirements providing for a high level of protection of health and safety of persons, and of domestic animals and property, while guaranteeing the functioning of the internal market.

The Directive applies to electrical equipment designed for use with a voltage rating of between 50 and 1,000 V for alternating current and between 75 and 1,500 V for direct current, which is new to the Union market when it is placed on the market, i.e. it is either new electrical equipment made by a manufacturer established in the Union or electrical equipment, whether new or second-hand, imported from a third country. Also for household appliances, inter alia washing machines and washer-dryers, the Directive covers all health and safety risks, thus ensuring that these appliances will be used safely and in applications for which they were made.

Manufacturers of electrical equipment covered by the Directive are obliged to carry out the conformity assessment procedure. The CE marking, indicating the conformity of electrical equipment, is the visible consequence of a whole process comprising conformity assessment.

The new requirements under LVD 2014/35/EU will be applicable from 20 April 2016 and replace the former LVD 2006/95/EC.

EMC Directive 2014/30/EU

Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States regulates the electromagnetic compatibility of equipment (European Parliament 2014a). It aims to ensure the functioning of the internal market by requiring equipment to comply with an adequate level of electromagnetic compatibility, i.e. the ability of equipment to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to other equipment in that environment.

Equipment shall be so designed and manufactured, having regard to the state of the art, as to ensure that:

- the electromagnetic disturbance generated does not exceed the level above which radio and telecommunications equipment or other equipment cannot operate as intended;

- it has a level of immunity to the electromagnetic disturbance to be expected in its intended use which allows it to operate without unacceptable degradation of its intended use.

Manufacturers of equipment covered by the Directive are obliged to carry out the conformity assessment procedure. The CE marking, indicating the conformity of apparatus, is the visible consequence of a whole process comprising conformity assessment. Apparatus shall be accompanied by information on any specific precautions that must be taken when the apparatus is assembled, installed, maintained or used, in order to ensure that, when put into service, the apparatus is in conformity with the essential requirements set out in the Directive.

The new requirements under EMC 2014/30/EU will be applicable from 20 April 2016 and replace the former EMC Directive 2004/108/EU.

Further legislation

Further, according to stakeholders, the following legislation might be relevant for household washing machines and washer-dryers:

- Radio and Telecommunications Terminal Equipment (R&TT) Directive 1999/5/EC
- The new European Radio Equipment Directive (RED) 2014/53/EU (mandatory in 2016).

1.2.2. European standards, basis for ecodesign and energy efficiency legislation

1.2.2.1. Performance standard for washing machines

The standard EN 60456:2011 "Clothes washing machines for household use. Methods for measuring the performance" was developed under mandate M/458, which relates to Directive 2009/125/EC of the European Parliament establishing a framework for the setting of ecodesign requirements for energy-related products, to Council Directive 92/75/EEC on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances and to measures implementing these Directives, for which a Harmonised Standard(s) should be developed to cover essential requirements.

This European Standard also specifies, as far as necessary, the test methods which will be applied in accordance with the Commission Delegated Regulation (EU) No. 1061/2010, supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to Energy Labelling of household washing machines, and in accordance with the Commission Regulation (EU) No. 1015/2010, implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household washing machines.

In brief, the testing procedure, as laid out in this standard, prescribes a well-defined measurement procedure of how to load a washing machine using distinct textiles (white cotton items only: sheets, pillowcases and towels. The partial load is half of the nominal load or rated capacity) under well-controlled conditions (ambience, water, voltage, frequency), together with well-specified test swatches with five different stain monitors and using a well-defined powder detergent. The amount of textiles, test swatches and detergent depend on the rated capacity of the washing machine to be tested. The rated washing capacity is the maximum mass of conditioned textiles (conditioned according to sub-clause 6.3.3 in EN 60456), in kg, which the manufacturer declares can be treated in one complete washing cycle.

According to the 2011 regulation, and with the aim to simulate real use conditions, two tests are carried out in a programme called “standard cotton 40 °C programme” with half the rated capacity, and additional two programmes in the "standard cotton 60 °C programme" with half of the load, and three programmes in the "standard cotton 60 °C programme" with a full load.

No measurement of the real temperature in the load is determined. The standard allows the programme temperature to be a maximum value suitable for the kind of textiles to be washed. The actual temperature used during the programme cycle can be lower. This is supported by the sentence in Annex I of the Ecodesign Regulation 1015/2010, which states that the booklet of instructions should indicate that the values are based on "the 'standard 60 °C cotton programme' and the 'standard 40 °C cotton programme'", that these programmes are "suitable to clean normally soiled cotton laundry" and "the most efficient programmes in terms of combined energy and water consumption", and that "the actual water temperature may differ from the declared cycle temperature".

After having carried out a washing process, the test monitors are evaluated by measuring the colour of any remaining stains by a spectral photometer. The averaged sum of the values of the remaining stains are then compared to the results achieved by a washing process carried out under similar conditions and in parallel to the machine under test in a reference washing system. This usage of a reference system allows the leverage of uncontrollable factors of the whole test, such as batch to batch variations of the stain monitors or the detergent. In parallel to the washing process, all consumption values (water, energy, programme time) are recorded and the weighted average of all relevant measures of all seven cycles is calculated.

At the end of the spinning process, the final humidity is determined by comparing the amount of water retained in the load with the conditioned weight of the load. Additionally, the spinning speed is recorded during the spinning process and analysed afterwards to determine the maximum spin speed as the highest spin speed determined during a period of 60 seconds.

The standard is available and in line with the current regulations. It was published in the OJ (2013/C 355/04) together with EN 60456:2011/AC:2011, which corrected the amount of detergent to be used for the reference machine. In the OJ, a note states that "This standard needs to be completed to clearly indicate those legal requirements aimed to be covered. Clause ZB on tolerances and control procedures is not part of the present citation." This clarification is underway in an amendment of this standard (see below).

EN 60456:2011, which supersedes EN 60456:2005 + A11:2006 + FprAB:2010, consists of the text of the analogous international standard IEC 60456:2010 with common modifications prepared by CENELEC TC 59X.

There are significant technical differences compared to IEC 60456:2010:

a) A test procedure for a combined test sequence of cotton 40 °C and cotton 60 °C with full load and partial load is introduced;

b) A test procedure for measuring power consumption in low power modes is introduced;

c) A formula to calculate the energy consumption of washing machines, including low power modes, is added;

d) The detergent dosage is reduced to 75% for cotton and synthetic/blends; the dosage is depending on the load: 40 g + 12 g/kg load

e) The detergent dosage of the reference machine type 1 (new type in IEC60456) is adjusted to maintain the washing performance level of the reference machine type 2 (old type);

f) The reference machine type 1 is to be used for testing according to Commission Regulations with regard to Energy Labelling and Ecodesign; and

g) Control procedures for checking measured values in comparison to values declared by the manufacturer under consideration of permitted tolerances are updated.

The procedures described in this European Standard were modified substantially compared to the previous versions, e.g. with regard to detergent dosage. Therefore, results of tests according to this standard cannot be directly compared to results of similar procedures of previous versions. Additionally, results based on a specific reference programme cannot be compared to results based on other reference programmes, like they are used for other countries or textile types.

Rinsing performance

Mandate M/458 also requires the development of “procedures and methods for measuring the rinsing efficiency of household washing machines”. In principle, EN60456:2011 describes a procedure for measuring rinsing efficiency by measuring the remaining alkalinity in the load after final spinning. This methodology is well used within laboratories of manufacturers and test houses and used for publishing results in consumer organisation tests of washing machines. Unfortunately, tests of the same washing machine in different locations have shown a poor reproducibility of this methodology. This means that it is possible to compare rinsing efficiencies of machines within one laboratory, but a re-measurement on the similar machines in other laboratories may deliver significantly different absolute results. A workshop on washing machine rinsing efficiency measurement took place in Brussels on the 27 October, 2010, with participants from the EU (DG Energy) and relevant experts from the textile, detergent, consumer and machine industries to review the status and discuss possible options to improve rinsing performance measurements. As this resulted in no immediate solution, the task to work on an improved method was forwarded to CLC TC59X WG1 and IEC 59D WG20.

Actually, a new measurement procedure is developed in Europe (CENELEC TC59X WG1) based on measuring the remaining surfactant (LAS - Linear Alkylbenzene Sulfonate) via UV spectroscopy on the unsoiled part of the test strip after the washing and rinsing process. This procedure has the advantages that it is a direct measure of one relevant detergent‘s ingredient (compared to the alkalinity which is influenced by many factors) and it is applicable also for washer-dryers. In the latter case the alkalinity method cannot be used in the continuous washing and drying cycle as no separate water extraction of the washed load can take place. Additionally this new procedure may be used also for liquid detergents. This procedure is now under comparison with other procedures developed and used in other countries, namely in US, China and Australia/ New Zealand (cf. section 1.2.5.5). The result of this investigation is expected to deliver sound data to answer the question how precise and how reproducible a rinsing process in a washing machine can be measured.

Further standardisation activities of CLC TC59X WG1

Further, the responsible working group at CENELEC level (CENELEC TC59X WG1) is preparing an amendment of EN60456:2011 which corrects some editorial mistakes and will update the performance measurement procedure (e.g. load definition, half load definition, reference machine, soils strips, low power mode measurements). This is especially needed for all references to EN 62301:2005 “Household electrical appliances. Measurement of standby power” (cf. section 1.2.2.4), as it was replaced by the new standard EN 50564:2011 “Electrical and electronic household and office equipment – Measurement of low power consumption” prepared by a combined working group of CLC TC59X and TC108X. This European standard was prepared under standardisation mandate M/439. To fulfil the requirements of the mandate, the scope of EN 50564 had to be broadened in comparison with IEC 62301:2011 to cover a range of electrical and electronic household and office equipment. This is reflected in the title of EN 50564 in comparison with the title of IEC 62301:2011.

Additionally this amendment will have a new Annex ZB 'Tolerances and control procedures' clarifying the rule of tolerances in the verification procedure (see above).

The CLC TC59X WG1 is also working on new methods for the preparation of hard water to include in the standard IEC/EN 60734:2012 "Household electrical appliances - Performance - Water for testing".

1.2.2.2. Performance standard for washer-dryers

The European Standard EN 50229 'Electric clothes washer-dryers for household use - Methods of measuring the performance' specifies the test methods which shall be applied in accordance with the Commission Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to Energy Labelling of household combined washer-dryers. It deals with:

- Performance criteria, including energy and water consumption, for the 60 °C cotton wash programme as specified in EN 60456 (cf. section 1.2.2.1),
- Energy and water consumption of the drying cycle based on the "Dry cotton programme" as specified in EN 61121 (cf. section 1.2.2.3).

It defines relevant terms:

- Rated washing capacity - maximum mass of conditioned textiles (conditioned according to sub-clause 6.3.3 in EN 60456), in kg, which the manufacturer declares can be treated in one complete washing cycle,
- Rated drying capacity - maximum mass of conditioned textiles (conditioned according to sub-clause 6.3.3 in EN 60456), in kg, which the manufacturer declares can be treated in one complete single drying operation,
- Complete operation cycle - complete washing and drying process, as defined by the required programme(s), consisting of the washing cycle and the drying cycle,
- Washing cycle - complete washing process, as defined by the required programme, consisting of a series of different operations (wash, rinse, spin),
- Drying cycle - complete drying process, as defined by the required programme, consisting of a series of different operations (heat, cool down). The drying cycle comprise drying of all partial loads, if the base load is split up,
- Automatic drying - drying process which automatically switches off when a certain moisture content of the load is reached.

As the rated washing capacity is normally higher as the rated drying capacity this standard requires that the load after being washed is divided in two or more parts that are dried individually. Water and energy consumption are calculated by adding up all individual consumption values, so from washing and two or more drying processes (when the rated washing capacity is more than twice the rated drying capacity).

Updates of EN 50229

The basic standards for measuring the energy consumption and performance of a washer-dryer (EN 50229) are the measurement standards for washing machines (EN 60456) and for tumble dryers (EN 61121)

EN 50229 was first published in 1997 but was regularly updated to adjust to the modification of EN 60456 and EN 61121, the European standards for testing washing machines' and tumble dryers' performance, respectively. The latest version of EN 50299 (2007) needs to be updated to align with recent changes applied to the standards for washing machines (EN 60456:2011) and for tumble dryers (EN 61121:2013), as shown in Figure 1.1.

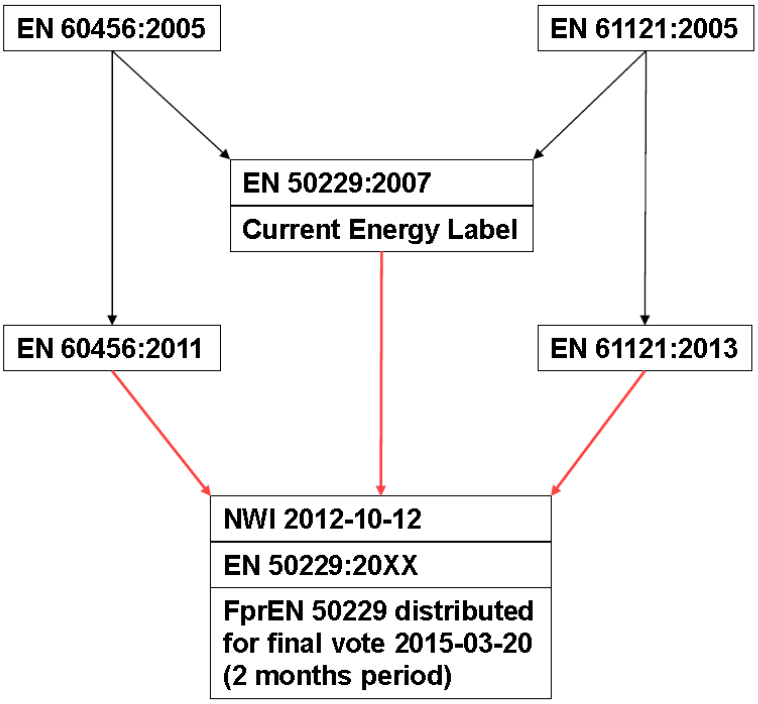


Figure 1.1: Relationship between the washing machine standard EN 60456 and the standard for measuring tumble dryers EN 61211 with the measurement standard for washer-dryers EN 50229. Timeline is from top to bottom of the graph.

The revision of the standard EN 50229:2007 is currently in formal voting process (draft standard prEN 50229 finalised in March 2015 by CENELEC TC 59X). The main changes introduced with the 2015 update are:

- Alignment with EN 60456:2011 and EN 61121:2013 due to e.g.
    - New reference machine for washing performance test
    - New stains and corresponding detergent composition; also the detergent dosage for the washing cycle will be adapted to the changes in EN 60456:2011, i.e. 40 g + 12 g/kg load
    - New general structure of EN 60456 and EN 61121 (update of performance measurement procedures and references)
- New structure to improve readability
- Clear definition how to test e.g.
    - Drying performance test in automatic or timer mode
    - Load splitting (Rated capacity and load composition)
    - Implementation of test procedure to ensure getting valid tests for drying process
- Clear structure of data to be reported
- Technical modification to avoid circumvention

For measuring the performance of the washing performance according to EN 60456, the continuous wash&dry cycle of washer-dryers presents some challenges. Firstly, information about the residual moisture content is lost since the drying process follows immediately the wash cycle. Moreover, measuring the rinsing performance according to alkalinity method as described today in EN 60456 (measured after the washing process) is not possible, as in the continuous wash&dry process no extractable water will be available at the end of the drying process. Some options to overcome these challenges have been proposed by stakeholders, including a very brief stop (e.g. less than two minutes) between washing and drying that would allow to undertake the required measurements.

1.2.2.3. Performance standard for tumble-dryers

The European Standard EN 61121:2013 specifies, as far as necessary, the test methods which shall be applied in accordance with the Commission Delegated Regulation (EU) No 392/2012 implementing Directive 2010/30/EU the European Parliament and of the Council with regard to energy labelling of household tumble dryers and in accordance with the Commission Regulation (EU) No 932/2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to Ecodesign requirements for household tumble dryers.

This standard sets methods for the measurement of following performance parameters for tumble dryers (without specifying minimum performance requirements):

- Electric energy consumption;
- Water consumption;
- Programme time;
- Condensation efficiency;
- Evenness of drying;
- Volumetric flow rate of exhaust air;
- Off mode power and left-on mode power.

Any claims of performance referring to this standard have to be qualified with load type and capacity used for the test.

The procedures described in this standard were modified substantially compared to the previous version, e.g. with regard to partial load. EN 61121:2013 includes the following significant technical changes with respect to EN 61121:2005:

a) a test procedure for a combined test sequence of full and partial loads was introduced;
b) a test procedure for measuring power consumption in low power modes was introduced;
c) a formula to calculate the energy consumption of tumble dryers including low power modes was added;
d) measurement tolerances were updated.

Therefore, results of tests according to this standard cannot be directly compared to results of similar procedures of previous versions. In addition, results based on a specific reference programme cannot be compared to results based on other reference programmes.

1.2.2.4. Low-power modes measurements for washing machine)

Low-power modes measurements for washing machine are provided in EN 60456 and for tumble dryers in EN 61121. No specifications are instead available for washer-dryers.

According to EN 60456, 'left-on mode' power and energy consumption measurements must be made once for each treatment. The measurement will be started after the end of the programme.

Power measurements for the 'left-on mode' must be in accordance with the requirements of EN 62301 "Household electrical appliances - Measurement of standby power" (IEC 62301:2005, modified), except the requirement defining the air speed (EN 62301:2005, 4.2). The air speed close to the appliance under test is not limited to ≤ 0.5 m/s. It is not possible to reduce it, because there is too much ventilation around the washing machine. The washing machine is not disconnected from the power supply after the end of the programme. No user intervention, besides unloading, takes place on the test washing machine before the 'left-on mode' power and energy measurement. Data for the parameters required are recorded at regular intervals of 1 second or less throughout the test, using a data logger or computer. These provisions are necessary to ensure that the real-life 'left-on mode' consumption is correctly measured. However, this requires specific energy measuring equipment, as the normal power level is at about 2,300 W during the washing operation, while it may be below 0.5 W during 'left-on mode' operation and only a tolerance of 0.1 W is given by the regulation. This may require manual switching of the measurement range on the instrument.

Additionally, the machine also needs some time after the end of the programme (e.g. when indications about the end of the programme are provided in the control panel and lamps may be turned on inside the drum to ease unloading) to revert to a steady state. This is the 'left-on mode', which is defined in EN 60456:2011 as the "lowest power consumption mode that may persist for an indefinite time after the completion of the programme and unloading of the machine without any further intervention of the user". This is different from the 'off-mode', which is defined as the "condition where the product is switched off using appliance controls or switches that are accessible and intended for operation by the user during normal use to attain the lowest power consumption that may persist for an indefinite time while connected to a mains power source and used in accordance with the manufacturer's instructions. Where there are no controls, the washing machine is left to revert to a steady state power consumption of its own accord." Both definitions are equivalent as defined in the EU Energy Label regulation 1061/2010 on washing machines.

The Delegated Regulation (EU) No 1061/2010 requires that the energy consumption in 'left-on mode' and 'off-mode' is to be calculated differently depending on the presence of a power management system in the machine itself. If the household washing machine is without a power management system, the time of the year the machine is not in operation is split 50:50 to be in 'left-on mode' and 'off-mode'. If the household washing machine is equipped with a power management system, with the household washing machine reverting automatically to 'off-mode' after the end of the programme, the weighted annual energy consumption is calculated, taking into consideration the effective duration of the 'left-on mode'. According to Regulation 1275/2008 for standby and off mode, since 2013 a power management system is mandatory for all household washing machines, however the maximum timeframe to switch into off mode has not been defined.

A testing laboratory asked to verify the energy consumption of a washing machine would, therefore, need to measure the time it takes this machine to revert from the 'left-on mode' status to the 'off-mode' automatically. This would mean an indefinite time to wait and observe the machine behaviour. As this is not a practical (and is a very expensive) procedure, standardisation had to transfer the requirements given in the regulation into an operational procedure. This was done by splitting the left-on phase into two parts:

- The post-programme phase LU (unstable 'left-on mode') starts after the end of programme and adjustment of measurement devices, and immediately after opening the door.
- The post-programme phase LO ('left-on mode') starts after LU is finished. Its measurement will last for 10 min.

When the test washing machine is equipped with a power management system to revert the machine automatically to ‘off-mode’ after the end of the programme and the ‘left-on mode’ duration is declared by the manufacturer to last longer than 30 min, the measurements of the post-programme phase LU will be prolonged to the duration declared.

When the test washing machine is equipped with a power management system to revert the machine automatically to ‘off-mode’ after the end of the programme and the ‘left-on mode’ duration is declared by the manufacturer to last less than 30 min, the measurements of the post-programme phase LU will be carried out for 30 min, irrespective of the declared duration.

The time between the end of programme and start of unstable ‘left-on mode’ power and energy consumption measurements should be ≤ 5 min. After starting power and energy consumption measurements in post programme phase LU, the load will be removed within 5 minutes. The door remains fully open at the completion of unloading.

The measurements to determine ‘off-mode’ power and energy consumption will be run for the test washing machine once for each treatment. At the completion of the programme, the test washing machine will be unloaded. For the determination of this mode, the test washing machine will then be switched off in accordance with the manufacturers’ instructions.

A graphic representation of this procedure is given in Figure 1.2. This procedure avoids any circumvention possibility which might exist during the unstable part of the ‘left-on mode’ and ensures that the measurement of the ‘left-on mode’ can be finished within a reasonable length of time (45 min) after the programme end. Consequently, the calculation of the Annual Energy consumption AEc had to be adjusted in the standard EN 60456 compared to the regulation:

$$AE_C = W_{total} \times 220 + \left\{ \frac{P_O}{1.000} \times \left[\frac{525.600 - ((t_t + t_{mLU}) \times 220)}{2 \times 60} \right] \right\} + \left\{ \frac{P_{LO}}{1.000} \times \left[\frac{525.600 - ((t_t + t_{mLU}) \times 220)}{2 \times 60} \right] \right\} + \left[\frac{P_{LU}}{1.000} \times \frac{(t_{mLU} \times 220)}{60} \right]$$

where

- W_{total} is the average total energy consumption kWh;
- P_{LU} is the average power during post-programme phase LU in W;
- P_{LO} is the average power during post-programme phase LO in W;
- t_{mLU} is the measurement time for post-programme phase LU in min;
- P_O is the average power in ‘off-mode’ in W;
- t_t is the average programme time in min;
- 220 is the total number of standard washing cycles per year;
- 525 600 are the minutes in a year.

It has been indicated that with this formula, the calculated annual energy consumption values are equal to or slightly higher than with those formulas given in the regulation.

1.2.2.5. Safety

Safety for wash appliances (washing machines and washer-dryers) is mainly dealt by the following standards:

- The general part EN 60335-1:2012 Household and similar electrical appliances - Safety - Part 1: ‘General requirements’ that is common to all the electric motor appliances. A set of "Part 2 documents" addresses safety issues for specific products. Updates of the EN 60335-1:2012 + A11:2014 + AC:2014 "General requirements for household appliances" include also new requirements considering use by vulnerable people (children and persons with reduced physical, sensory or mental capabilities) and reduction in the surface temperatures.

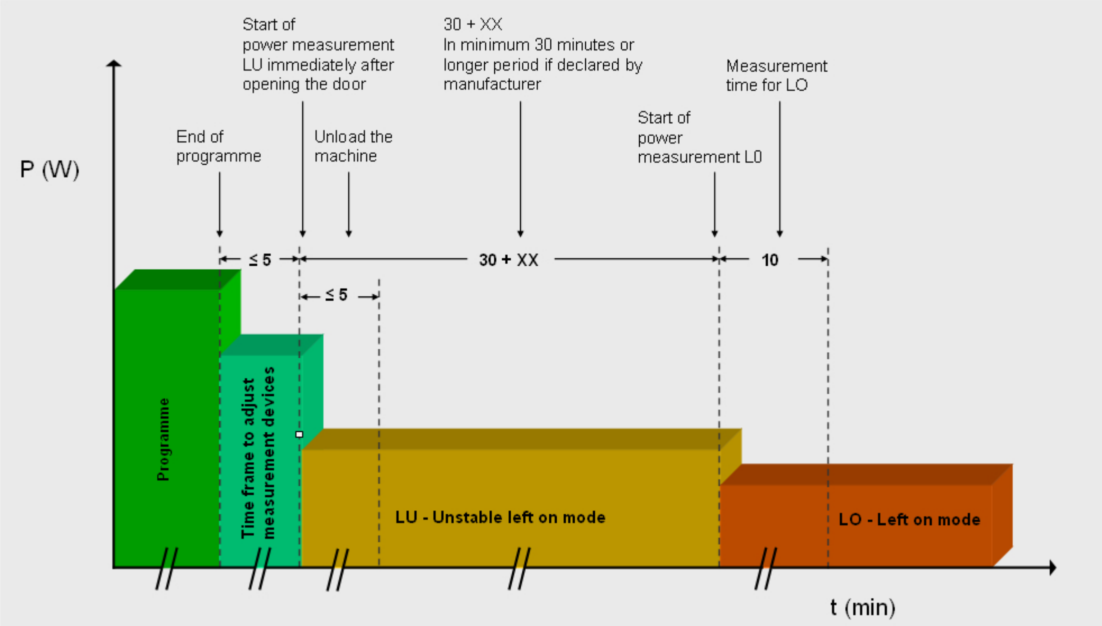


Figure 1.2: Graphical presentation of low power modes timing and testing

- For washing machines, EN 60335-2-7:2014 'Household and similar electrical appliances - Safety - Part 2-7: Particular requirements for washing machines' applies.
  - If the washing machine includes also a spinning function, then EN 60335-2-4:2010 'Household and similar electrical appliances - Safety - Part 2-4: Particular requirements for spin extractors' applies.
  - If also a drying function is included in the appliance (the so called "washer-dryer"), the standard EN 60335-2-11:2014 'Household and similar electrical appliances - Part 2-11: Particular requirements for tumble dryers' deals with the drying part.
  - Recent updates to these standards include EN 60335-2-7:2010 + A1:2013 + A11:2013 (i.e. similar changes as for Part 1 and to the conduction of the spillage test) and EN 60335-2-11:2010 + A11:2012 (i.e. additional standards of relevance for washer-dryers).
- As far as the connection with the water supply is concerned, washing machines shall also comply with EN 61770:2010: 'Electric appliances connected to the water mains - Avoidance of back-siphonage and failure of hose-sets'.

The mentioned standards address and implement an internationally accepted level of protection against hazards (such as electrical, mechanical, thermal, fire and radiation) when appliances are operated as in normal use, taking into account the manufacturer's instructions. The same standards cover also protection against further hazards deriving from abnormal situations that can be expected to happen during normal use.

It has been assumed in the drafting of these international standards that the execution of its provisions is entrusted to appropriately qualified and experienced persons.

The standards take into account the requirements of IEC 60364 'Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics' as far as possible so that there is compatibility with the wiring rules when the appliance is connected to the supply mains. However, national wiring rules may differ.

If the functions of an appliance are covered by different parts 2 of IEC 60335, the relevant part 2 is applied to each function separately, as far as it is considered reasonable by the test performer. If applicable, the influence of one function on the other is taken into account.

For appliances not covered by a particular Part 2 of EN 60335 additional consideration may need to be given to particular categories of likely users, including vulnerable people and children and to related specific risks (e.g. access to live parts, or to hot surfaces or to moving parts) that may be covered by a particular Part 2 considered to be closest to the product under examination.

When a part 2 standard does not include additional requirements to cover hazards dealt with in Part 1, Part 1 applies.

Individual countries may wish to consider the application of the standard, as far as is reasonable, to appliances not mentioned in a part 2, and to appliances designed on new principles.

An appliance that complies with the text of this standard will not necessarily be considered to comply with the safety principles of the standard if, when examined and tested, it is found to have other features which impair the level of safety covered by these requirements.

An appliance employing materials or having forms of construction differing from those detailed in the requirements of this standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be considered to comply with the standard.

The principal objectives of the Low Voltage Directive, 2006/95/EC, are covered by these standards. The essential safety requirements of the following directives, which might be applicable to some household and similar appliances, have also been taken into account in these standards:

- 2006/42/EC – Machinery directive;
- 89/106/EEC – Construction products directive;
- 97/23/EC – Pressure equipment directive.

The Essential Health and Safety Requirements (EHSR) of the Directive 2006/42/EC are covered by Annex ZE of EN60335-1. The application of EN 60335-1 alone does not give presumption of conformity for a product. This is achieved by complying with the requirements of EN 60335-1 and the relevant Part 2, when this Part 2 is also listed in the OJ under the Directive.

1.2.2.6. Noise

M/458 requires the measurement of airborne acoustical noise emissions:

- EN 60704-1:2010+A11:2012 "Household and similar electrical appliances - Test code for the determination of airborne acoustical noise - Part 1: General requirements"
- EN 60704-2-4:2012 "Household and similar electrical appliances – Test code for the determination of airborne acoustical noise — Part 2-4: Particular requirements for washing machines and spin extractors", which is a modified version of IEC 60704-2-4:2011. Compared to the previous version, this standard has specified the textile load and the test programme more clearly. Additionally the test enclosure was modified. The publication of this standard in the OJ 2013/C 355/04 notes that: "This standard needs to be completed to clearly indicate those legal requirements aimed to be covered." This sentence refers to the missing Annex ZZ in this standard.
- EN 60704-3:2006 "Household and similar electrical appliances. Test code for the determination of airborne acoustical noise. Procedure for determining and verifying declared noise emission values"

A standard for the measurement of noise in washer-dryers is also under development.

1.2.2.7. Electromagnetism

- EN 55014-1: 2006 + A1: 2009 + A2: 2011 Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
- EN 55014-2: 1997 + A1: 2001 + A2: 2008 Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity
- EN 61000-3-2: 2006 + A1: 2009 + A2: 2009 Electromagnetic compatibility (EMC) – Part 3-2: Limits - Limits for harmonic current emissions (equipment input current <= 16 A per phase)
- EN 61000-3-3: 2013 Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current <= 16 A per phase and not subject to conditional connection
- EN 62233: 2008 Measurement methods for electromagnetic fields of household appliances and similar apparatus with regard to human exposure

1.2.2.8. Additional standardisation activities

Avoiding test cycle recognition

Mandate M/458 also asks “to ensure that the prospective harmonised standard(s) includes a procedure that avoids an appliance being programmed to recognize the test cycles, and reacting specifically to them”. This provision is overruled by the delegated Energy Label Regulation (EU) 1061/2010 and the Ecodesign Regulation (EU) 1015/2010, asking specifically for a clear identification of the “standard 60 °C cotton programme” and the “standard 40 °C cotton programme”.

Uncertainty and tolerances, repeatability and reproducibility

To encourage the efficient use of energy and other resources, the European Parliament and Commission have issued regulations, which mandate the provision of information to consumers or set up essential requirements. This information is conveyed by label obligations according EU Label Directive 2010/30/EU and Ecodesign requirements according to the EU Energy Related Products Directive 2009/125/EC. According to these regulations the information has to be provided by manufacturers at the point of sale or in the manuals. EU Mandates may be issued in order to cover these obligations.

Methods for measuring resource consumptions and performance characteristics must be of sufficient accuracy to provide confidence to governments, consumers and manufacturers. The accuracy of a test method is expressed in terms of bias and precision. Precision, when evaluating test methods, is expressed in terms of two measurement concepts: repeatability (intra-laboratory variability) and reproducibility (inter-laboratory variability). Therefore, standard procedures are required for determining the repeatability and the reproducibility of test methods developed by a technical committee and its subcommittees. The repeatability of a test method must be sufficiently accurate for comparative testing. The reproducibility of a test method must be sufficiently accurate for the determination of values which are declared and for checking these declared values.

Uncertainty reporting is essential to ensure measured data are interpreted in a correct way. Especially when data of measurements are to be compared between laboratories or when normative requirements are set up, it is necessary to know the uncertainty with which data can be measured. Measurement uncertainty is unavoidable always a combination of the variance of the product itself and the measurement method applied. Only the latter is subject of the measurement standard only. It should not be confused with production variation which in contrast is the very own responsibility of the manufacturer.

The Market Surveillance Authorities have the responsibility for verifying the information given at the point of sale or requested by ecodesign measures and they do this by carrying out an independent set of measurements with other test sample(s). Both sets of measurements are subject to the uncontrollable factors described above. In addition to the product variation these uncontrollable factors will contribute to possible differences between the measurement result and the declaration by the manufacturer. Verification tolerances given in the regulations are supposed to consider these possible differences to ensure correct judgement of the compliance of the product under verification. A false judgement of non-compliance could have severe consequences (withdrawal from market, fines, etc.) for the manufacturer

The assessment of verification tolerances is identified as a revision need for both the Regulations 1061/2010 and 1015/2010.

CENELEC TC59X WG16 “Uncertainty and tolerances” has taken up the initiative of IEC 59D and produced an internal document (TC59X/(Sec.)0554/INF “Household and similar appliances – Method for calculation of uncertainty of measurements”) for all working groups under CLC TC59X “Household and similar Appliances” asking for the reporting of expanded uncertainty values for all measurements defined in their standards.

However, the assessment of the expanded uncertainty and the definition of verification tolerances will, in many cases, only be possible after a round-robin test (also called ring test) has been performed, where one or more appliances are sent around to many different laboratories to be measured under the same conditions as those defined in the measurement standard. The analysis of these results will deliver a good knowledge of the repeatability and reproducibility of the relevant measurement. How to perform such a round-robin test is also described in a technical report (CLC/TR 50619:2013 “Guidance on how to conduct Round Robin Tests”). Another informative document of CLC 59X was released (TC59X/ (Sec)0597/INF “Application of measurement uncertainty in setting verification tolerances”) in May 2014, where the relation of the expanded uncertainties as a characteristic value of the measurement to the political issue of how tolerances are set is explained.

Performing a round-robin test involves measurements in many, mostly independent, testing laboratories. If the latter are not willing to participate for free, it is necessary to provide some funding. Money is also necessary for the proper organisation and a qualified analysis of the round-robin test data. Present experience of CLC TC59X concerning asking for funding for round-robin tests shows that this is a time-consuming and bureaucratic process.

CECED has also provided the industry positions with respect to

- the verification tolerances in Ecodesign and Energy Labelling (see: http://www.ceced.eu/site-ceced/media-resources/Position-Papers/2014/10/Verification-tolerances-in-Ecodesign-and-Energy-Labelling-future-legislation.html)
- the noise verification procedure (see: http://www.ceced.eu/site-ceced/media-resources/Position-Papers/Archive/2015/03/CECED-comments-on-the-noise-verification-procedure.html)

With respect to washer-dryers, tolerances applicable for this appliance (fixed in the test standard EN50229, but not in the EU Directive 96/60/EC) are not based on any round robin test to estimate the expanded uncertainty of the measurement method. The value is influenced by washing machines – though not 100% mirrored.

Stakeholders were asked to provide any preliminary indications about the actual uncertainty associated with the measurement of the levels of performance for washing machines and washer-dryers, and how tolerances should be set to reflect such inherent uncertainties. Industry stakeholders generally reported that products are designed in a manner which seeks to meet safely the verification tolerances provided in the relevant standards and regulations.

According to their feedback, the current tolerances (15% for single tests and 10% for 3 appliances tests) have been indicated to fit well from the manufacturers' point of view. Results of round robin tests done among different laboratories in the last years have shown that an important uncertainty exists. Verification tolerances should fit to the expanded uncertainties of the measurement procedure. For WM this was established by a round robin test together with the rework of the IEC 60456: 2010. For WD a round robin test was conducted for the IEC 62512:2013. If a future test procedure for WD is according to this IEC standard, this may be applicable according to one stakeholder.

However, a stakeholder suggests that tolerances could be smaller, about 6%. Another stakeholder informs that the variance of the results is often close or higher than the 10% tolerance and that 6% tolerance is really the minimum feasible. It is also recommended that tolerance for WD should be higher because more processes are involved in sequence (washing and drying process sum the variance).

Uniformly it was referred to the technical report IEC TR 62617 whose second edition will contain the latest results of uncertainty assessment for IEC 60456: 2010 (basis for European washing machines standard) and IEC 62512:2013 (not yet harmonised measurement standard for washer-dryers). This report was made available in October 2015.

Improvement of rounding methods

Industry operates globally. Thus, rounding has to follow international rules. IEC 59D and CLC 59X standards define rounding by using the methods described in the Rule B of the Annex B.3 of the ISO 80000-1:2009 'Quantities and units - Part 1: General'. These should be applied to the final result of any calculation. European standards and regulations should not differ more than necessary from international standards.

However, the methods described in the European standards and Regulations deviate from this target. Different rounding methods were found, e.g. for the water consumption of washing machines where the annual water consumption of a household washing machine is calculated in litres, rounded up to the nearest integer and after that multiplied by the total number of standard cleaning cycles per year (220) (cf. clause 3 of Annex II in EC/1015/2010 and clause 2 of Annex VII of EC/1061/2010). This method is different from ISO 80000-1, and implies double rounding, as a rounded-up value is multiplied by 220. Such deviations can lead to differences between the declared values and the values determined during the verification procedure.

At the 1st TWG meeting, also all stakeholders agreed that rounding of figures is an issue of concern for the Energy label and fiche figures in case that different rounding rules lead to results interpretable in different ways. Depending on the language and the translation, figures might currently not be the same (rounding versus rounding up).

There is no difference between washer-dryers and washing machines for this aspect. For rounding purposes, both standards EN60456 / EN50229 on performance measurement of washing machines and washer-dryers are indirectly referring to ISO 80000-1:2012 B.3, rule B. It is recommended that the rounding method of the applicable standard should be used (and no differing rounding rules introduced in the regulation), i.e. referring rounding to Rule B of the Annex B.3 of the ISO 80000-1:2009 'Quantities and units - Part 1: General' and applying it only to the final value of any calculation. This rule defines essentially that if there are two successive integral multiples equally near the given number, the greater in magnitude multiple is selected as the rounded number, meaning e.g. 12.25 is rounded to 12.3. In all other cases the rounding is to the next lower or higher number, e.g. 12.24 to 12.2 and 12.26 to 12.3.

Demand response appliances (*smart* appliances): overview on standardisation activities in Europe

In order to promote European Smart Grid deployment, several measures have been taken by the European Commission (EC). In 2011, the EC issued the Standardisation Mandate 490 to European Standardisation Organizations (ESOs) to support European Smart Grid deployment. To accomplish this task, a Joint Working Group (Smart Grid Coordination Group (SG-CG)) has been created by the three European Standardisation Organizations CEN (the European Committee for Standardisation), CENELEC (the European Committee for Electrotechnical Standardisation) and ETSI (the European Telecommunications Standards Institute). The aim was developing a set of consistent standards which will support the information exchange and the integration of all users into the electric system operation. These mandate's reports were finalised by the end of 2014.

Currently, the EU Ecodesign Preparatory Study on Smart Appliances is carried out for the European Commission, DG Energy under framework contract ENER.C3.2012-418-lot 1. The preparatory study analyses all technical, economic, environmental, market and societal aspects that are relevant for a broad market introduction of smart appliances. The project started in autumn of 2014 and is expected to be finished in September 2016 (cf. also section 1.2.1.1).

In the following, the most relevant standardisation activities in view of demand response appliances will be summarised:

SG-CG developed a generic functional architecture for the flexibility use cases, which is represented in the figure below.

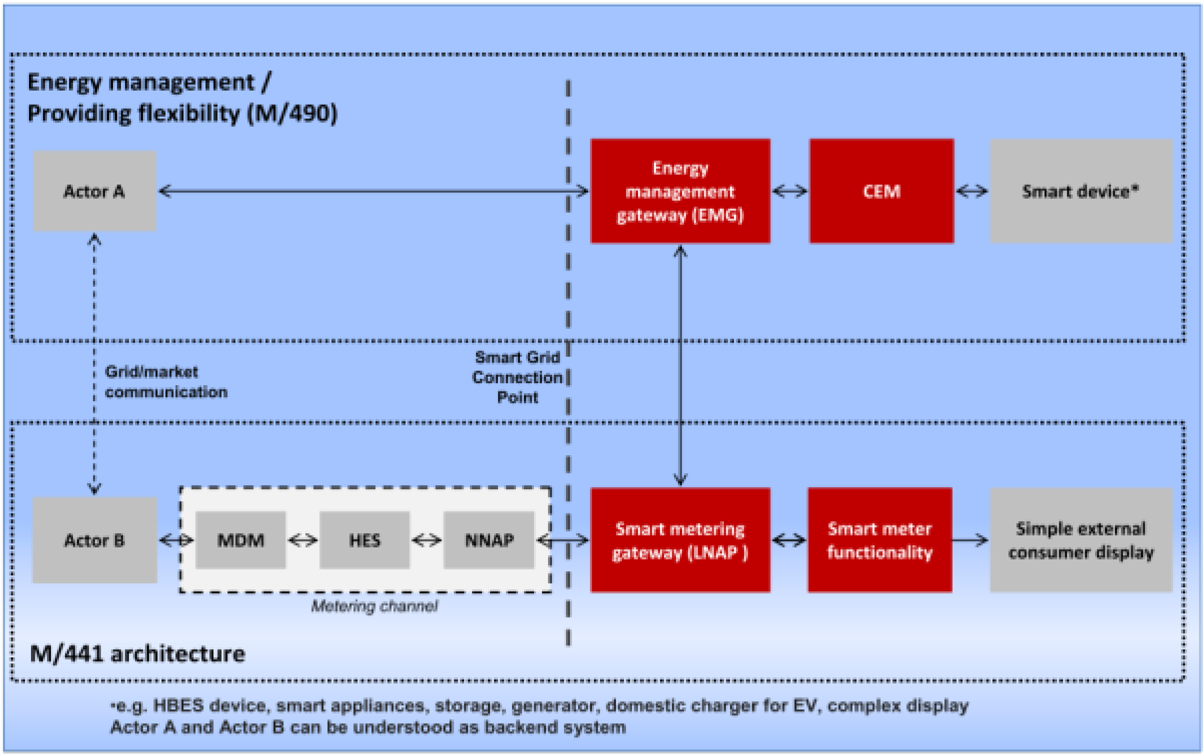


Figure 1.3: Flexibility functional architecture (CENELEC 2012)

In this architecture, the customer energy manager (CEM) provides the flexibility of connected smart devices, through the energy management gateway (EMG). The EMG communicates with the metering channel and the smart meter functionality through the Smart Metering Gateway. The gateways in this architecture split different networks and may be integrated with other functional entities. As the actors of this architecture are functional / logical entities, some of them may be part of the same physical device.

Standardisation aspects concerning smart meter interface are currently handled by IEC/TC 13 “Equipment for electrical energy measurement and load control”, CEN/TC 294 “Communication systems for meters and remote reading of meters”, CLC/TC 205 “Home and Building Electronic Systems (HBES)” and IEC/TC 57 “Power systems management and associated information exchange”. The most relevant standards developed in this field are IEC 62056 series covering the exchange of consumption information registered in the electricity meter and the transfer of demand response related data (e.g. tariff information, power limitation, prepayment settings). EN 13757 series are the corresponding standards with focus on non-electricity meters (e.g. gas, water and heat). IEC 62056-7-5 standard covers the unidirectional data transfer from a meter to an external device (e.g. consumer display). prEN 50491-11 concerns Smart Metering - Application Specifications in view of simple external consumer display, prEN 50491-12 Smart grid - Application specification concerning interface and framework for customer.

Standardisation activities related to smart appliances and smart home interoperability are handled by IEC/TC 57 WG 21 “Interfaces and protocol profiles relevant for systems connected to the electrical Grid”, IEC/TC 59 WG 15 “Connection of household appliances to smart grids and appliances interaction” and CLC/TC 59x WG 7 “Smart household appliances”. Data definitions for demand response and functionalities (Use Cases) are provided in IEC TR 62746. In IEC TR 62476-2, use cases and requirements for Smart Grid/ Smart Home are listed covering for example the provision of energy consumption information, controlling smart appliances, charging of electric vehicles, battery management and consumer offering flexibility.

The focus of IEC/TS 62950 “Household and similar electrical appliances - Specifying and testing smart capabilities of smart appliances – General aspects” is on the development of a common architecture that applies to different appliance types and use cases. Moreover, general aspects of measuring smart performance within the context of the common architecture are addressed.

prEN 50631 “Home network and smart grid connectivity” deals with the improvement of functionalities of domestic appliances through the use of network communication (e.g. smart grid, smart home or home network).

1.2.3. European and national ecolabels – focus on energy and other performance criteria

NOTE: This section only presents energy and other performance criteria of European national ecolabels existing for washing machines and washer-dryers. Resource related criteria are presented separately in section 1.3.2.

In the preparatory study for Ecodesign requirements Lot 14 on domestic dishwashers and washing machines, Task 1 on definitions (ISIS 2007a), the following European policy instruments and measures were described:

- Two Voluntary Industry Commitments on Reducing Energy Consumption of Domestic Washing Machines (2000 to 2001 and 2002 to 2008), and
- EU Ecolabel for washing machines.

The Voluntary Industry Commitment was not renewed. The EU Ecolabel for washing machines expired in 2007 and no new criteria have been established, although AEA published a ‘Discussion Report: EU Ecolabel for Washing Machines’ in September 2009 (AEA 2009).

Further, few additional national ecolabelling schemes were described: in Lot 14:

- The Nordic Swan for washing machines (see Section 1.2.3.1),
- the Czech Environmentally Friendly Products label for washing machines (not valid any more), and
- the National Programme of Environmental Assessment and Ecolabelling in the Slovak Republik (NPEHOV) for washing machines (not valid any more).

In addition to them, the Blue Angel Environmental Label for Household Washing Machines (RAL-UZ 137) is currently available on the German market (see Section 1.2.3.2).

The Swedish "Environmental Product Declaration (EPD) scheme for washing machines and dishwashers for household use", described in Lot 14, has been valid until September 2004 (cf. http://epdsystem.it/en/PCR/Detail/?Pcr=5656). On 12 March 2015, however, the EPD secretariat has launched a call for product category rules (PCR) moderators in order to update these expired product category rules (cf. http://www.environdec.com/en/News-archive/).

The "UK Energy Saving Trust Recommended" logo described in Lot 14 was a UK-based labelling and certification scheme for energy efficient products. The scheme was run by the Energy Saving Trust and was launched in 2000. The logo was registered with the UK Patent Office and could be used by manufacturers, retailers and suppliers to signpost consumers to best-in-class energy efficient products. Today, the Energy Saving Trust no longer awards a "Recommended" certification. Its product certifications now include "Energy Saving Trust Endorsed" (brandmark shows products on the market which have met industry agreed standards for energy performance), "Energy Saving Trust Listed" (independent listing of energy efficient products; however only covering insulation products), and "Verified by Energy Saving Trust" (manufacturers can enhance the credibility of their claims concerning the energy efficiency of their products with a product verification service) (Energy Saving Trust n.d.). For washing machines, 25 models of two manufacturers are currently listed as "verified"; no washer-dryers are listed.

Last but not least, the Topten web portal for best products of Europe is also an important activity run at European level to guide consumers towards the purchase of the most energy efficient appliances and cars (see Section 1.2.3.3).

1.2.3.1. Nordic countries: Nordic Ecolabelling of white goods

In September 2014, version 5.0 of the Nordic Ecolabelling requirements for white goods (refrigerators and freezers, dishwashers, washing machines and tumble dryers) has been published, valid from 20 June 2013 to 30 June 2017. Gas-powered appliances and washer-dryers are not in the scope of this criteria document (Nordic Ecolabelling 2014).

Criteria are referring to the manufacture and to the operation of the white goods; further, there are specific product requirements for each of the product categories, and finally, there are criteria on customer information as well as quality and regulatory requirements. The following energy efficiency and performance criteria apply to washing machines.

Table 1.8: Nordic Ecolabelling criteria for washing machines; source: Nordic Ecolabelling (2014)

Criteria category	Requirements
Operation requirements for washing machines	
Energy efficiency	Washing machines must achieve energy efficiency class A+++ or better in accordance with the applicable Energy Labelling Regulation.

Criteria category	Requirements
Noise	Maximum limit for airbourne noise of washing machines (wash programme, cotton 60 ˚C, to EN 60456): • 56 dB(A) during wash programme • 76 dB(A) during spin
Specific product requirements for washing machines	
Water consumption	The washing machine must meet the requirement for maximum permitted water consumption on the standard programme as outlined in Ecodesign Regulation (EU) No 1015/2010.
Spinning performance	• Machines with a capacity of over 3.5 kg must achieve a remaining moisture content of less than 54% (According to EN 60456 standard, the final humidity is determined by comparing the amount of water retained in the load with the conditioned weight of the load) • Machines with a capacity of 3.5 kg or less must achieve remaining moisture content of less than 60%
Washing performance	The machine must, on the standard programme, have a wash efficiency index ≥ 1.03 in line with Ecodesign Regulation (EU) No 1015/2010
Rinsing performance, alkali method	The machine must pass a rinsing performance test using the alkali method with an index 1.5 or lower. The requirement can be fulfilled based on the standard programme, a separate programme or with the help of an option function for the standard programme. If the rinsing performance is fulfilled based on the standard programme, separate programme or with the help of an option function for the standard programme, the washing machine energy consumption should not exceed 0.19 kWh/kg.
Requirements on customer information for washing machines	
Installation and user instructions for washing machines	Inter alia • Information on the washing machine's consumption of energy and water at different temperatures and with different load sizes, so that the consumer can select the appropriate programme for minimum energy and water consumption. • Energy consumption of switched off, timer set and programme finished; Instructions that the washing machine should be turned off once the programme has finished to avoid any energy losses. • Information on how long the different programmes take.

1.2.3.2. Germany: Blue Angel Environmental Label for Household Washing Machines (RAL-UZ 137)

In January 2013, basic criteria for award of the German environmental label "Blue Angel" have been published for household washing machines, expiring end of December 2015.

The Blue Angel ecolabel for washing machines (RAL-UZ 137) is to distinguish appliances that apart from featuring low power consumption also offer minimal low water consumption at different washing temperatures. In addition, the laundry must even be washable at a temperature of only 20 degrees. This saves energy and – by using the proper washing agents – delivers equally good wash results. Thus, Blue Angel-labelled washing machines can help consumers to tangibly reduce the running costs for electricity, water and wastewater.

According to (Ral gGmbH 2013b), the Blue Angel eco-label for washing machines may be awarded to appliances with the following environmental properties: low water consumption, low energy consumption at different wash temperatures, reduced water and energy consumption at half load, low-temperature wash cycles (e.g. 20 °C wash cycle), low noise emissions, longevity and serviceability, avoidance of pollutants, and consumer information on environmentally friendly and economical washing.

Besides consumption criteria (energy and water), the Blue Angel Ecolabel further sets performance criteria on spin drying efficiency and noise emissions. Further, there are requirements on materials (prohibition of certain hazardous substances and biocidal silver, requirements for insulation materials), and finally criteria facilitating repairs (spare parts) and recycling, which are detailed in section 1.3.2.2.

The detailed energy efficiency and performance criteria are as follows (Ral gGmbH 2013b):

Energy Efficiency and Spin-Drying Efficiency

- The appliances shall be rated at least A+++ for their energy efficiency (equal to energy efficiency index (EEI) < 46) in accordance with Regulation (EU) 1061/2010 relating to household washing machines.
- The appliances shall be rated at least Class A for their spin-drying efficiency (spin-drying efficiency class) and come with a maximum spin speed of at least 1400 rpm.

Power Consumption in „End-of-cycle“, „Delay Start” and “Off” Mode

- In “End of Cycle” mode (from this time on, the door can be opened) the power consumption of the appliance shall not exceed 0.5 watts. If the device comes with a display the power consumption in “End of Cycle“ mode (End of cycle in „Left On“ mode is defined as the period between the pumping out of the water and the opening of the door) shall not exceed 1.00 watt.
- In “Delay Start” mode, the power consumption of the appliance shall not exceed 4 watts.
- In “Off” mode, the power consumption shall not exceed 0.3 watts.

Water Consumption of the Appliances

The appliance shall not exceed the annual water consumption limits listed in the following table. The calculation of the average load shall be based on a mixed calculation of full load at 60 °C, partial load at 60 °C and partial load at 40 °C at a ratio of 3:2:2. For washing machines with a load capacity ≥ 5 kg to 7 kg the calculation shall be based on a maximum water consumption of 12 litres per kg of laundry, for washing machines with a load capacity ≥ 7 kg the calculation shall be based on a maximum water consumption of 10 litres per kg of laundry.

Table 1.9: Maximum allowable water quantities (in litres) of washing machines per year according to Blue Angel requirements; source (Ral gGmbH 2013b)

Rated capacity (target load) [kg]	Average load/cycle [kg]	Annual laundry amount for 220 cycles/year [kg]	Maximum allowable water consumption per year [litres]
5	3.6	785.7	9,429
6	4.3	942.9	11,315
7	5.0	1,100.0	11,000
8	5.7	1,257.2	12,572
9	6.4	1,414.3	14,143
10	7.1	1,571.5	15,715
11	7.9	1,728.6	17,286

The calculation shall be made using the following formula (based on German EcoTopTen criteria 2011):

- Machines with a rated capacity c < 7kg:

(c x 42.86% + ((c x 57.14%)/2)) x 220x12) = maximum allowable annual water consumption [litres]

- Machines with a rated capacity ≥ 7kg:

(c x 42.86% + ((c x 57.14%)/2)) x 220x10) = maximum allowable annual water consumption [litres]

AquaStop

The appliance shall come with an aquastop system for the inlet water hose and a "drip tray". These are design / safety systems for preventing water leakage and collecting water in case of leakage, respectively. The applicant shall provide warranty on the proper functioning of the system for the entire life of the washing machine, if properly installed. The product manual shall include the corresponding warranty information.

Noise Emissions

The evaluation of the noise emissions shall be based on the sound power levels in dB(A) rounded up to the integer L_{Cn}. The washing machines shall not exceed the following sound power levels L_C in the following operation modes:

- operating mode: „washing": L_{C1} ≤ 50 dB(A)
- operating mode: „spin-drying": L_{C2} ≤ 72 dB(A)

The product manual shall list both the operating modes and the sound power levels.

Requirements for Low-Temperature Wash Cycles

The washing machine shall feature a low-temperature wash option (20 °C). The product manual shall include information on its use.

Auto Half Load

The appliance shall come with an "auto half load" feature to automatically reduce water and energy consumption when the washing machine is not fully loaded. This function shall reduce the water consumption irrespective of the temperature by at least 15% on appliances with a rated capacity <7 kg and by at least 20% on appliances with a rated capacity ≥7 kg. Electric power consumption shall be reduced at half load irrespective of the rated capacity by at least 20% on the 60 °C cycle and by at least 15% on the 40 °C cycle.

Delay Start/ Interconnectivity

The appliance shall feature a delay start option (delay timer) that allows the user to delay the start of the wash cycle for at least 8 hours. From January 1, 2015, the appliances shall additionally be equipped with an interface enabling communication and control (interconnectivity) via the grid.

Consumer Information with regard to energy efficiency and performance

The energy, water and detergent consumption of washing machines greatly depends on the user behaviour (above all, by the user's way of loading and cleaning program selection). The operating instructions/product manual as well as manufacturer's website shall at least include the following basic user information/instructions:

- Instructions for proper loading of the drum,

- Instructions for sorting the laundry according to type of fabric and colour,
- Information on the use of low-temperature cycles (e.g. 20 °C wash cycle),
- Information on water and energy consumption as well as on the length of all wash cycles (in minutes),
- A note that energy and water consumption won't be reduced by 50 percent when the drum is filled to half its capacity. The actual power and water saving potentials shall be expressed in percent.
- Information on the offers for the use of time-variable power supply.
- Explanation of the EU Energy Labelling,
- Reference to the website „Forum Waschen" providing information on proper washing: http://www.forum-waschen.de/waeschewaschen.html

1.2.4. European consumer associations tests and other consumer information portals

The Energy Label gives valuable information at the point of sale. Before purchasing white goods, many consumers inform themselves about latest state of the art in technologies, consumptions and relevant product factors that have to be considered. Therefore, they read users advice online and/or recommendations of independent consumer organisations, e.g. German "Stiftung Warentest" (STIWA, www.test.de), British "Which?" (www.which.co.uk), French "Que Choisir" (www.quechoisir.org), Italian "Altroconsumo" (www.altroconsumo.it), or Spanish "OCU" (www.ocu.org). Those consumer associations periodically perform tests of washing machines and discontinuously of washer-dryers, and publish the results in their magazines and on their webpages, together with useful information about automatic washing and drying in general, e.g. best practices and new technologies and features.

Consumer associations and their magazines can be considered as driving forces for the market. Knowing how consumer associations actually test washing machines and washer-dryers, which categories are assessed and how they contribute to the final test judgement promises insight in consumer relevant aspects and market trends.

1.2.4.1. Stiftung Warentest (STIWA)

Testing magazines often use their own test measurements. For example, in its latest test on washing machines and washer-dryers (Stiftung Warentest 2015), STIWA tested the performance according to IEC 60456, but with modifications, such as additionally the 40 °C cotton programme at 2 kg partial load as well as with half load but time reduced. Further, the performance of the 30 °C easy-care programme and the 60 °C normal cotton programme were tested. They also aim to cover aspects which are not declared on the Energy Label but influence product quality, such as ease of use, the programme duration, maximum temperature in the 60 °C cotton programmes (normal and standard) at half load or durability.

In addition, those consumer associations get feedback from their readers and users. Thereby, they get valuable insights in consumer relevant information and reflect consumer expectation and market trends related to washing machines. Compared with official test standards, consumer associations are able to focus on new or more consumer-relevant aspects (Brückner 2013)

The latest washing machine testing was published in 11/2015 (Stiftung Warentest 2015). Every washing machine model tested gets a final test score ("test-Qualitätsurteil") following a school grade system (grades 1 to 6). The final test score is calculated out of the weighted results from five major testing categories: the performance of the washing programmes (including programme duration), a durability testing, ease of use, environmental impacts (water and energy consumption, noise) as well as safety against damage caused by water.

Usability assesses the practicability in everyday use, e.g. operating of the washing machine, filling of the detergent, automatic dosage system (if applicable), loading and unloading, maintenance of the machine. It also includes the comprehensibility of the manual. Safety assesses the protection against water damages. Noise emission is measured according to IEC 704-2-4.

Test results are published in the magazine "test" and on the STIWA webpage (fee-based). They are embedded in articles about washing, dealing with current trends, developments and best practice tips. E.g. in (Stiftung Warentest 2015) it is explained why the programme duration of the 60 °C standard cotton programme is often longer (principle of the Sinner's Circle), why the real temperatures of the 60 °C standard cotton programme are often lower than the indicated temperature, as well as new technologies such as automatic dosage systems for washing machines

Test results are presented in a table form, using a schematic presentation of results instead of concrete test values. The table also indicates further relevant information about the washing machine model that did not influence the final test score:

- Average price (in €)
- Operating costs on a ten years basis
- Technical details and equipment features: capacity in different programmes, energy and water consumption as well as programme duration of different programmes, maximum spin speed, maximum time-delay of the programme start.

1.2.4.2. EU and several Member States: Topten web portal for best products of Europe

Topten (www.topten.eu) is a web portal guiding consumers to the most energy efficient appliances and cars in Europe. By December 2014 funded by EU's programme Intelligent Energy Europe (IEE) in the programme area "SAVE, Market transformation for energy-efficient products", from 2015 it is funded for three more years under the Horizon 2020 programme by the Executive Agency for Small and Medium-Sized Enterprises (EASME).

Altogether 19 national Topten websites present up-to-date, consumer-oriented information on the most energy-efficient models in a number of product groups, inter alia domestic appliances, cooling and lighting equipment, consumer electronics, and vehicles. Also washing machines and partly washer-dryers are listed. The selection of the most energy-efficient models is based on specific selection criteria for each of the product categories. The information is built on independent market surveys selecting the best available technologies (BATs) amongst the product categories. Participating Member States with national Topten websites are: Austria, Belgium, Croatia, Czech Republic, Finland, France, Germany, Greece, Italy, Lithuania, Luxemburg, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the UK.

The national Topten web portals including the national product lists and country-specific selection criteria can be retrieved via www.topten.eu.

Topten Washing machines

Topten.eu presents three categories of the most energy efficient household washing machines of Europe:

- Washing machines with a capacity < 8 kg
- Washing machines with a capacity of 8 kg
- Washing machines with a capacity > 8 kg

In order to qualify for topten.eu, washing machines must meet the following technical criteria:

- Energy efficiency class: A+++ according to the EU Energy Label
- Spin-drying efficiency class: A according to the EU Energy Label
- Water consumption: according to the ecodesign requirements for washing machines Commission Delegated Regulation (EU) No 1061/2010 (≤ 5 x c1/2 + 35):

In addition, suppliers have to provide Topten with the following data:

- Energy Efficiency Index (EEI)
- Energy consumption per cycle in kWh for the 60 °C programme at full load, the 60 °C programme at half load and the 40 °C programme at half load
- Programme time for the 60 °C programme at full load, the 60 °C programme at half load and the 40 °C programme at half load
- Power in left-on-mode and off-mode
- Availability of a 20 °C programme (cotton)
- Maximum spin speed
- Availability of a water protection system (Aqua Stop, waterproof, water control system etc.)

TopTen Washer-dryers

Topten.eu presents washer-dryers (combined washing machine and tumble dryer in one appliance) with integrated heat pump. These are the most energy efficient washer-dryers and have moderate water consumption.

In order to qualify for topten.eu, washer-dryers must meet the following criteria (data sources: suppliers' declarations):

- Energy efficiency: max. 0.5 kWh per kg laundry (full wash & dry cycle / washing capacity)
- Water consumption: max. 12 litres per kg laundry (full wash & dry cycle / washing capacity)

The products are ordered according to their Energy Efficiency (kWh/kg full cycle).

1.2.5. International legislation and standards

1.2.5.1. EC 60456 standard for washing machines

The sub-committee SC59D "Performance of household and similar electrical laundry appliances" of IEC is in charge for preparing global standards for measuring performance on laundry appliances. The major standard describing the measurement of primary performance measures is IEC 60456 'Clothes washing machines for household use – Methods for measuring the performance'. The 5th ed. published in 2010 has considerable changes compared to the 4th edition from 2003.

This edition includes the following significant technical changes from the previous edition:

- Modified test load mass requirement for cases where rated capacity of test machine is not declared. Test load mass determination in case rated capacity is not declared was changed, to remove ambiguity and to encourage declaration.
- Introduction of soft water option.
- Expanded stain/soil set (for assessment of washing performance).

- Improved method of loading and folding test load items to better suit vertical axis, horizontal axis and twin tub systems.
- Revised and amended reference machine specification reflecting full qualification of new Electrolux Wascator CLS.
- New reference programmes for lower temperatures and vertical axis systems. New informative annex comparing reference programmes to typical household programmes.
- Refined rinsing efficiency method.
- Introduction of low power modes “Off” and “Left On” (for assessment of energy consumption).
- New annex about uncertainty of measurements.

Additional work was invested to define an alternative rinsing performance measurement which should have a better reproducibility than the present alkalinity method. Work is also under way to define a load calibration procedure which may eliminate, to some extent, the change of the properties of cotton load items during each washing process in which the load is used in testing of a washing machine.

Mechanical action – gentleness of action

Mechanical action is a main parameter in a washing process. This parameter improves, on the positive side, the washing performance, but can cause, on the other side, damage to the textiles. Mechanical action has not been determined as a single parameter in washing processes in today’s IEC 60456 measurement standard.

Mechanical action has a high relevance for consumers and manufacturers of washing machines and, therefore, a comparison of this parameter (especially in relation to the washing performance achieved as measured in IEC 60456) in different washing machines is very important.

“Gentleness of action” defines the mechanical action influence of washing machine parameters on irreversible changes of the textile properties. These changes can be visible or invisible.

Examples of these irreversible changes are:

- Loss of tensile tear strengths,
- Surface friction (abrasion, pilling),
- Dimensional changes (shrinkage or elongation),
- Creasing, or
- “Structural disorientation”.

Due to the fact that washing programmes cover a wide range of mechanical action (gentle cycles to heavy-duty cotton programmes, single cycles to multiple cycles), three methods for different ranges of mechanical action are described to measure and quantify the influences of the machine parameters by measuring one or several of these irreversible changes:

- Thread Removal Method (TRM – preferable for low to medium mechanical action),
- Dot Removal Method (DRM – preferable for high mechanical action) and
- Fraying Method (FM – preferable for medium to high mechanical action).

All three methods are described in document IEC/PAS 62473:2007 “Clothes washing machines for household use - Methods for measuring the mechanical action in household washing machines.” Meanwhile, this document has expired, as, in the IEC, any PAS document may exist only for a maximum of six years. Nevertheless, it was decided by the IEC 59D committee to include parts of it in the 6th ed. of the IEC 60456 measurement standard.

There is not much experience and no information on measurement uncertainty regarding "gentleness of action". Nevertheless, it is a complementary measure to the washing performance, as a very long washing time, which is positive to get a better washing performance, may cause increased damage to the textiles.

Hygiene assessment

IEC59D decided to limit its standardisation activities for washing machines to the measurement of the microbial contamination reduction on textiles. SC 59D decided to develop a globally acceptable Publicly Available Specification (PAS) to respond to the increase in consumer complaints regarding odour from washed laundry caused by the presence of microorganisms. This IEC/PAS 62958 Ed.1: "Clothes washing machines for household use – Method for measuring the microbial contamination reduction" was published in 2015.

There is not much experience and no information on measurement uncertainty on the use of PAS 62958. Nevertheless, this measure may be seen as a complementary measure to the washing performance.

Uncertainty reporting

In order to encourage the efficient use of energy and other resources, national governments and regional authorities have issued regulations which mandate the provision of information to consumers regarding the energy and water consumption of household appliances and associated performance characteristics. This information is usually conveyed by labels attached to appliances at the point of sale and also by brochures provided by manufacturers.

Methods for measuring declared values for energy and water consumption and performance characteristics must be of sufficient accuracy to provide confidence to governments, consumers and manufacturers. The accuracy of a test method is expressed in terms of bias and precision. Precision, when evaluating test methods, is expressed in terms of two measurement concepts: repeatability and reproducibility. Therefore, standard procedures are required to determine the repeatability and the reproducibility of test methods developed by the Technical Committee 59 and its subcommittees. Repeatability and reproducibility of a test method must be sufficiently accurate for the determination of values which are declared and for verifying and comparing these values.

Uncertainty reporting is essential to ensure measured data are interpreted in a correct way. It is necessary to know the uncertainty with which data can be measured especially when data of measurements are to be compared between laboratories or when normative requirements are set up. Details of this are described in IEC TR 62617 "Home laundry appliances – uncertainty reporting of measurements".

IEC TR 62617 publishes expanded uncertainty of measured values of IEC 60456 4th Edition for horizontal drum washing machines (see Table 1.10). Values for IEC 60456 5th Edition have not yet been published. No round-robin test for EN 60456:2011 was carried out. The values may not be the same as the testing procedure is somehow different from the procedure defined in IEC 60456.

Table 1.10: Expanded uncertainty of measured values of IEC 60456 4th Edition for horizontal drum washing machines (from IEC TR 62617)

	Relative expanded uncertainty of measured value (k = 2)
Wash performance ratio q	4%

	Relative expanded uncertainty of measured value (k = 2)
Total energy Wtotal (in kWh)	10%
Total water Vtotal (in l)	5%
Remaining moisture RM (in %)	5%
Programme time (in min)5	6%

Future standardisation activities

In preparation for the 6th edition of IEC 60456, the Technical Sub-Committee IEC SC59D is actually working on many additional issues which may improve the measurement standard, e.g. in terms of consumer relevance (change of cotton load to mixed polyester-cotton load, liquid detergent), coverage and ease of testing. Usually any new IEC standard will be taken over in Europe as a new EN standard. So these modifications may be relevant for Europe as well. However, no new version of IEC60456 is expected to come before 2020.

1.2.5.2. IEC 62512 standard for washer-dryers

The first edition of IEC 62512 'Electric clothes washer-dryers for household use - Methods for measuring the performance' has been prepared by the International Electrotechnical Commission (IEC) subcommittee 59D: Home laundry appliances, of IEC Technical Committee 59: Performance of household electrical appliances.

Based on the fourth edition (2012) of IEC 61121 for measuring the performance of tumble dryers and the fifth edition (2010) of IEC 60456 for measuring the performance of clothes washers, this standard specifies the conditions needed to test the combined function of washing and drying in a washer-dryer. This International Standard therefore specifies only the test methods for testing of household combined washer-dryers in their function to wash and dry textiles. **This international standard does not apply for testing individual washing or drying functions.**

The object is to state and define the principal performance characteristics of household electric washer-dryers of interest to users and to describe standard methods for measuring these characteristics.

A note clarifies that washer-dryers for communal use in blocks of flats or in launderettes are also included within the scope of this standard. However, it does not apply to washer-dryers for commercial laundries.

The main elements of this standard are:

- The definition of the loads to be tested in continuous and interrupted operation cycles;
- The method for testing automatic and not automatic operation of the drying cycles;
- The way to handle the load for interrupted operation cycles;
- The correction to be applied to test results for continuous and interrupted operation cycles.

For the purposes of this standard, the terms and definitions given in IEC 60456, as well as the following apply:

- Rated washing capacity: maximum mass of conditioned textiles, in kg, which the manufacturer declares can be treated in one complete washing cycle
- Rated drying capacity: maximum mass of conditioned textiles, in kg, which the manufacturer declares can be treated in one complete drying cycle

- Rated washing-drying capacity: maximum mass of conditioned textiles, in kg, which the manufacturer declares can be treated in one continuous operation cycle
- Complete operation cycle: washing and drying process, consisting of a washing and a drying cycle
- Continuous operation cycle: complete operation cycle without interruption of the process or additional action by an operator
- Interrupted operation cycle: complete operation cycle where operators action is required to continue the process
- Washing cycle: complete washing process, as defined by the required programme, consisting of a series of different operations (wash, rinse, spin, …)
- Drying cycle: complete drying process, as defined by the required programme, consisting of a series of different operations (heat, cool down, …) and comprising drying of the partial load with the rated drying capacity
- Automatic drying: drying process which automatically switches off when a certain moisture content of the load is reached
- End of programme: the programme is complete when the machine indicates the end of the programme and the load is accessible to the user. Where there is no end of programme indicator and the door is locked during operation, the programme is complete when the load is accessible for the user. Where there is no end of programme indicator and the door is not locked during operation, the programme is complete when the power consumption of the appliance drops to some steady condition and is not performing any function.

IEC 62512 defines in detail the procedure how an interrupted and a continuous operation cycle of a washer-dryer has to be tested.

If the test shall be done at the rated washing capacity, this amount of test load is washed and dried. If the rated drying capacity of the machine under test is lower as the rated washing capacity, the base load is split after the washing cycle into a first partial load p whose weight is equal to the weight of the rated drying capacity and a second partial load of the remaining items. This causes an interrupted operation cycle as the test load has to be split between washing and drying operation. Stain test strips have to be removed at the end of the washing process. The items used in the first partial load have to be identified in advance of a test series in using their conditioned weight forming a test load at the required rated drying capacity.

If test shall be done at the rated washing-drying capacity a test load according to IEC 60456 shall be used and washed and dried in a continuous operation cycle. Stain test strips are removed at the end of the drying process.

For washer-dryers with automatic drying (continuous and interrupted) the programme shall be selected which gives the target final moisture content value. For washer-dryers without automatic drying (continuous and interrupted) the timer shall be set to obtain the target final moisture content value given above. The time required for this shall be determined by monitoring the drying process. This can be done by pre-testing.

If at the end of programme the final moisture content is not below the upper limit of the range of allowable moisture contents a time depending programme may be added with the shortest possible time, but not less than 20 minutes. The additional use of time controlled programmes shall be reported.

The time this programme takes (including cool-down of this programme) and all energy and water used during this time are added to the consumption values. In the IEC standard any programme can be tested.

This IEC 62512 standard was exempted from harmonisation in Europe as it would create a conflict to EN 50229 and the existing energy label for washer-dryers. However, it might be used as a basis for a new standard for measuring the performance of washer-dryers in Europe based on revised energy labelling and ecodesign regulations for washer-dryers. The advantage of using IEC 62512 would be that it well defines how the continuous washing and drying process has to be measured which is not specified in EN 50229 so far. Beside this fundamental difference other details are included in IEC 62512.

1.2.5.3. United States

Washer Energy regulations & standby power - History and summary

In December 2007, the Congress enacted EISA, setting the first minimum water efficiency requirements for clothes washers. Minimum energy efficiency requirements, however, were left unchanged from the existing levels set by DOE in 2001, which became effective in January 2007. The 2007 standards which went into effect on January 1, 2011, required residential clothes washers to be manufactured with a **modified energy factor (MEF)** of at least 1.26 and a maximum **water factor (WF)** of 9.5 or less.

- MEF is expressed in cubic feet of washer capacity per kWh per cycle and incorporates the machine electrical energy consumption, the hot water energy consumption, and the energy required to remove the remaining moisture in the clothes.
- WF is expressed in gallons per cubic feet of capacity. A higher MEF indicates better energy efficiency while a lower WF indicates better water efficiency.

In May 2012, DOE adopted new clothes washer standards based on a 2010 agreement between manufacturers and efficiency proponents. DOE uses new metrics called **IMEF (integrated modified energy factor)** and **IWF (integrated water factor)** which add standby and off-mode energy consumption into the formula.

Integrated modified energy factor (IMEF) means the quotient of the cubic foot (or litre) capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of:

a) The machine electrical energy consumption;

b) The hot water energy consumption;

c) The energy required for removal of the remaining moisture in the wash load; and

d) The combined low-power mode energy consumption.

Integrated water factor (IWF) means the quotient of the total weighted per-cycle water consumption for all wash cycles in gallons divided by the cubic foot (or litre) capacity of the clothes washer.

The IMEF/IWF standard levels in the 2012 final rule are equivalent to the MEF/WF levels in the negotiated agreement.

Standards for top-loading washers with capacity equal or greater than 1.6 ft^3 (45.3 litres) require:

- a minimum IMEF of 1.29 (corresponding to a MEF of 1.72) and a maximum IWF of 8.4 (corresponding to WF of 8.0) effective since March 2015 and
- a minimum IMEF of 1.57 IMEF (2.0 as MEF) and a maximum IWF of 6.5 (6.0 as WF) effective since January 2018.

Compared to the current standards, the energy and water savings achievable with the 2018 standards are about 33% and 19%, respectively.

Standards for front-loading washers with capacity equal or greater than 1.6 ft^3 (45.3 litres) are effective since March 2015 and require

- a minimum IMEF of 1.84 (2.2 as MEF) and
- a maximum IWF of 4.7 (4.5 as WF).

Compared to the current standards, the energy and water savings achievable with the 2015 standards are about 15% and 35%, respectively. According to DOE, the standards for top and front loading washers will save about 2 quads of energy, 3 trillion gallons of water and about 113 million metric tons of CO2 emissions over 30 years. DOE estimates total net dollar savings for U.S. consumers over that same period will exceed $31 billion.

Currently, ENERGY STAR-qualified products must meet a minimum MEF of 2.0 and a maximum WF of 6.0.

Front-loaders are generally more efficient than top-loaders, although manufacturers have introduced some new high-efficiency top-loading models that are as efficient as some front-loaders (cf. section 4.3.3.1). Until recently, top-loaders were much more common than front-loaders, but front-loaders now make up about half of annual sales in the US market. Clothes washer efficiency improvements can be achieved through advances in mechanical technology (efficient motors); reductions in the amount of water consumed to clean a given volume of laundry; and higher spin speeds to remove more moisture from the clothes at the end of the cycle (see for instance: www.appliance-standards.org/product/clothes-washers).

US Federal Energy Conservation Standard for residential clothes washers – amended

Clothes washers manufactured and distributed in commerce, as defined by 42 U.S.C. 6291(16), on or after March 7, 2015, and before January 1, 2018, must meet the energy conservation standards shown in the Table 1.11, as specified in the Code of Federal Regulations, 10 CFR 430.32(g)(3).

Table 1.11: Amended Energy Conservation Standards for Residential Clothes Washers as of March 7th, 2015

Product Class	Integrated Modified Energy Factor IMEF (ft^3/kWh/cycle) (Minimum values)	Integrated Water Factor IWF (gal/cycle/ft^3) (Maximum values)
1. Top-loading, Compact (less than 1.6 ft^3 capacity)	0.86	14.4
2. Top-loading, Standard (1.6 ft^3 or greater capacity)	1.29	8.4
3. Front-loading, Compact (less than 1.6 ft^3 capacity)	1.13	8.3
4. Front-loading, Standard (1.6 ft^3 or greater capacity)	1.84	4.7

Clothes washers manufactured and distributed in commerce on or after January 1, 2018 must meet the energy conservation standards shown in the Table 1.12.

Table 1.12: Amended Energy Conservation Standards for Residential Clothes Washers as of January 1st, 2018

Product Class	Integrated Modified Energy Factor IMEF (ft^3/kWh/cycle) (Minimum values)	Integrated Water Factor IWF (gal/cycle/ft^3) (Maximum values)

Product Class	Integrated Modified Energy Factor IMEF (ft^3/kWh/cycle) (Minimum values)	Integrated Water Factor IWF (gal/cycle/ft^3) (Maximum values)
1. Top-loading, Compact (less than 1.6 ft^3 capacity)	1.15	12.0
2. Top-loading, Standard (1.6 ft^3 or greater capacity)	1.57	6.5
3. Front-loading, Compact (less than 1.6 ft^3 capacity)	1.13	8.3
4. Front-loading, Standard (1.6 ft^3 or greater capacity)	1.84	4.7

New Test Procedure for Measuring the Energy Consumption of Clothes Washers

The test methods for domestic and commercial washing machines in force since March 2012 in USA is described in the Federal Register: 10 CFR Section 430.23(j), Appendix J2 to Subpart B of Part 430—Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers (U.S. Government [n.d.]). This replaces Appendix J1 from 2005 which was already described in Lot 14 Task 1 in 2007. Changes of the current test standard compared to the Appendix J1 can be summarised as follows (see ENER Lot 14, Task 1).

- IMEF & IWF calculations: The effects of all power modes and other changes are included. The metrics now 'integrate' all of these items.
- Annual number of cycles revised from 392 to 295: Based on 2005 surveys, 295 cycles / year have been considered to represent consumer use. This is also needed for the annual cost calculation.
- Updates of TUFs (Temperature Use Factors) and DUFs (Dryer Use Factors): All the same TUFs (Temperature Use Factors) have been kept, but warm/warm will be now treated as a complete wash/rinse cycle and warm/cold will be adjusted when warm/warm is available (US machines do not have temperature setting but just warm or cold water inlets). Based on 2005 survey data, the DUF (Dryer Use Factor) has been increased from 0.84 to 0.91 to reflect higher use of spin drying.
- Elimination of LAF (Load Adjustment Factor) and replacement of the representative load size with the weighted average load size: The LAF was judged to be duplicative and was eliminated. Representative Load Size used in the drying energy equation will be replaced with an average load size that utilizes the LUFs (Load Usage Factors).

Energy Test Cycle definition changes: Extensive changes and discussion on the new definition took place. The new energy test cycle will require testing of the normal cycle similar to J1 but also requires testing of TUFs that are available in other cycles but not in the normal cycle.

- New Capacity Measurement method: To assure consistency among stakeholders, the measurement methods have either been revised or clarified.
- Test Cloth: Clarification of 'lot' and 'roll' definitions, size and weight tolerances and preconditioning requirements. These are detailed in the J2 test procedure.
- Detergent: Use of the detergent formula described in the AHAM (Association of Home Appliance Manufacturers) standard test at a dosage of 27.0g + 4.0 g/lb in J1 & J2
- Water extractor: J1 specifies tests for extractors up to 500 units of gravitational acceleration (g, or g-force) in order to determine the remaining moisture content (RMC)

correlation curve for test cloth lots. To account for washers that can spin faster, a 650 g extraction test has been added to J2.

- Annual operating cost calculation (includes low-power modes & number of cycles): Since new power modes are part of the calculations, these costs must be added to the annual cost.
- Low-Power mode inclusion (based on IEC 62301 ed. 2.0): The new test procedure includes energy use in low-power modes in addition to the regular washing mode.
  - Active mode: Includes all of the washing functions along with delay start and cycle finished functions.

  "... a mode in which the clothes washer is connected to a mains power source, has been activated, and is performing one or more of the main functions of washing, soaking, tumbling, agitating, rinsing, and/or removing water from the clothing, or is involved in functions necessary for these main functions, such as admitting water into the washer or pumping water out of the washer. Active mode also includes delay start and cycle finished modes..."

  - Active washing mode: Includes only the washing functions in a test cycle (i.e. not delay start and cycle finish)

  "... a mode in which the clothes washer is performing any of the operations included in a complete cycle intended for washing a clothing load, including the main functions of washing, soaking, tumbling, agitating, rinsing, and/or removing water from the clothing..."

  - Inactive mode: This is one of two 'Low-power' modes and includes the stand-by modes

  "... a standby mode that facilitates the activation of active mode by remote switch (including remote control), internal sensor, or timer, or that provides continuous status display..."

  - Off mode: This is one of two 'Low-power' modes and can include power for an indicator

  "... a mode in which the clothes washer is connected to a mains power source and is not providing any active or standby mode function, and where the mode may persist for an indefinite time. An indicator that only shows the user that the product is in the off position is included within the classification of an off mode..."

  - Standby mode: Included in the 'Inactive mode' and includes functions that take place outside of the active washing mode

  "... any mode in which the clothes washer is connected to a mains power source and offers one or more of the following user oriented or protective functions that may persist for an indefinite time:

  (a)To facilitate the activation of other modes (including activation or deactivation of active mode) by remote switch (including remote control), internal sensor, or timer;

  (b) Continuous functions, including information or status displays (including clocks) or sensor-based functions.

  A timer is a continuous clock function (which may or may not be associated with a display) that provides regular scheduled tasks (e.g., switching) and that operates on a continuous basis..."

Delay Start' falls within this mode because by definition in J2, it "… is facilitated by a timer."

'Cycle Finish' falls within this mode because by definition in J2, it "… provides continuous status display …"

– Combined low-power mode: This includes all of the low-power modes

"… the aggregate of available modes other than active washing mode, including inactive mode, off mode, delay start mode, and cycle finished mode."

– Energy use is accounted for in 2 distinct areas:

1. Active Power – Basically the same as J1. Accounts for power consumed during the energy cycle and includes all energy used in the Active washing mode.
2. Low Power – Accounts for power consumed in all modes other than the Active Washing mode. Modes included are Standby, Off, Delay Start, Cycle Finish

– Low-power energy consumption per cycle is calculated by (section 4.4 in the J2 procedure):

a. measuring and averaging power consumption in each low power mode per IEC 62301
b. multiplying this average power consumption by the annual hours not accounted for by annual use hours (i.e. 8465 hours = 8760 hours per year – 295 hours of use per year)
c. and then divide this total by the annual number of cycles (295 cycles)

Combined Low-Power (E_{TLP}) per cycle = $[(P_{ia} \times S_{ia}) + (P_o \times S_o)] \times K_p/295$ = Average of (Inactive power + Off power)/annual cycles

Where:

- P_{ia} = Washer inactive mode power, in watts, for clothes washers capable of operating in inactive mode; otherwise, P_{ia} = 0.
- P_o = Washer off mode power, in watts, for clothes washers capable of operating in off mode; otherwise, P_o=0.
- S_{ia} = Annual hours in inactive mode as defined as S_{oi} if no off mode is possible, [S_{oi}/2] if both inactive mode and off mode are possible, and 0 if no inactive mode is possible.
- S_o = Annual hours in off mode as defined as S_{oi} if no inactive mode is possible, [S_{oi}/2] if both inactive mode and off mode are possible, and 0 if no off mode is possible.
- S_{oi} = Combined annual hours for off and inactive mode = 8,465.
- K_p = Conversion factor of watt-hours to kilowatt-hours = 0.001.
- 295 = Representative average number of clothes washer cycles in a year.

US Energy Guide label (mandatory)

According to (US EPA [n.d.]b), major home appliances such as clothes washers must meet the Appliance Standards Program set by the US Department of Energy (DOE). Manufacturers must use standard test procedures developed by DOE to prove the energy use and efficiency of their products (cf. section above).

Test results are printed on a yellow Energy Guide label, which manufacturers are required to display on their appliances according to the Appliance Labeling Rule of the Federal Trade Commission (FTC). This label estimates how much energy the appliance uses, compares energy use of similar products, and lists approximate annual operating costs. The exact costs will depend on local utility rates and the type and source of your energy. Appliances which are ENERGY STAR qualified (cf. next section) must carry the Energy Guide label.

For clothes washers, the Energy Guide label shall provide the following information (FTC 2012):

- Models for which the Energy Guide label applies
- Capacity class; and capacity (tub volume) in cubic feet
- Estimated Yearly Energy Cost (US Dollar), when used with an electric water heater (the indication of a cost range of similar models, as for example given for dishwashers, is not available for clothes washers).
- Estimated yearly electricity use (kWh).
- Estimated Yearly Energy Cost (US Dollar), when used with a natural gas water heater.
- US Energy Star logo if applicable for the Energy Guide labelled appliance.

The estimated energy cost is based on six wash loads a week and a national average electricity cost of 12 cents per kWh and natural gas cost of $1.09 per therm.

US Energy Star label for Residential Clothes Washers (voluntary)

ENERGY STAR is a U.S. Environmental Protection Agency (EPA) voluntary programme to identify and promote energy–efficient products in order to reduce energy consumption through voluntary labelling of or other forms of communication about products that meet the highest energy efficiency standards.

Specifications for residential clothes washers_(status: March, 2015) are reported in Table 1.12. Clothes washers that have earned the ENERGY STAR are about 25% more efficient than non-qualified models and are more efficient than models that simply meet the federal minimum standard for energy efficiency.

Only front and top loading clothes washers meeting the ENERGY STAR definitions for residential clothes washer and commercial clothes washer, with capacities greater than 1.6ft^3 (45.3 l) are eligible to earn the ENERGY STAR certification. Such definitions correspond with the definitions provided for the DOE standards.

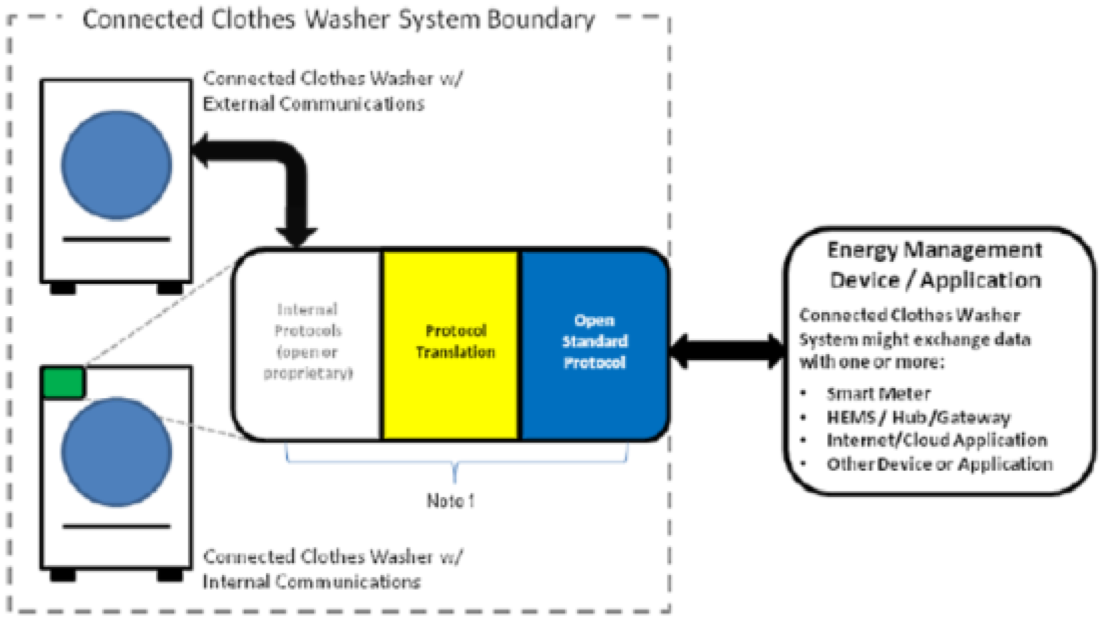
ENERGY STAR allowance for connected appliances

Energy Star has published new eligibility criteria and partner commitments which are effective since March 2015 to qualify a product for the ENERGY STAR label. These include some 5% allowance on the Integrated Modified Energy Factor (IMEF) if the washing machine fulfils some 'connected criteria'. With this allowance it will be easier to qualify for the ENERGY STAR or any of the established tiers of the Consortium for Energy Efficiency (CEE) (cf. next section and Table 1.13 further below).

The following criteria are required for being a 'connected appliance' (extracted from ENERGY STAR® Program Requirements Product Specification for Clothes Washers Eligibility Criteria Version 7.0) (US EPA [n.d.]a):

Connected Clothes Washer System

To be recognized as 'connected' and to be eligible for the connected allowance, a "connected clothes washer system" as shown in Figure 1.4 shall include the base appliance plus all elements (hardware, software) required to enable communication in response to consumer-authorized energy related commands.



Note 1: Communication device(s), link(s) and/or processing that enables open standards-based communication between the Connected Clothes Washer System and Energy Management Device/Application(s). These elements could be within the base appliance, and/or an external communication module, a hub/gateway, or in the Internet/cloud.

Figure 1.4: Connected Clothes Washer System Boundary – Illustrative Example

Communications

1. Open Standards – Communication with entities outside the Connected Clothes Washer System that enables connected functionality must use, for all communication layers, standards.

2. Communications Hardware Architecture – Communication with entities outside the Connected Clothes Washer System that enables connected functionality shall be enabled by any of the following means, according to the manufacturer's preference:

a. Built-in communication technology

b. Manufacturer-specific external communication module(s) and/or device(s)

c. Open standards-based communication port on the appliance combined with open standards-based communications module

d. Open standards-based communication port(s) on the appliance in addition to a, b or c, above

Open Access

To enable interconnection with the product, in addition to the section above that requires open-standards, an interface specification, Application Programming Interface (API) or similar documentation shall be made available to interested parties that at a minimum, allows transmission, reception and interpretation of the following information:

1. Energy Consumption Reporting specified (must include accuracy, units and measurement interval);

2. Operational Status, User Settings & Messages (if transmitted via a communication link);

3. Demand Response

Energy Consumption Reporting

In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services, or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals.

The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., $/month).

Remote Management

The product shall be capable of receiving and responding to consumer authorized remote requests (not including third-party remote management which may be made available solely at the discretion of the manufacturer), via a communication link, similar to consumer controllable functions on the product. The product is not required to respond to remote requests that would compromise performance and/or product safety as determined by the product manufacturer.

Operational Status, User Settings & Messages

1. The product shall be capable of providing the following information to energy management systems and other consumer authorized devices, services or applications via a communication link:

- Operational / Demand Response (DR) status (e.g., off/standby, cycle in process, delay appliance load, temporary appliance load reduction).

2. The product shall be capable of providing the following information on the product and/or to energy management systems and other consumer authorized devices, services or applications via a communication link:

- At least two types of messages relevant to the energy consumption of the product. For example, messages for clothes washers might address performance issues or report of energy consumption that is outside the product's normal range.

Demand Response

A connected clothes washer shall have the capability to receive, interpret and act upon consumer-authorized signals by automatically adjusting its operation depending on both the signal's contents and settings from consumers. At a minimum, the product shall be capable of providing the following:

- Delay Appliance Load Capability: The capability of the product to respond to a signal in accordance with consumer settings, except as permitted below, by delaying the start of an operating cycle beyond the delay period.
    a. Default settings –The product shall ship with default settings that enable a response for at least 4 hours.
    b. Consumer override – The consumer shall be able to override the product's Delay Appliance Load response before or during a delay period.
    c. The product shall be able to provide at least one Delay Appliance Load response per consumer initiated operating cycle.
- Temporary Appliance Load Reduction Capability: TBD

Information to Consumers

If additional modules, devices, services and/or infrastructure are part of the configuration required to activate the product's communications capabilities, prominent labels or other forms of consumer notifications with instructions shall be displayed at the point of purchase and in the product literature. These shall provide specific information on what consumers must do to activate these capabilities (e.g. “This product has Wi-Fi capability and requires Internet connectivity and a wireless router to enable interconnection with an Energy Management System, and/or with other external devices, systems or applications.”). Compliance with Connected functionality shall be through examination of product and/or product documentation. In addition, demand response functionality shall be evaluated using the TBD ENERGY STAR Clothes Washers Test Method to Validate Demand Response in order to be eligible for the connected allowance.

This allowance given to the energy consumption or energy efficiency for cloth washers is part of a more general strategy of the U.S. Environmental Protection Agency (EPA) to support the connectivity of seven appliances as the (outdated) chart from EPA shows (cf. Figure 1.5).

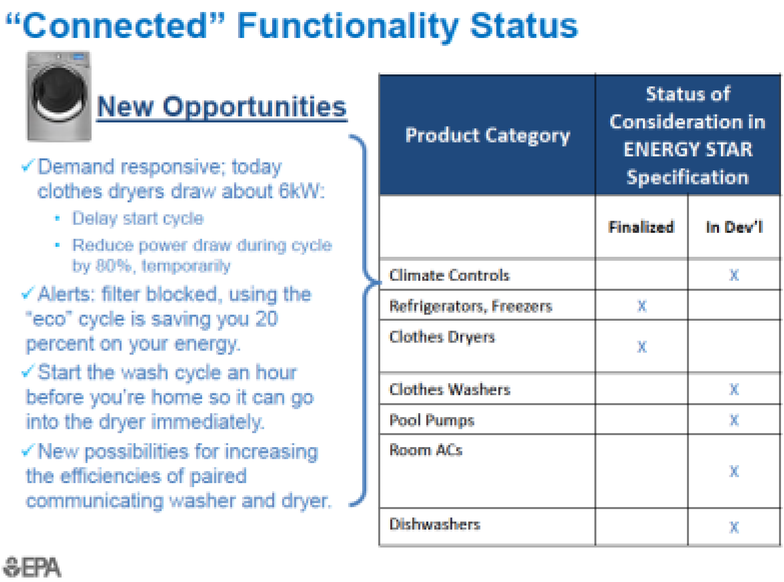


Figure 1.5: **Connected functionality status**

CEE - Consortium for Energy Efficiency

CEE is a consortium primarily of energy efficiency programme administrators from across the United States and Canada. Members leverage individual efforts by working together to accelerate energy efficient products and services in targeted markets.

The CEE role is not to develop or implement the programmes delivered at the local level, but to influence national players - manufacturers, stakeholders, government agencies - to maximize the impact of efficiency programmes. CEE also supports crosscutting trends in behavioural programmes and evaluation.

CEE members, the energy efficiency programme administrators, are investor-owned or municipal utilities, state or provincial energy offices, government agencies, and non-utility programme administrators. What they all have in common is a mission to serve the public by encouraging their customers to use efficient products and practices.

<u>High efficiency specifications for residential clothes washers</u>

The following requirements are requested since March 2015 (Table 1.13):

Table 1.13: **High efficiency specifications for residential clothes washers**

Efficiency Level	Integrated modified energy factor (IMEF)	Integrated water factor (IWF)

Efficiency Level	Integrated modified energy factor (IMEF)	Integrated water factor (IWF)
Federal Standard Top Load	1.29	8.4
Federal Standard Front Load	1.84	4.7
ENERGY STAR® Top Load	2.06	4.3
ENERGY STAR® Front Load	2.38	3.7
CEE Tier 1	2.38	3.7
CEE Tier 2	2.74	3.2
CEE Tier 3	2.92	3.2

1.2.5.4. Asia

China – Mainland

Minimum Energy Efficiency Standards

According to CELC - China Energy Label Centre ([n.d.]b), the standard GB12021.4-2004, implemented in May 2005, specifies the maximum energy consumption and water consumption per kilogram of laundry, and methods for determining the evaluating values of energy conservation and energy efficiency grades of household electric washing machines. It applies to household electric washing machines with a rated washing capacity of less than 13 kg cotton, hereinafter referred to as "washing machines"; it does not apply to washing machines with a washing capacity of less than 1.0 kg and single container washing machines with no water extraction function. For washer-dryers, only the washing function is assessed.

The following maximum values of energy and water consumption are allowed:

Table 1.14: Maximum values of power and water consumption allowed for household electric washing machines under Chinese Minimum Energy Efficiency Standard GB12021.4-2004; source CELC - China Energy Label Centre ([n.d.]b)

Washing machine type	Maximum allowable value of power consumption per kilogram (kWh/cycle/kg)	Maximum allowable value of water consumption per kilogram (l/cycle/kg)
Impeller-type and fully automatic agitator-type washing machines	0.032	36
Drum-type washing machines	0.350	20

These maximum allowable values are the mandatory minimum requirements for products to access the market and correspond to tier 5 of the China Energy Label programme (cf. next section). Impeller-type and fully automatic agitator-type washing machines have no market relevance in the EU.

Mandatory Energy Efficiency Label

The China's energy efficiency labelling management system, also known as the China Energy Label, is a mandatory energy efficiency labelling programme which is based on China's Energy Conservation Law, Product Quality Law and Regulations on Certification and Accreditation. The 'Catalog of Products to Implement Energy-Efficiency Labelling' and the 'Rules for Implementing Relevant Product Labels' are the rules for execution that standardise the format specifications, testing requirements, filing procedures and verification requirements for labelling of specific products (CELC - China Energy Label Centre [n.d.]a).

The China Energy Label programme was launched in 2005 and covers 27 products (end of 2012). It is based on an energy efficiency classification set in correspondence with the energy efficiency standards. The label shows consumers how close an appliance comes to meet minimum efficiency standards, ranging from 100% (which corresponds to meet the minimum standard) to 55% of the value set with the minimum standard. Such labels now appear on 19 products, including air conditioners, household refrigerators, and clothes washers (ChinaFAQs, The Network for Climate and Energy Information 2010).

The implementation date of the China Energy Label for washing machines was in 2007. The China Energy Label programme has two classification scales – with either 3 or 5 tiers. In both scales the lower the number of the tier, the higher the energy efficiency. Tiers 3 or 5 are the mandatory minimum requirements for products to access the market (cf. section above). Tiers 2 and 1 are generally endorsement requirements for the energy efficient product certification and incentive policies (Hu B. et al. 2013).

According to CELC - China Energy Label Centre ([n.d.]b), the following values of energy and water consumption as well as wash ability ratio are corresponding to the five tiers of the mandatory energy efficiency label.

Table 1.15: China Energy efficiency label grades for washing machines; source CELC - China Energy Label Centre ([n.d.]b)

Washing machine efficiency tier	Impeller-type washing machines			Drum-type washing machines		
	Energy consumption kWh/cycle/kg	Water consumption l/cycle/kg	Wash ability ratio	Energy consumption kWh/cycle/kg	Water consumption l/cycle/kg	Wash ability ratio
1	≤0.012	≤20	≥0.90	≤0.19	≤12	≥1.03
2	≤0.017	≤24	≥0.80	≤0.23	≤14	≥0.94
3	≤0.022	≤28		≤0.27	≤16	
4	≤0.027	≤32	≥0.70	≤0.31	≤18	≥0.70
5	≤0.032	≤36		≤0.35	≤20	

The market analysis for China energy efficient products (Hu B. et al. 2013) states that for washing machines, tier 1 products reach a share of almost half of the market, whereas the share of tiers 4 and 5 products is so low that these products can be ignored when looking at the market.

Table 1.16: Share of different technologies of washing machines covered by the China Energy efficiency label; source: Hu B. et al. (2013)

	Front-load	Top-Load	All
Tier 1	100%	22.4%	44.5%
Tier 2	0%	70.2%	42.7%
Tier 3	0%	6.4%	10.3%
Tier 4	0%	1%	2.6%
Tier 5	0%	0%	0%

When both front-load and top-load models are considered together, Tier 1 and tier 2 products equally share the market. Having a detailed look into the different technologies, 100% of the front-load models are tier 1 products, and there are no front-load washing machines available on the market for the other tiers. On the other hand, only 22% of the top-load models are tier 1. Tier 2 takes the largest share of the top-load technology (Hu B. et al. 2013).

According to (Hu B. et al. 2013), different testing conditions are applied for front-load and top-load models. Top-load washing machines have cold water inlet at a temperature of 30±2 °C and tested with cold water as inlet. Front-load washing machines have cold water inlet at a temperature of 15±2 °C and are tested with warm water heated by the washing machine at a temperature around 50±2 °C. The front-load washing machine has lower energy efficiency requirements for the same tier than the top-load washing machine due to the different testing conditions. The share of the top-load washing machines is much higher than the front-load ones.

Voluntary Energy Conservation Label

Besides the mandatory minimum energy efficiency standards and the Energy Efficiency Label, China has a voluntary energy efficiency endorsement labelling programme highlighting the 'best in class' products similar to the U.S. Energy Star programme. The following values of energy and water consumption as well as wash ability ratio are maximal allowable for the Voluntary Energy Efficiency endorsement label which corresponds to Tier 2 of the mandatory energy efficiency label:

Table 1.17: China Evaluating indices of energy conservation for washing machines; source: CELC - China Energy Label Centre ([n.d.]b)

	Energy consumption (kWh/cycle/kg)	Water consumption (l/cycle/kg)	Wash ability ratio*
Impeller-type and fully automatic agitator-type washing machines	≤0.017	≤24	≥0.80
Drum-type washing machines	≤0.23	≤14	≥0.94

* Rate of washing ability: The indicator shows the quality of the washing machine's washing service. The higher the rate is the better.

China Environmental Labelling

The China Environmental Labelling programme was initiated in 1993. The China Environmental Labelling is a type I eco-labelling scheme organised by MEP (Ministry of Environmental Protection of the People's Republic of China). The Environmental Certification Centre (CEC), which is the organization authorized by MEP, develops a set of technical criteria documents and carries out China Environmental Labelling certification, supervised and managed by China Certification Committee for Environmental Labelling Products (CCEL). Certification standards for 95 categories of products have been set by now, including automotive, electronics, building materials etc.

For household electric washing machines, the Technical Requirement for Environmental Labelling Products HJ/T 308-2006 is effective as of January 2007 (Chinese Government 2006).

The aims of these requirements are to improve the energy efficiency, foster low-noise machines and guarantee the indoor air quality. The scope covers washing machines, which have a rated washing capacity not exceeding 13 kilograms (including spin dryer). The scope shall NOT apply to washing machines with nominal wash capacity equal to or less than 1 kilogram and without spin drying. For energy consumption, water consumption and the wash ability ratio, the same criteria as for the Voluntary Energy Conservation Label as reported in Table 1.17 apply for washing machines under the Chinese Environmental Labelling.

Table 1.18: The China Environmental Labelling criteria for washing machines with regard to noise emission

Machine type	Impeller-type (including spin dryer)		Drum-type		Agitator-type
	Capacity ≥4 kg	Capacity <4 kg	Number of turns > 600 r/min	Number of turns ≤600 r/min	-
Noise Level dB(A)	60	55	65	60	60

Further resource related criteria are listed in section 1.3.2.3.

Topten China

Topten China (http://www.top10.cn/english.html) is a member of the TopTen International Group (TIG), a global alliance of organizations dedicated to promote high efficiency products (cf. section 1.2.4).

Top10 China is an internet-based platform that provides independent and up-to-date information on the best available energy efficient products currently available on the Chinese market. Top10 provides a neutral, transparent selection and evaluation of products based on impartial testing and analysis. For large household appliances, Top10 China lists energy efficient refrigerators and washing machines; washer-dryers are not included.

For washing machines, following product sub-categories are defined:

- Drum machines < 7 kg, 7 kg and > 7 kg
- Impeller machines < 7 kg and ≥ 7 kg

To be selected in the Top10 China product lists, the energy consumption, water consumption of the products must meet the following criteria:

Table 1.19: Top10 China criteria for washing machines

Machine type	Washing Capacity (kg)	Energy Consumption (kWh/cycle/kg)	Water Consumption (L/cycle/kg)	Rate of Washing Ability*
Drum machines	<7 kg	≤0.097	≤8.0	≥1.03
	7 kg	≤0.097	≤7.6	≥1.03
	> 7 kg	≤0.089	≤7.1	≥1.03
Impeller machines	≤7 kg	≤0.011	≤16.7	≥0.90
	7 kg<WC	≤0.011	≤17.3	≥0.90

* Rate of washing ability: The indicator shows the quality of the washing machine's washing service. The higher the rate, the better.

China – Hong Kong

Hong Kong introduced a Mandatory Energy Efficiency Labelling Scheme (MEELS) through the Energy Efficiency (Labelling of Products) Ordinance enacted on 9 May 2008. Besides that, Hong Kong runs a Voluntary Energy Efficiency Labelling Scheme (VEELS).

The Mandatory Energy Efficiency Labelling Scheme (MEELS)

To further facilitate the public in choosing energy efficient appliances and raise public awareness on energy saving, the Government has introduced the Mandatory Energy Efficiency Labelling Scheme (MEELS) through the Energy Efficiency (Labelling of Products) Ordinance. Under MEELS, Energy Labels are required to be shown on the prescribed products for supply in Hong Kong to inform consumers of their energy efficiency performance. MEELS currently covers five types of prescribed products. Since September 2011, MEELS also has been fully implemented to washing machines. A Code of Practice on Energy Labelling of Products has been approved and issued to provide practical guidance and technical details in respect of the requirements under the Ordinance, cf. (EMSD 2014).

The scope covers “Washing machines”, defined as (a) a household appliance for cleaning and rinsing of textiles using water with or without a means of extracting excess water from the textiles; and (b) includes washing machines that (i) use mains electricity as the primary power source; and (ii) have a rated washing capacity not exceeding 7 kilograms, whether or not they have built-in dryers for drying textiles by means of heating. It excludes washing machines that (a) may also use other energy sources; or (b) have no spin extraction capability.

The energy efficiency grading of a washing machine shall be determined as shown in the following table, with Grade 1 having the best performance and Grade 5 having the worst performance.

Table 1.20: Energy efficiency grades of the Hong Kong Mandatory Energy Efficiency Labelling Scheme (MEELS); source: (EMSD 2014)

Specific Energy Consumption, E_{sp} (kWh/kg/cycle)		Energy Efficiency Grade
Horizontal Axis Type	Vertical Axis Type	
$E_{sp} \leq 0.130$	$E_{sp} \leq 0.0160$	1
$0.130 < E_{sp} \leq 0.150$	$0.0160 < E_{sp} \leq 0.0184$	2
$0.150 < E_{sp} \leq 0.172$	$0.0184 < E_{sp} \leq 0.0208$	3
$0.172 < E_{sp} \leq 0.195$	$0.0208 < E_{sp} \leq 0.0232$	4
$0.195 < E_{sp}$	$0.0232 < E_{sp}$	5

In order to obtain Grade 1 to 4, the washing machine concerned shall also meet all the washing performance and water extraction performance requirements laid down in the Code of Practice.

The Voluntary Energy Efficiency Labelling Scheme (VEELS)

Hong Kong has also introduced a Voluntary Energy Efficiency Labelling Scheme (VEELS). The scheme now covers twenty two types of household appliances and office equipment, inter alia washing machines. The scheme runs two kinds of Energy Labels: grading-type and recognition-type Energy Label. For household washing machines, the grading-type applies. The revision of the scheme for washing machines has been implemented from 8 July 2013 and Energy Labels will expire on 31 December 2016 when re-registration is necessary.

The Hong Kong Voluntary Energy Efficiency Labelling Scheme for washing machines (EMSD 2013) applies to top-loading agitator/impeller-type and top-loading/front-loading drum-type clothes washing machines.

The energy efficiency index of an appliance is defined as the ratio of the actual specific energy consumption of the appliance to the average specific energy consumption. The indices are expressed in percentages. Thus, by comparing the energy efficiency indices, all appliances can have meaningful comparison of their energy efficiencies. In other words, within a category appliance that has a lower energy efficiency index (i.e. lower percentage) consumes less energy than an appliance of higher energy efficiency index (i.e. higher percentage). The energy efficiency index is calculated as follows:

Energy Consumption Index ($I\varepsilon$) = E_{sp} / E_{av} * 100%

Where E_{sp} is the actual appliance "Specific Energy Consumption" obtained from energy consumption test per rated washing capacity; and E_{av} is the Average Specific Energy Consumption: E_{av} = 0.26 for drum type washing machines and E_{av} = 0.0264 for agitator or impeller type washing machines.

To make the concept of appliance energy efficiency more readily understood by ordinary consumers, appliance energy efficiency grade is introduced by linking the energy consumption index (percentage) to the 5 grades as shown in the following table, with Grade 1 being the most energy efficient and Grade 5 the least.

Table 1.21: Converting Energy Consumption Indices to Energy Efficiency Grades within the Voluntary Energy Efficiency Labelling Scheme (VEELS); source: (EMSD 2013)

Energy Consumption Index: Iε (%)	Energy Efficiency Grade
Iε ≤ 80	1
80 < Iε ≤ 95	2
95 < Iε ≤ 110	3
110 < Iε ≤ 125	4
125 < Iε	5

In order to obtain Grade 1 to 4, the washing machine concerned shall also meet all the washing performance and water extraction performance requirements.

The Hong Kong Green Label Scheme (HKGLS)

According to (Hong Kong Green Council 2010a), the Hong Kong Green Label Scheme (HKGLS) is an independent and voluntary scheme, which aims to identify products that are, based on life cycle analysis consideration, more environmentally preferable than other similar products with the same function. The Scheme is organized by the Green Council (GC) with contributions from the HKGLS Advisory Committee and a number of supporting organizations. Product environmental criteria have been established for a wide variety of consumer products, inter alia washing machines and dishwashers.

The aim of the environmental criteria developed for washing machines is to: reduce energy consumption and promote energy-saving washing machines; reduce water consumption and promote water-saving washing machines; reduce noise emission and the use of the environmentally harmful substances; reduce detergent consumption; minimize waste production by reducing the amount of primary packaging and promoting its reusability and/or recyclability. These product environmental criteria apply to domestic washing machines with spinning function with a drum volume not exceeding 62 litres, but do not include combined washing machines and tumble dryers. Spinning may take place in the washing drum or as in twin-tub machines in a separate drum.

The product environmental criteria for washing machines are the following (Hong Kong Green Council 2010b):

- The Energy Consumption Index (ECI) of the appliance shall meet the HKSAR EMSD Energy Efficiency Label Scheme (EELS) energy efficiency grade 3 requirement or better (cf. section above).
- Water consumption per kilogram of clothing load shall not exceed 22 litres.

- Noise Emission: Airborne noise emission from the appliance, measured as sound power level, shall not exceed 60 dB (A) during washing and 76 dB(A) during spinning.

Further resource related criteria are listed in section 1.3.2.3.

China – Taiwan

The Green Mark Programme is the official ecolabelling programme in Chinese Taipei which was founded in 1992 by the Environmental Protection Administration (TEPA). At present, the programme has issued Green Mark ecolabel certificates of around 112 product categories, including various cleaning products, office supplies and equipment, energy/water-saving products, information technology products, construction materials, and home appliances; there are criteria documents for washing machines; washer dryers are not in the scope of the Green Mark Programme.

The Green Mark criteria apply to clothes washers; they do not include products which only have the water removal or cloth drying functions. The standard is applicable to the following types of products: Front-load/drum type; and top-load/upright type, including those involving jet stream, stirring, scrolling or whirlpool movements for cleaning purpose. The following criteria apply to clothes washers (Government of the Republic of China (Taiwan): Environmental Protection Administration 2014):

- The product's energy efficiency shall meet the Energy Efficiency and Labelling Requirements for Clothes Washers of the Energy Labelling Programme managed by the Bureau of Energy of the Ministry of Economic Affairs.
- The noise level for products during water removal operation shall be below the regulatory limit of ≤ 53 dB(A).

Further resource related criteria are listed in section 1.3.2.3.

Republic of Korea

Under the Korean Energy Efficiency Label and Standard Programme, manufacturers and importers are required to produce and import products meeting a minimum energy performance standard (MEPS). Manufacturers and importers must report product energy efficiency standards. Products must be labelled according to their energy performance, from grades 1 to 5, showing the energy performance of the product. 1 is the highest grade, and 5 the lowest grade, representing the MEPS. Any product falling below grade 5 is banned from sale. 22 products are covered under the programme, including refrigerators, washing machines and air conditioners (International Energy Agency IEA 2012).

<u>Korea Ecolabel</u>

The Korea Ecolabel has been implemented since 1992. Inter alia, this scheme has certification criteria for washing machines. The scope of the Korea Ecolabel for washing machines (Korea Environmental Industry & Technology Institute KEITI 2011) applies to the volute type (i.e. revolving motion of a propeller equipped on the bottom of laundry tub) and agitator type (i.e. agitating motion of a propeller equipped on the bottom of laundry tub) household fully automatic washing machine below 12 kg class. The criteria document includes requirements with regard to

- The amount of water consumption
- Indication of Water-saving level based on water consumption
- Drum type washing machines being equipped with Cool-Water Washing function
- First class Energy Efficiency Rating (cf. bullet above)

- Noise during the operation (washing / dehydrating) of the product
- Dehydrating level > 50%; rinsing ration > 1.05
- Consumer information

Further resource related criteria are listed in section 1.3.2.3.

Other Asian countries

Further Asian countries do have voluntary Ecolabel for washing machines:

- The Singapore Green Labelling Scheme (SGLS) was launched in May 1992 to endorse consumer products and services that have less undesirable effects on the environment. This is administered by the Singapore Environment Council (SEC). The SGLS is also recognised as a member of the international Global Ecolabelling Network (GEN), allowing certification by mutual recognition of SGLS endorsed products by other members of the network (http://www.sec.org.sg/sgls/). This means that the countries in this network accept the Ecolabel criteria of other Members of the Network to mark products with their own label. The last updated of the Singapore Green Label Scheme (SGLS) for washing machines was in 2009.
- The Thai Green Label Scheme was initiated by the Thailand Business Council for Sustainable Development (TBCSD) in 1993. It was formally launched in August 1994 by the Thailand Environment Institute (TEI) in association with the Ministry of Industry (http://www.tei.or.th/greenlabel/). The Thai Green Label Scheme covers also clothes washing machines for household use.
- The Indonesia Energy Efficiency Labelling Program (voluntary comparative label), a component of the Indonesian Government Regulation No. 70/2009 on Energy Conservation, is intended to provide information to consumers about the energy efficiency level of a product, as well as to encourage manufactures to increase the level of energy efficiency of products that they produce. The labelling system uses a star-rating system of 4 stars and includes information about the absolute energy efficiency of the product (kWh/year). The star rating shows the product's energy efficiency rank relative to similar products in the market, and is assigned by an independent and accredited test facility that tested the product. The labelling programme currently covers air conditioning (voluntary), compact fluorescent lightbulbs (mandatory), refrigerators (voluntary) and freezers (voluntary) (International Energy Agency IEA 2015). Programmes to cover clothes washers (and other product groups such as rice cookers, irons, ballasts, televisions, and fans) are under development in 2015.
- Philippines: development of Mandatory Minimum Energy Performance Standards and of a Mandatory Comparative Label for clothes washers are under consideration (Ecofys 2014)
- India: a Voluntary Comparative Label for clothes washers was developed but neither information on registered products nor update of the criteria has been found in the literature (status 2010); source: Ecofys (2014)

1.2.5.5. Australia & New Zealand

The Equipment Energy Efficiency (E3) program aims to increase the energy efficiency of lighting, appliances and equipment used in the residential, commercial and manufacturing sectors in Australia and New Zealand. This is achieved through the delivery of an energy efficiency standards and labelling program which apply performance standards (Minimum Energy Performance Standards [MEPS] and High Efficiency Performance Standards [HEPS]) and comparative energy rating labelling. The Australian labelling programme is based on a star system, rated from one to ten. Performance standards and energy rating labelling are regulated through state and territory government regulations and penalties exist for non-compliance. The E3 program is part of the National Strategy on Energy Efficiency and overseen at a ministerial level by the Standing Committee on Climate Change. Operational oversight occurs through the E3 committee comprising officials from the Australian Government, State and Territory government agencies and the New Zealand Government (International Energy Agency IEA 2014).

Energy

Minimum Energy Performance Standards (MEPS)

Minimum Energy Performance Standards (MEPS) specify the minimum level of energy performance that appliances, lighting and electrical equipment must meet or exceed before they can be offered for sale or used for commercial purposes. MEPS are mandatory for a range of products in Australia and New Zealand. These products must be registered through an online database and meet a number of legal requirements before they can be sold in either of these countries. For white goods, Minimum Energy Performance standards are only defined for domestic fridges and freezers, not for dishwashers, washing machines or washer-dryers.

However, the ‘Greenhouse and Energy Minimum Standards Determination 2012 for clothes washing machines’ defines labelling and communication requirements and other requirements on performance (Australian Government 2012):

- The Determination covers clothes washing machines that are ordinarily supplied and used for personal, domestic and household purposes irrespective of the context in which they are used. For example, the Determination applies to household clothes washing machines that are used in a commercial context. Examples of appliances covered by this Determination are both horizontal and vertical axis single bowl machines (front or top loading), twin tub units and the washing function of combination washer/dryer units. The Determination does not cover:
- Clothes washing machines that have:
    - a rated load capacity of less than or equal to 2 kilograms for all textile materials;
    - no connections to a mains water supply; and
    - no pump or other means for extracting water; and
- Clothes washing machines that are only capable of being used for cold wash operations and have:
    - no provision for internal water heating;
    - a single water connection marked only for cold water;
    - automatic fill control;
    - no programme that indicates (directly or indirectly) that a programme other than a cold wash programme is possible;
    - a user manual that explicitly states it is only suitable for cold washing operations; and
    - no associated product literature that states it is suitable for anything other than cold washing operations.
- Labelling and communication requirements, as well as the product performance requirements (Percentage Soil Removal and Standard Deviation; Water Consumption; Water Extraction Index; Severity of Washing Action Index; Rinse Performance; and Water Pressure) refer to the requirements stated in the Australian standard AS/NZS 2040.2:2005 (cf. next section).

Performance standard AS/NZS2040 for clothes washing machines

Washing machines in Australia and New Zealand are measured according to the standard: AS/NZS 2040.1:2005/Amdt. 1:2007 (Energyrating) *Performance of household electrical appliances - Clothes washing machines* prepared by the Joint Standards Australia/Standards New Zealand Committee EL-015, Quality and Performance of Household Electrical Appliances. The AS/NZS 2040 series comprises two parts:

- AS/NZS2040: Performance of household electrical appliances - Clothes washing machines Part 1: Energy Consumption and Performance
- AS/NZS2040: Performance of household electrical appliances - Clothes washing machines Part 2: Energy labelling requirements

Part 1 of the standard defines the test procedures for the determination of energy consumption and performance of clothes washers in Australia. Part 2 of the standard sets out the requirements for Energy Labelling of clothes washers in Australia. An approved Energy Label for clothes washers must be displayed on all products which are offered for sale in Australia (cf. next section).

The overall objective of the AS/NZS 2040 series is to promote high levels of performance and energy efficiency in electric clothes washers. It is in some aspects (e.g. load) based on IEC 60456:1994, *Electric clothes washing machines for household use-Methods for measuring the performance*. Nevertheless, it differs from IEC standard in a number of ways, as follows:

- Specific minimum performance requirements for washing, spinning and severity of washing are included (these are not specified by the IEC) in Part 2;
- The water hardness is specified as 0.45 mmol/litre (in IEC 60456 it is 2.5 mmol/litre);
- The cold water temperature is 20 °C (in IEC 60456 it is 15 °C);
- A particular phosphate-based detergent is used for other than drum type machines (not specified by IEC);
- Only IEC Type B phosphate-based detergent is used for drum type machines (IEC nominates two detergents, with the stated intention of deleting Type B in the future);
- AS9 soil swatches are used (IEC specifies four separate soil swatches which include carbon, blood, wine and chocolate);
- A mixed cotton and polyester/cotton load is used (IEC specifies only sheets, towels and pillowcases for cotton);
- Each AS9 soil batch is calibrated against a reference batch (soil batch calibration is not specified by IEC);
- Same laboratory reference machine is not used to normalize results (IEC specifies a Wascator reference machine to normalize results);
- The water extraction (spin) index is based on bone dry mass (IEC index is based on normalized mass with a nominal 8% moisture content);
- Whiteness retention test (informative) is included (not specified by IEC);
- Tests for rinse performance are included in Annex N (added in Amendment 4, of August 2005, with a different method compared to IEC);
- Tests for acoustical noise are not included (these are specified by IEC).

The standard AS/NZS 2040-1, Amendment No. 4, August 2005 includes Appendix N - Determination of rinse performance and Appendix O – Measurement of PBIS concentration in the supply water and extracted liquor samples.

Appendix N sets out the procedure for determining the rinse performance of a clothes washing machine, through UV spectrophotometric measurement of a chemical marker (2-phenyl-5-benzimidazole-sulfonic acid or PBIS) in the rinse liquor extracted from the wet load at the end of the programme. The test for rinse performance is carried out in conjunction with tests to determine percentage soil removal, energy and water consumption, water extraction index, and severity of washing action index in accordance with Appendices D, E, F and G respectively of the standard AS/NZS 2040-1.

Rinse performance of a washing machine is determined by measuring the mass, per kilogram of rated load, of a marker (PBIS) present in the rinse liquor that is retained in the wet load at the end of the programme. The marker, analytical grade 2-phenyl-5-benzimidazole-sulfonic acid (PBIS) with a purity of 98% or better, is dosed into the wash program in proportion to the rated load, the dosage being 100mg PBIS per kilogram of rated load. A standard percentage soil removal test is then conducted in accordance with Appendix D of AS/NZS 2040-1, using a conditioned load. At the completion of this test (following the weighing of the load) the load is placed in a spin extractor and a sample of rinse liquor recovered. A spin extractor of any size may be used for the purpose of this test provided that it can generate sufficient G force to extract from the rinsed load sufficient rinse liquor (typically 100 ml, but no more than 150 ml) for the purpose of UV spectrophotometric measurement of the extracted sample. Ideally a spin extractor that can accommodate the entire load in a single run should be used. If a smaller spin extractor is used, the entire load will need to be divided into two or more equal parts.

Using UV spectrophotometry the concentration of retained PBIS is then determined by comparison with measurements from solutions of known PBIS concentration.

The rinse performance is then determined from the concentration of PBIS in the extracted rinse liquor multiplied by the mass of retained moisture in the load measured at the end of the program. As a check on the accuracy of the dosing of PBIS, a sample of the wash liquor is also collected during the test and measured for PBIS concentration.

The rinse performance score (in mg/kg of load) is determined from the following equation:

$$\text{Rinse performance score} = \frac{C_m \times m_r}{RC}$$

where:

C_m = concentration of PBIS found in the rinse liquor adjusted as required for the apparent concentration of PBIS in the supply water (mg/l)

m_r = mass of retained moisture in the load (kg)

RC = rated load capacity claimed by the manufacturer for a normally soiled load (kg).

A test is not valid unless the following criterion is met:

$$PBIS_{wash} \geq 0{,}7 \times \frac{M_{PBIS}}{Q_{washtot}}$$

where:

$PBIS_{wash}$ = the concentration of PBIS found in the sample of wash liquor (mg/l)

M_{PBIS} = the dose (mass) of PBIS used in the test (mg)

$Q_{wash\ tot.}$ = the total volume of water, including any water added with the detergent, used in the initial wash operation (i.e. up until first pump out) (litres)

The procedure for measuring the concentration of PBIS in the supply water and extracted liquor samples is specified in Appendix O: the test procedure employs the measurement of the absorbance of ultraviolet light by a sample water at the absorbance maximum for PBIS (302 nm) and at a background point of 330 nm. The measurement of a background point at 330 nm enables correction for background absorbance due to turbid samples.

However, the PBIS method presents some drawbacks, e.g. it has not been investigated whether the dilution effect of freshwater on PBIS in the wash liquor and wash load is the same as the dilution effect of freshwater on the detergent ingredients. The same AS/NZ standardisation organisation is at the moment exploring the possibility of adopting different methods (cf. also section 1.2.2.1 for European standardisation activities on rinsing performance).

<u>Energy Rating Label</u>

The Energy Rating Label, or ERL, is a mandatory comparative Energy Label that provides consumers with product energy performance information at point-of-sale on a range of appliances. Attached to each appliance, it allows comparison between similar appliance models through a star rating of between one and six stars (the greater the number of stars, the higher the efficiency) and the annual energy consumption. Further, the label provides information about the energy use of the appliance in kilowatt-hours (kWh) per year when tested to the relevant standard.

In Australia and New Zealand, clothes washers are mandatory required to display the Energy Rating Label under the Greenhouse and Energy Minimum Standards (GEMS) Act 2012. For clothes washers, the standard star rating system has a minimum of 1 star and a maximum of 6, shown in half star increments, cf. sample label in the figure below.

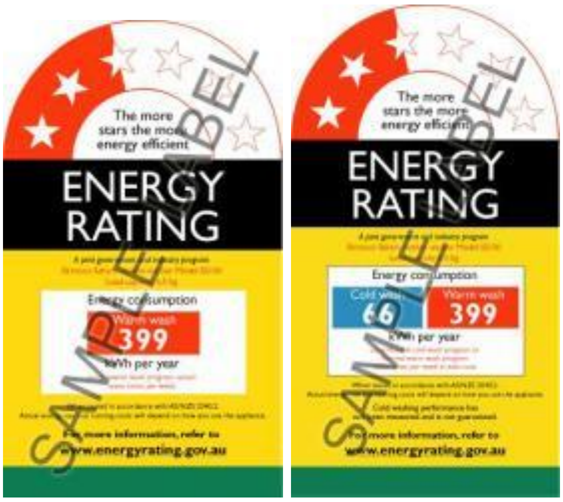


Figure 1.6: **Australia's Energy Rating Label for washing machines. Left: warm wash; right: warm and cold wash; source: Australian, State and Territory and New Zealand Governments (2014c)**

Different procedures and equations have been developed to rate the least efficient products at around 1 star. The Base Energy Consumption (BEC) defines the "1 star" line for particular products. An additional star is awarded when the so called Comparative Energy Consumption (CEC) of the model is reduced by a defined percentage from the BEC.

For washing machines, the Base Energy Consumption is defined as BEC = 115 x rated capacity. The energy reduction factor per star is 0.27, i.e. 27%. For example, a model that had a CEC that was 0.73 of the BEC or less would achieve 2 stars. Similar, a CEC of 0.533 (0.73 x 0.73) of the BEC or less would achieve 3 stars and so on. For clothes washers, front and top loading models are rated on the same basis. The warm wash energy consumption and a component of residual moisture (spin performance) are used to define the star rating in comparison with the BEC. Therefore a model that has a good spin performance may get a marginally higher star rating than a model of the same capacity and CEC with a poor spin performance (Australian, State and Territory and New Zealand Governments 2014b).

The Comparative Energy Consumption of a washing machine is measured under conditions specified in an Australian and New Zealand Standard (cf. section above). Over a year, it is assumed that the washing machine is used 7 times per week (365 times per year). For clothes washers, the star rating index is also influenced by the spin performance of the machine, as it is assumed that some of the load will be put into a dryer. So the normal ratio of CEC/BEC in the Star Rating Index (SRI) equation is replaced as follows (EES 2010):

$$SRI = 1 + \left[\frac{\log_e\left(\frac{CEC + Em}{BEC + Eref}\right)}{\log_e(1 - 0.27)} \right]$$

where

$$\mathrm{Em} = \frac{F \times WEI \times RC \times 365}{1.08}$$

$$\mathrm{Eref} = \frac{F \times WEI_{ref} \times RC \times 365}{1.08}$$

SRI = Star Rating Index

F = 0.1;

WEI = water extraction index for the model (also called spin index);

WEI_{ref} = 1.03.

WEI is usually in the range of 1.1 (maximum allowable) to about 0.55 (best on the market) and is the ratio of moisture remaining in the load compared to the bone dry mass of the test load (which is nominally the rated capacity / 1.08).

Energy Star Australia

The US Energy Star has been adopted by several countries, also by Australia. The Energy Star mark is awarded to the top 25% most energy efficient products; inter alia to washing machines (Australian, State and Territory and New Zealand Governments 2014a).

Water

Water Efficiency Labelling and Standards (WELS) scheme

WELS is the Australia's water efficiency labelling scheme that requires certain products to be registered and labelled with their water efficiency in accordance with the standard set under the national Water Efficiency Labelling and Standards Act 2005. The WELS label replaces a prior voluntary water conservation rating 'AAAAA' label endorsed by the Water Services Association of Australia. The water-using WELS products are inter alia washing machines, including combination washer/dryers (Australian, State and Territory Governments 2014b).

The standard that sets out the criteria for rating the water efficiency and/or performance of each WELS product type is the Australian and New Zealand Standard AS/NZS6400:2005 "Water-efficient products - Rating and labelling". This standard is the basis for the star ratings and water consumption and flow displayed on the WELS label.

The average total water consumption for washing machines is determined by testing three models on a programme recommended to wash a normally soiled cotton load at the rated load capacity of the machine. The water efficiency rating is determined by using a formula derived from the total water consumption. Other tests performed include soil removal, water extraction, severity of wash and rinse performance. These tests have performance thresholds which must be met in order for the product to be registered and labelled (Australian, State and Territory Governments 2014a):

Combined washer-dryer machines may use water to dry loads. Since 1 November 2011 it has been mandatory for combined washer-dryers registered after that date to carry a WELS label stating the water usage of the dryer function.

Minimum Water efficiency Standards (WES)

Washing machines also have minimum water efficiency standards (WES): Washing machines with a capacity of 5 kg or more must rate at least 3 stars, while those with a capacity of less than 5 kg must rate at least 2.5 stars (Australian, State and Territory Governments 2014b). The minimum Water Efficiency Standard (WES) for washing machines came into effect on 1 November 2011.

1.2.5.6. Latin America (LATAM)

For LATAM, vertical-axis (VA type) machines still are the majority of the markets either with an agitator or an impeller. Semi-automatic (or manual) washing machines requiring some user intervention during the programme are a huge share of the Latin America market , so energy efficiency requirements have been established to regulate this type of washing machines. Front loader (horizontal-axis, HA) washers have larger market share only in Argentina. In general, these are more expensive and consumers notice the cycle time being longer.

As in other regions, LATAM strives to get more efficient products through mandatory and voluntary policy instruments. The concept of high efficiency has been growing into consumer minds recently, especially in countries like Mexico (for its closeness to Canada and US markets).

Table 1.22 shows legislation in place in Latin America (i.e. Minimum Energy Performance Standards or comparative labels).

Table 1.22: Latin America legislation (Minimum Energy Performance Standards or comparative labels) for washing machines and washer-dryers; source: Ecofys (2014)

Country	Minimum Energy Performance Standards	Comparative Labels
Argentina	Mandatory Minimum Energy Performance Standards for clothes washers; status: entered into force (2013)	Mandatory Comparative Label for clothes washers; status: entered into force – no activity (2010)
Brazil	---	Mandatory Comparative Label for clothes washers; status: under revision (2005)
Mexico	Mandatory Minimum Energy Performance Standards for clothes washers; status: entered into force - no activity – (2013)	Mandatory Comparative Label for clothes washers; status: entered into force - no activity – (2013)

In general, more efficient washers have no special recognition and promotion in Latin America. Just in Brazil and in Mexico there is an ecolabel that informs somehow that the product is more efficient.

Standardisation in LATAM

As in many other geographic regions, methodologies have been explored and evaluated to provide a suitable way to measure and report energy efficiency values. Basically there are two methodologies in place: based on the U.S. standard DOE and based on the international standard IEC. Free commerce trades play an important role when deciding which standards each country is going to follow. The general decision profile for the American continent is shown in Figure 1.8

Generally speaking, some areas can be identified for the America's energy efficiency legislation:

North America region (in yellow) based on U.S. DOE methodology, measuring water and energy consumption (with some slight differences). This region includes countries that have recognized laboratories and similar certification processes: Canada, US, Mexico, Ecuador and Colombia.

South America region (in dark blue) based on the international IEC methodology. This region includes Argentina, Brazil, Chile, Paraguay and Uruguay.

Central America region (in white) where there are several schemes in place since there are countries under CB-scheme (Worldwide System for Conformity Testing and Certification of Electrotechnical Equipment and Components (IECEE)) or that have no evaluation infrastructure in place but accept the certificates from other countries based on Trade agreements. Examples are Guatemala, Honduras, Belize, El Salvador and Nicaragua.

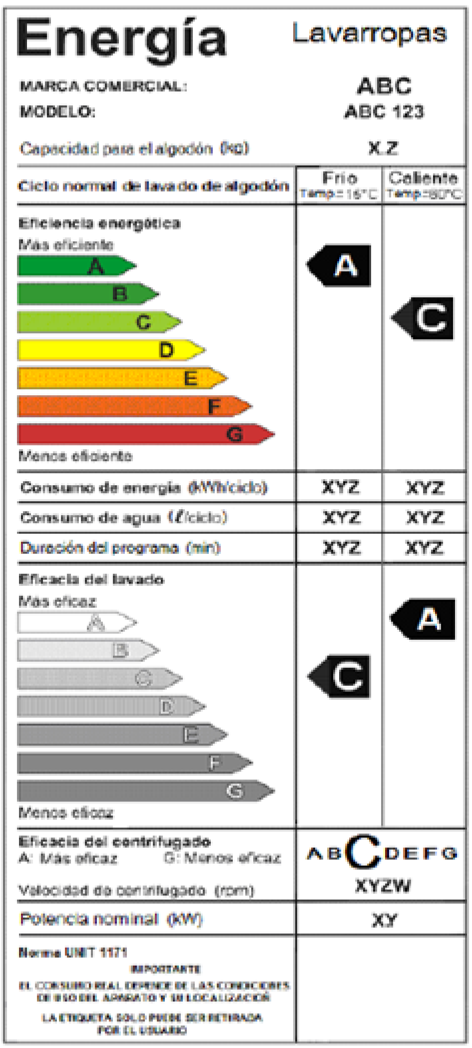


Figure 1.7: Labelling examples in Latin America (left: Argentina & Uruguay; top right: Brazil; bottom right: Mexico)

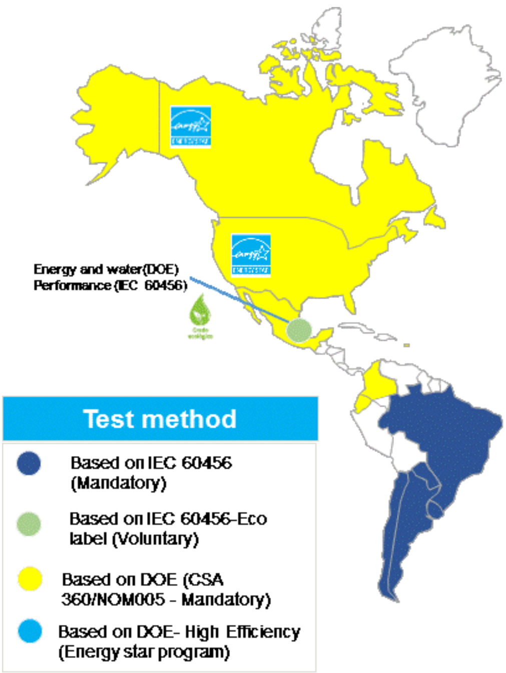


Figure 1.8: Energy efficiency Washing Machine Standards in (Latin) America

Open markets: several methodologies are suitable to be approved for commercialization. Example of this could be Costa Rica, which has no testing capabilities and due to Free Trade Agreements the country will accept Energy Efficiency certificates from US, Mexico, Europe and so on.

Venezuela: regulations are particular for the country.

However for each group (even within members of each group we have differences) there are some differences on which parameters are included in the standards, as shown in

Table 1.23.

Table 1.23: Washing machine energy efficiency comparison in Latin America

	DOE based	IEC 60456 based and used edition (ed)	
Countries included	Mexico, Central America, Colombia	South America Argentina 4th ed Uruguay 4th ed Brazil 3rd ed Chile 5th ed	Mexico 5th ed (Eco label only)
Parameters included	MEF (no standby) WF (only for Eco label in Mexico)	Washing performance Cotton 20 ° cycle, Cotton 40 ° cycle (Argentina only)	Washing performance Cotton 20 ° cycle
Semi-automatic Washing Machine included	Yes	Yes (except Chile)	No
Product Qualification	Compliance value	A to G range	Compliance value
Exceptions		Brazil test also WM w/heater inc Uruguay use 15° water intake	Only report washing efficiency

In general, automatic washing machines limits do not differentiate between horizontal axis (HA) versus vertical axis (VA) machines. Of course on labelling it is clearly stated which type of machine is evaluated so the consumer will have the information.

Future standardisation in LATAM

South America countries have a common standardization body as part of Mercosur Trade agreement. Copant, the Panamerican Standards Commission approved last year the publication of an Energy efficiency Washing Machine labelling where the established test method is the IEC 60456 5th edition.

It is expected that in the near future all the region will be harmonized on the same edition.

1.2.5.7. Other world regions and/or countries

Ecofys (2014) has conducted a comprehensive study ("Impacts of the EU's Ecodesign and Energy/Tyre Labelling Legislation on Third Jurisdictions") gathering considerable detailed information on equipment energy efficiency standards and labelling programmes in place in forty eight countries outside the EU. According to this study, for washing machines following countries have Minimum Energy Performance Standards or comparative labelling schemes, besides those listed in the sections before:

Table 1.24: Third-country legislation (Minimum Energy Performance Standards or comparative labels) for washing machines and washer-dryers; source: Ecofys (2014)

Country	Minimum Energy Performance Standards	Comparative Labels (e.g. energy and environmental labels)
Egypt	Mandatory Minimum Energy Performance Standards for clothes washers; status: under revision (2006)	Mandatory Comparative Label for clothes washers; status: entered into force – no activity (2003)
Jordan	Mandatory Minimum Energy Performance Standards for clothes washers; status: under development (2014)	Mandatory Comparative Label for clothes washers; status: development completed – under revision (2012)
	---	Mandatory Comparative Label for washer-dryer; status: development completed - pending implementation (2013)
Russia	Voluntary Minimum Energy Performance Standards for clothes washers; status: under consideration for development	Comparative label for clothes washers; status: ---
South Africa	Mandatory Minimum Energy Performance Standard for washing machines; status: under development	Voluntary Comparative Label for clothes washers; status: adopted (2012)
	---	Voluntary Comparative Label for washer-dryer; status: adopted (2012)
Tunisia	---	Mandatory Comparative Label for clothes washers; status: under consideration for development
Turkey	Mandatory Minimum Energy Performance Standards for clothes washers; status: entered into force – no activity – (2011)	Mandatory Comparative Label for clothes washers; status: entered into force – no activity (2012)
	---	Mandatory Comparative Label for washer-dryer; status: entered into force – no activity (2002)

1.2.6. Testing and market surveillance

The project Atlete II was an EU-funded project (see www.atlete.eu) with the main objective to check the compliance of washing machines with the relevant provisions of EU Energy Labelling and Ecodesign legislation. Market surveillance authorities (MSA) were involved in its execution. Specific results concerning market distribution of appliances are presented in Chapter 3. Below, some conclusions related to the testing and market surveillance are presented:

- A Pan-EU compliance verification exercise can be carried out in a systematic, effective and cost-efficient way.
- An effective, accurate and timely procedure for compliance verification has been defined that creates a stable framework for all stakeholders and supports market surveillance by national MSA.
- The project has re-assessed the importance and need for Step 2 in the EU verification procedure for Energy Label and Ecodesign legislation.
- Laboratory testing is re-confirmed as both technically feasible and economically sustainable. It also, paradoxically, appears to be the “easiest” phase of the entire procedure.

In addition, the project has offered MSAs qualified and independent product checks and test results, reducing the burden and the use of the MSAs’ own resources for national market surveillance actions. The project has shown that pan-European check activities can help tackle (and in most cases resolve through voluntary remedy actions) non-compliance cases before delivering the final results to each MSA. These checks contribute to keep alive the awareness of manufacturers concerning the fact that their products can be controlled (although not sanctioned) by third parties.

The involvement of laboratories has been fundamental for the project. It has helped improving the template for the reporting of results, from the first draft to the final version, and for the discussion about the identification of e.g. standard programmes on the front of a machine. In addition, laboratories recognized the importance of meeting each other, exchanging experiences and commenting on the test results and elements of the regulations which were unclear.

1.2.7. Summary

Test standards should produce reliable, repeatable and reproducible results. These include delivering data for the purpose of assigning an Energy Label, and checking if Ecodesign requirements are met. In addition, declarations require verification.

Standardisation bodies and their technical working groups (e.g. CLC/TC 59X/WG 1 for washing machines) are continually working and implementing technical updates to ensure the relevance and appropriateness of test standards and to ensure a level playing field for manufacturers. Some of the testing procedures currently in standards (like low power modes) require currently a testing effort that might not be in line with their added value. Other procedures (like textile care / gentleness of action) are relevant but not used and other relevant parameters (like rinsing performance) are currently missing.

There will always be conflict between the need for reproducibility on the one side, which requires specific test conditions to be met, and the higher variability of user conditions in real life on the other side. These differences will always exist. However, it is neither possible nor necessary for standards to mirror exactly real-life conditions.

Regulation 1061/2010 on energy labelling and Regulation 1015/2010 on ecodesign already foresee an update mechanism 'in light of technological progress' and mention specifically an assessment of verification tolerances, ecodesign requirements on rinsing and spin-drying efficiency and the potential for hot water inlet.

The actual status, need for future standardisation, and international comparability of requirements and standards have also been recently assessed in two studies:

- The Omnibus review. The "Omnibus" Review Study on Cold Appliances, Washing Machines, Dishwashers, Washer-dryers, Lighting, Set-top Boxes and Pumps (VHK 2014 / Status 2013);
- CLASP/ The Policy Partners (2014) Improving Global Comparability of Appliance Energy Efficiency Standards and Labels.

As the market of washing machines and washer-dryers is international, proposals for changes in standards need to check how this will affect trade and international comparability. Differences in standards may introduce competitive advantage to producers or sellers of specific regions. The data presented in this chapter illustrates that many countries worldwide have implemented energy and other environmental requirements for washing machines. Some of them include elements not currently addressed in EU Regulations, e.g.:

- The US Department of Energy introduced a 5% bonus in the energy star regulation if the product has smart grid connection capability.
- The Australian standardisation body has announced its willingness to adopt the IEC rinsing method, which is still under development. The development of a new rinsing method is under way in the US and in the EU (AHAM will adopt a new standard soon; CENELEC is checking whether the same principle can be implemented for EN60456 under the mandate from the EC).

The study by CLASP (2014) concludes that 'for clothes washers, EU and US MEPS values appear virtually the same'; however, they are not comparable. EU energy tests include a fairly stringent test of wash performance, whereas US tests do not. Wash performance requirements have a substantial impact on energy demand, and since it is not known how wash performance compares between regions, resulting energy performance data may not represent the same functionality".

1.3. Legislation, standards and related activities with regard to substances, material and resource efficiency and end-of-life

The Ecodesign Directive 2009/125/EC in Annex I, Part 1.3 defines parameters which must be used, as appropriate, and supplemented by others, where necessary, for evaluating the potential for improving the environmental aspects of products. According to (European Parliament 2009a), this includes inter alia

- *Ease for reuse and recycling as expressed through: number of materials and components used, use of standard components, time necessary for disassembly, complexity of tools necessary for disassembly, use of component and material coding standards for the identification of components and materials suitable for reuse and recycling (including marking of plastic parts in accordance with ISO standards), use of easily recyclable materials, easy access to valuable and other recyclable components and materials; easy access to components and materials containing hazardous substances;*
- *Incorporation of used components;*
- *Avoidance of technical solutions detrimental to reuse and recycling of components and whole appliances;*

This section identifies and provides an overview of legislation, standards, and labels in the EU, Member States and at third-country level for the products in scope with focus on resources use and material efficiency.

1.3.1. Legislation on hazardous materials, material resource efficiency and end-of-life aspects

<u>NOTE</u>: This section only presents material efficiency - related legislation for washing machines and washer-dryers. Legislation related to ecodesign, energy efficiency and other performance criteria are presented separately in section 1.2.1.

Table 1.25 shows an overview of the European Directives and Regulation discussed in this section.

Table 1.25: Overview of the European directives and regulation related to use of substances, material and resource efficiency

European Directive or regulation	
RoHS 2 Directive	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment
WEEE Directive	Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)
REACH Regulation	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
CLP Regulation	Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
F-Gas Regulation	Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006
Detergent Regulation	Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents Regulation (EU) No 259/2012 of the European Parliament and of the Council of 14 March 2012 amending Regulation (EC) No 648/2004 as regards the use of phosphates, other phosphorus compounds in laundry and dishwasher detergents

1.3.1.1. EU RoHS Directive 2011/65/EU

The Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2011/65/EU (commonly referred to as RoHS 2) restricts the use of certain hazardous substances in electrical and electronic equipment to be sold in the EU (European Parliament 2011).

Directive 2011/65/EU replaces Directive 2002/95/EC (commonly referred to as RoHS 1), which entered into force on the 1st of July 2006. RoHS 2 entered into force on 21 July 2011 and has led to the repeal of RoHS 1 on the 3rd of January 2013. The RoHS-Directive **restricts the presence of the substances** listed in Annex II of the Directive, currently including the following substances:

- Lead
- Mercury
- Cadmium
- Hexavalent chromium
- Polybrominated biphenyls (PBB)

- Polybrominated diphenyl ether (PDBE)

The RoHS-Directive limits the presence of these substances in electrical and electronic equipment to be placed on the Union market, to concentrations not exceeding 0.1% by weight of homogenous material. For Cadmium the threshold level is at 0.01%.

Exemptions from these provisions are only possible, provided that the availability of an exemption does not weaken the environmental and health protection afforded by Regulation 1907/2006/EC (commonly referred to as REACH, cf. section 1.3.1.3), and that at least one of the following conditions is fulfilled:

- Substitution is not possible from a scientific and technical point of view;
- The reliability of substitutes is not ensured;
- The negative environmental, health and consumer safety impacts caused by substitution are likely to outweigh the benefits;

Decisions on exemptions and on their duration may also take into consideration the following aspects, though it is understood that these do not suffice on their own to justify an exemption:

- The availability of substitutes;
- Socio-economic impacts of substitution;
- Impacts on innovation; and
- Life-cycle thinking on the overall impact of an exemption;

Applications for granting, renewing or revoking exemptions have to be submitted to the European Commission in accordance with Annex V of the Directive, are required to include among others a justification including comprehensive information on the substance-application and possible substitutes. All applications undergo a technical analysis as well as a stakeholder consultation.

In general, applications exempted from the restriction are listed in Annex III of the RoHS Directive. As most of the exemptions are very specific, it is not possible to generalise certain topics for household appliances. Possible exemptions might be for example lead in various alloys (steal, copper, aluminium) probably being relevant for housings, though depending on the applied housing materials, as well as other components for which such alloys are in use. Theoretically, another example of exemptions might be CFL backlight systems if still being used in displays of washing machines/washer dryers, although it is assumed that most displays have been shifted to LED backlight systems.

During the preparation of RoHS 2, an **amendment of the list of restricted substances** in Annex II was discussed. Preparatory studies, in particular the review of restricted substances under RoHS (Groß et al. 2008), revealed that further relevant hazardous substances are used in EEE. According to Recital 10 of RoHS 2 in particular the risks to human health and the environment arising from the use of the following substances were to be considered as a priority for the first review:

- Hexabromocyclododecane (HBCDD)
- Bis (2- ethylhexyl) phthalate (DEHP)
- Butyl benzyl phthalate (BBP)
- Dibutyl phthalate (DBP)

RoHS 2 sets the rules for amending the list of restricted substances in Article 6(1). A review and amendment of Annex II was to be performed and considered by the Commission before 22 July 2014, and is to be considered periodically thereafter. In preparation of the 2014 review, the Austrian Umweltbundesamt GmbH (AUBA) conducted a first study in 2012-2014. Among others, the outcomes of this study included a **24 entry priority substance list** (see Table 1.26), and detailed dossiers for the four substances prioritised already in RoHS 2, Recital 10. Further details can be found under this link:http://www.umweltbundesamt.at/rohs2.

Table 1.26: Substances with priority as indicated by the Austrian Umweltbundesamt GmbH (excluding the four substances listed in Directive 2011/65/EU, Recital 10)

Substances	CAS-No	EC-No
Highest priority		
Diisobutylphthalate (DIBP)*	84-69-5	201-553-2
Tris(2-chloroethyl) phosphate (TCEP)	115-96-8	204-118-5
Dibromo-neopentyl-glycol	3296-90-0	221-967-7
2,3-dibromo-1-propanol (Dibromo-propanol)	96-13-9	202-480-9
Second highest priority		
Antimontrioxid	1309-64-4	215-175-0
Diethyl phthalate (DEP)	84-66-2	201-550-6
Tetrabromobisphenol A	79-94-7	201-236-9
MCCP (medium chained chlorinated paraffins), C14 – C17: alkanes, C14-17, chloro;	85535-85-9	287-477-0
Third highest priority		
Polyvinylchloride (PVC)	9002-86-2	-
Fourth highest priority		
Nickel sulphate	7786-81-4	232-104-9
Nickel bis(sulfamidate); Nickel sulfamate	13770-89-3	237-396-1
Beryllium metal	7440-41-7	231-150-7
Beryllium oxide (BeO)	1304-56-9	215-133-1
Indium phosphide	22398-80-7	244-959-5
Fifth highest priority		
Di-arsenic pentoxide; (i.e. Arsenic pentoxide; Arsenic oxide)	1303-28-2	215-116-9
Di-arsenic trioxide	1327-53-3	215-481-4
Cobalt dichloride	7646-79-9	231-589-4
Cobalt sulphate	10124-43-3	233-334-2
Sixth highest priority		
Cobalt metal	7440-48-4	231-158-0
4-Nonylphenol (branched and linear)	84852-15-3 25154-52-3	284-325-5 246-672-0

* This substance was reviewed by Oeko-Institut; for more information, please refer to the Substance specific Dossier compiled by Gensch et al. (2014).

AUBA recommended adding HBCDD (brominated flame retardant), DEHP, BBP and DBP (three phthalate plasticisers), to Annex II of RoHS. The study also showed that in some cases a selective ban of a substance from a larger substance group might drive industry towards the use of a problematic alternative from the very same group (e.g. substituting one phthalate plasticiser for another). An assessment of the phthalate diisobutylphthalat (DIBP) was thus carried out by Öko-Institut (Gensch et al. 2014), recommending its addition to Annex II together with the other three phthalates. Decisions as to the addition of these five substances to Annex II of RoHS 2 are still pending. The 24 entry priority substance list prepared by AUBA (excluding the 5 substances listed above) has also been developed by Öko-Institut to include quantitative usage data and is understood to provide a further basis for the EU COM to assess the need to amend the substances listed in Annex II in the future.

Once new substances are added to Annex II of RoHS, it is assumed that a transition period shall be provided for stakeholders to establish compliance of their products and components with the consequential new RoHS substance restrictions. Where substitutes are available, this shall mean that such alternatives are to be implemented in the redesign and manufacture of EEE to be made available on the Union market by the end of the transition period. Where substitutes are not sufficiently developed, exemptions may be applied for, on the basis of the criteria listed above.

Dalhammar et al. (2014) see interlinkages between RoHS and the Ecodesign Directive; the latter might complement the rules in the RoHS Directive through setting additional rules for chemicals for certain product groups when this would be required to stimulate recycling and contribute to cleaner materials streams. However, this might probably require first developing methodologies within the MEErP.

1.3.1.2. EU WEEE Directive 2012/19/EU

The Directive on waste electrical and electronic equipment (WEEE) 2012/19/EU (commonly referred to as WEEE-Directive) regulates the separate collection, treatment and recycling of end-of-life electrical and electronic equipment. The Directive 2012/19/EU replaces Directive 2002/96/EC of 27 January 2003, which entered into force on 1st of July 2006. Amongst others, Directive 2012/19/EU requires member states to achieve quantitative collection targets (e.g. 65% of the average weight of EEE placed on the market in the three preceding years). It also requires Member States to ensure that producers provide for the financing of the collection, treatment, recovery and environmentally sound disposal of WEEE (Article 12).

The WEEE-Directive classifies EEE in various categories. In this system, household washing machines and washer-dryers are classified under category 1 “Large household appliances”. Nevertheless, this classification is under transition and will follow a new system from the 15th of August 2018 onwards. Under this new system, washing machines and washer-dryers might not be classified in one single category, but instead fall under the following of the six new categories:

- Category 4: Large equipment (any external dimension more than 50 cm); this category will generally apply to household washing machines and washer-dryers;
- Category 5: Small equipment (no external dimension more than 50 cm); this category might apply to few very small washing machines or washer-dryers;
- Category 1: Temperature exchange equipment; this category might apply to washer-dryers and washing machines with heat pumps;
- Category 2: Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2; this category might apply to washing machines and washer-dryers in case of having a large control panel.

Annex V of the Directive also contains minimum targets for recovery and recycling. For the initial category 1 equipment (large household appliances), these targets were 80% for recovery and 75% for recycling until 14^{th} August 2015. Since 15^{th} of August 2015, these targets have been raised to 85% for recovery and 80% for recycling. From 15^{th} August 2018, the targets are split to the new categories: 85% recovery and 80% recycling for categories 1 and 4; 80% recovery and 70% recycling for category 2, and 75% recovery and 55% recycling for category 5.

Furthermore, Annex VII of the Directive specifies substances, mixtures and components that have to be removed as a minimum from any collected WEEE for selective treatment. Regarding household washing machines and washer-dryers, the following components might be of relevance:

- Today's appliances < 20 years old:
    - Printed circuit boards of devices if the surface of the printed circuit board is greater than 10 square centimetres
    - Plastic containing brominated flame retardants: enclosures of power electronics, and electronic components like casting compound of transformers, capacitors and PCBs contain brominated flame retardants (e.g. Tetrabrombisphenyl A, TBBA).
    - Gas discharge lamps: might be in backlight units of LCD control panels, if not realized with LED
    - External electric cables
    - Components containing refractory ceramic fibres as described in Commission Directive 97/69/EC of 5 December 1997 adapting to technical progress for the 23rd time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances: Theoretically these might be in insulation materials of large household appliances; in general, however, they are made of bitumen sheets.
    - Chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC) or hydrofluorocarbons (HFC), hydrocarbons (HC): washing machines and washer-dryers with heat pump
- Future appliances:
    - Liquid crystal displays (together with their casing where appropriate) of a surface greater than 100 square centimetres and all those back-lighted with gas discharge lamps: today's control panel displays are slightly smaller than 100 cm^2
- Possibly in historical appliances > 20 years old:
    - Polychlorinated biphenyls (PCB) containing capacitors in accordance with Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT): might be found in capacitors of motors
    - Mercury containing components, such as switches or backlighting lamps: might be found in fill level switches
    - Asbestos waste and components which contain asbestos: might be in the ducts of heating elements
    - Electrolyte capacitors containing substances of concern (height > 25 mm, diameter > 25 mm or proportionately similar volume): might be found in capacitors of motors

Dalhammar et al. (2014) see interlinkages between WEEE and the Ecodesign Directive; the latter might complement the horizontal rules in the WEEE Directive through implementing measures for a design of products that better enables recycling of certain components and materials. In this context, section (11) of the WEEE Directive 2012/19/EU clearly states "*Ecodesign requirements facilitating the re-use, dismantling and recovery of WEEE should be laid down in the framework of measures implementing Directive 2009/125/EC. In order to optimise re-use and recovery through product design, the whole life cycle of the product should be taken into account.*"

1.3.1.3. EU REACH Regulation 1907/2006/EC

The European chemicals regulation REACH 1907/2006/EC entered into force on 1st of June 2007. Under the REACH Regulation, certain substances that may have serious and often irreversible effects on human health and the environment can be identified as Substances of Very High Concern (SVHCs). If identified, the substance is added to the Candidate List, which includes candidate substances for possible inclusion in the Authorisation List (Annex XIV). Those SVHC that are included in Annex XIV become finally subject to authorisation. By this procedure REACH aims at ensuring that the risks resulting from the use of SVHCs are controlled and that the substances are replaced where possible.

In this regard, REACH also introduced new obligations concerning general information requirements on substances in articles. Producers and importers of articles that contain substances of very high concern (SVHC) included in the candidate list, will be required to notify these to the Agency (ECHA) if both of the following conditions are met:

- The substance is present in those articles in quantities totalling over 1 t/y per producer or importer;
- The substance is present in those articles above a concentration of 0.1% weight by weight (w/w).

Notification will not be required in case the SVHC has already been registered for this use by any other registrant (Article 7(6)), or exposure to humans or environment can be excluded (Article 7(3)).

In addition, Article 33(1) requires producers and importers of articles containing more than 0.1% w/w of an SVHC included in the candidate list, to provide sufficient information to allow safe handling and use of the article to its recipients. As a minimum, the name of the substance is to be communicated.

The provisions of Article 33(1) apply regardless of the total amount of the SVHC used by that actor (no tonnage threshold) and regardless of a registration of that use. Furthermore, this information has to be communicated to consumers, on request, free of charge and within 45 days (Article 33(2)).

The above mentioned Candidate list is updated regularly (two to three times a year). At present (April 2015), 161 substances are on the list. Several of these substances can be present in household washing machines and washer-dryers, e.g. plasticisers in seals.

Dalhammar et al. (2014) see interlinkages between REACH and the Ecodesign Directive: Recyclers are not included as stakeholders that have a right to information about chemicals in articles in REACH Art. 33. As both the WEEE and REACH rules are sometimes considered inadequate in providing the information on toxic components to recyclers needed for improved recycling. This could be for example identification of chemicals that can be a barrier to recycling. Ecodesign implementing measures could, when possible, address such chemicals through banning or setting limits for their content. Another option would be to mandate information about the content through implementing measures; this information might then be used e.g. in public purchasing schemes to reward front-runners, or by recyclers in some cases. (Dalhammar et al. 2014)

1.3.1.4. EU CLP Regulation 1272/2008/EC

The Regulation (EC) No 1272/2008 of the European Parliament and the Council of 16 December 2008 on the classification and packaging of substances and mixtures entered into force on 20 January 2009.

The purpose of the so called CLP-Regulation is to identify hazardous chemicals and to inform their users about particular threats with the help of standard symbols and phrases on the packaging labels and through safety data sheets. The purpose of the globally harmonised system (UN-GHS) is to make the level of protection of human health and the environment more uniform, transparent and comparable as well as to simplify free movement of chemical substances, mixtures and certain specific articles within the European Union.

Substances had to be classified until 1 December 2010 pursuant to Directive 67/548/EEC and mixtures until 1 June 2015 pursuant to Directive 1999/45/EC. Differing from this provision, the classification, labelling and packaging of substances and preparation may already be used before 1 December 2010 and 1 June 2015 in accordance with the provisions of the CLP/GHS-Regulation. After these dates the provisions of the CLP-Regulation are mandatory. The REACH-Regulation (cf. section 1.3.1.3) is complemented by the CLP-Regulation.

1.3.1.5. EU F-Gas Regulation 517/2014/EU

The revised F-Gas Regulation (EU) No 517/2014 (European Parliament 2014c) has been published on 20 May 2014 in the Official Journal of the European Union. The text, which repeals the 2006-F-Gas Regulation, applies since 2015. The objective of this Regulation is to protect the environment by reducing emissions of fluorinated greenhouse gases.

This regulation applies to washing machines and washer-dryers in case they are using a heat pump system based on fluorinated hydrocarbons like the frequently applied refrigerant R134a. Accordingly, this regulation:

- establishes rules on containment, use, recovery and destruction of fluorinated greenhouse gases, and on related ancillary measures;
- imposes conditions on the placing on the market of specific products and equipment that contain, or whose functioning relies upon, fluorinated greenhouse gases;
- imposes conditions on specific uses of fluorinated greenhouse gases; and
- establishes quantitative limits for the placing on the market of hydrofluorocarbons.

Inter alia, with Article 12 of the regulation, there is a requirement that products and equipment that contain, or whose functioning relies upon, fluorinated greenhouse gases shall not be placed on the market unless they are labelled. The label required shall indicate the following information:

- a reference that the product or equipment contains fluorinated greenhouse gases or that its functioning relies upon such gases;
- the accepted industry designation for the fluorinated greenhouse gases concerned or, if no such designation is available, the chemical name;
- from 1 January 2017, the quantity expressed in weight and in CO_2-equivalent of fluorinated greenhouse gases contained in the product or equipment, or the quantity of fluorinated greenhouse gases for which the equipment is designed, and the global warming potential of those gases.

According to the regulation, the label shall be clearly readable and indelible and shall be placed either: (a) adjacent to the service ports for charging or recovering the fluorinated greenhouse gas; or (b) on that part of the product or equipment that contains the fluorinated greenhouse gas.

Other than e.g. for cooling and freezing appliances, where the heat pump is located externally at the backside of the appliance, i.e. a label near to that heat pump is clearly visible for recyclers, for washing machines and washer-dryers the heat pumps are covered by the housing of the appliance, so that a label near to the heat pump itself would only be visible by recyclers after removing the enclosure. At the 2nd TWG meeting, industry stakeholders confirmed that there is a different practice where to place that label; whereas some manufacturers place it near to the heat pump inside the appliance, others do it at the outside directly on the housing.

Further, the regulation specifies certain types of equipment to be banned from being placed on the EU market from certain dates. Washing machines and washer-dryers with heat pump technology applied are not listed under the prohibited products. Further, according to AREA (2014) bans will not apply to Ecodesign equipment that has less lifecycle CO_2-equivalent emissions than equivalent equipment that meets Ecodesign requirements and does not contain HFCs. The conditions for such an exception would be as follows (AREA 2014):

- The equipment falls under Ecodesign requirements, i.e. an Ecodesign measure has been adopted for the equipment in question.
- It is explicitly established in the Ecodesign that the equipment, due to higher energy efficiency, has lifecycle CO_2-equivalent emissions lower than equivalent equipment which meets all relevant Ecodesign requirements and does not contain HFCs. However, currently none of the adopted ecodesign standards contain such statement. Thus, for the revision of the Ecodesign regulation for washing machines and washer-dryers it will be decided based on the results of environmental analysis in Tasks 5 and 6 if such a statement should be included to exempt heat pump WM and WD from possible future banning of the market.

Some stakeholders have pointed out that the F-gas Regulation 517/2014 established constraints for the choice of cooling agents that might potentially be used in heat pumps part of washing machines/washer-dryers.

The new regulation also includes a phase-down scheme according to which the quantity of HFCs placed on the EU market will gradually decrease between 2015 and 2030. Although the new regulation does not name the alternative refrigerants, Ammonia (NH_3), Carbone Dioxide (CO_2), Hydrocarbons (HCs) and Hydrofluoroolefine (HFOs) are the main fluids affected. It is expected that the combination of the phase-down and the planned bans will result in an increase in use of alternative refrigerants and technologies to HFCs.

1.3.1.6. EU Detergents Regulation 648/2004/EC

EU detergents regulation 648/2004 (European Parliament 2004) stipulates the biodegradability of surfactants in detergents. The regulation introduced harmonized labelling requirements of detergents. The labelling comprises a labelling scheme on the packaging that includes the labelling of fragrance allergens. Besides, a detailed ingredient list has to be published at the internet. Manufacturers must hold additional information on the detergents such as ingredient datasheet and safety tests at the disposal of the Member States' competent authorities and medical personnel in cases of accidents.

The latest amendment of regulation 648/2004, regulation 259/2012 (European Parliament 2012b) concerned the limitations on the content of phosphates and of other phosphorus compounds in consumer laundry detergents. Phosphate acts as water-softeners and thereby prevents the deposition of lime scale; it dissolves grease and keep it suspended in the washing water. On the other hand, phosphates cause algae to grow at the expense of other aquatic life, which is commonly named eutrophication.

In consumer laundry detergents, the total phosphorous content limit is set at 0.5 grams in the detergent to be used in the main cycle of the washing process for a standard washing machine load (4.5 kg dry fabric for heavy-duty detergents and 2.5 kg dry fabric for low-duty detergents). The phosphate limitation was applicable by 30 June 2013. Many member states had already implemented measures to reduce phosphate in laundry detergents before 2013 (European Commission 2007).

As substitute to phosphate in laundry detergents zeolites (aluminosilicates) are used, mainly zeolite A; zeolite-based detergents need a higher concentration of polycarboxylates and phosphonates as additional water softener (co-builder) (European Commission 2007).

The European Chemical regulation No. 1907/2006 (REACH regulation, cf. section 1.3.1.3) stipulates the registration and evaluation of the substances in the detergents. Under REACH, manufacturers have to inform how the substance can be safely used, and they must communicate the risk management measures along the supply chain. The final detergents are considered mixtures under REACH. Also the Classification, Labelling and Packaging (CLP) regulation (cf. section 1.3.1.4) is applicable for detergents and their ingredients. The CLP regulation ensures that the hazards presented by chemicals are clearly communicated to workers and consumers in the European Union through classification and labelling of chemicals.

1.3.1.7. Other EU Ecodesign regulations with implemented resource efficiency criteria

There are some EU Ecodesign regulations not directly related to household washing machines and washer-dryers, but implementing material resource efficiency and end-of-life criteria which might serve as examples for the product groups in the scope of this study as well.

- EU Ecodesign Regulation 1194/2012/EU on directional lamps, light emitting diode lamps and related equipment
- EU Ecodesign Regulation 666/2013/EU on vacuum cleaners
- Draft EU Ecodesign Regulation on electronic displays
- Review of Regulation 327/2011 with regard to ecodesign requirements for fans
- Criteria are presented in detail in the Annex, section 8.1.

1.3.1.8. National legislation: France

Decree n° 2014-1482 of 9 December 2014 regarding information and supply requirements for spare parts which are essential for the use of a good

On 9 December 2014 the French government published a decree in France's Official Journal that puts into effect Article L111-3 of the Consumption Law (Code de la consommation, Version consolidée au 22 mars 2015, Art. L111-3). According to this article, French retailers will have to inform consumers about the availability of spare parts for products. The article requires manufacturers and importers to inform vendors how long spare parts that are essential for the use of a product will continue to be produced. This can be done either by specifying the period of availability or the final date. The vendor is then required to inform the buyer. The information is required to be displayed "in a visible manner" before a purchase is made and to be confirmed in writing after the purchase. Manufacturers will have to deliver the parts needed to make repairs to vendors or repair enterprises within two months. The rules apply to products placed on the market since March 2015 (French Government 2014).

Legislation against planned obsolescence

In France, the energy transition bill, which was passed by the national assembly on 22 July 2015, contains measures against programmed obsolescence. Article 99 introduces in the Code de la Consommation (Consumption Law), Art. L. 213-4-1, the following definition of planned obsolescence (Assemblé Nationale 2015):

"Programmed obsolescence is defined by each manoeuvre through which the lifetime of a good is knowingly reduced since its design stage, thereby limiting its usage time for business model reasons" (Assemblé Nationale 2015).

It is foreseen to penalize the fraud/ culprit with up to 2 years of imprisonment and a fine of up to 300,000 Euros or of 5% of the annual turnover of a company. Apart from that, it is foreseen to introduce voluntary consumer information from manufacturers on the life-time of a product.

> *« Art. L. 213-4-1.*
>
> *I. – L'obsolescence programmée se définit par l'ensemble des techniques par lesquelles un metteur sur le marché vise à réduire délibérément la durée de vie d'un produit pour en augmenter le taux de remplacement.*
>
> *II. – L'obsolescence programmée est punie d'une peine de deux ans d'emprisonnement et de 300 000 € d'amende.*
>
> *III. – Le montant de l'amende peut être porté, de manière proportionnée aux avantages tirés du manquement, à 5% du chiffre d'affaires moyen annuel, calculé sur les trois derniers chiffres d'affaires annuels connus à la date des faits.*

Further, a new Article L-110-1-2 paragraph II 1a shall be included into the environmental law (code de l'environnement), which defines as one target of the national waste management policy „to fight planned obsolescence of products by means of consumer information. Voluntary experiments may be conducted with a display of product lifetime in order to promote extended usage time of manufactured products by means of consumer information. They will allow putting in place standards shared by economic actors of industrial sectors who are concerned with the notion of lifetime".

1.3.2. Ecolabels and other voluntary schemes – focus on resource criteria

NOTE: This section only presents resource related criteria of European ecolabels existing for washing machines and washer-dryers. Energy and performance related criteria are presented separately in section 1.2.3.

1.3.2.1. Nordic countries: Nordic ecolabelling of white goods

In September 2014, version 5.0 of the Nordic Ecolabelling requirements for white goods (refrigerators and freezers, dishwashers, washing machines and tumble dryers) has been published, valid from 20 June 2013 to 30 June 2017. Gas-powered appliances and washer-dryers are not in the scope of this criteria document (Nordic Ecolabelling 2014).

The following resource related criteria apply to washing machines:

Table 1.27: Nordic ecolabelling resource related criteria for washing machines; source: Nordic Ecolabelling (2014)

Criteria category	Requirements
Manufacture – product requirements for washing machines	
Description of manufacturing process and materials	Summary of all parts (type, materials); manufacturing process including different stages, including production technology, cleaning technology for surface treatment and metal plating of parts; name and location of factories for final assembly of core components (e.g. drum, pipework etc.); subcontractors for production of core components and for surface treatment and metal plating
Chemical products, classification	List of chemicals used in final assembly; safety data sheets for the chemical products
Chemical substances	Certain substances prohibited to be actively added to the chemical products named in the criterion above (such as cleaning products, paints, lacquers, adhesives, sealants used in final assembly and surface treatment)

Criteria category	Requirements
Metal plating of parts	Metals may not be plated with cadmium, chromium, nickel, zinc or alloys of these. Exceptional cases are described as well as plating processes ensuring the greatest possible recovery of the chemical products.
Marking of plastic parts	Plastic parts that weight 50 grams or more must be marking in accordance with ISO 11469. (Cables and plastic parts with a smooth surface of less than 200 mm^2 are excluded from the requirement).
Flame retardants in plastic and rubber parts	Certain halogenated organic flame retardants and other flame retardants with certain risk phrases are not allowed to be added. An exemption from the latter requirement may be given for halogenated flame retardants in cases where these are required for electrical or fire safety reasons under the Low Voltage Directive 73/23/EEC or standard EN 60335-1; printed circuit boards PCBs; plastic and rubber parts weighing < 25 grams that are integral to electronic parts
Phthalates	Certain phthalates listed in the criteria document must not be added to plastic or rubber materials. The following are exempted from the requirement: Printed circuit boards PCBs; plastic and rubber parts weighing < 25 g that are integral to electronic parts
Antibacterial properties	Chemicals or additives (including nano materials such as silver ions, nano silver, nano gold and nano copper) that are added to create an antibacterial or disinfectant surface, in or on the product or to be released during the use of the product, must not be used.
Packaging	It must be possible to recycle or reuse the materials in the packaging and transport protection. Chlorine based plastics and biocide treated/impregnated timber must not be used in the packaging.
Waste	The manufacturer must sort different types of waste that arise from the production of the white good, for example glass waste, plastics and metals. A waste plan is to be included, listing waste fractions and a description of how the waste will be handled (e.g. recycling, landfill and incineration) and who will deal with the waste.
Requirements on customer information for washing machines	
Installation and user instructions for washing machines	Inter alia • Information on adaptions of detergent dosing necessary with regard to the water hardness, type of items, size and soiling of load
Warranties	The manufacturer has to provide a warranty that the washing machine will work for at least two years. The warranty is to apply from the day that the machine is delivered to the customer.
Replacement parts	The availability of replacement parts shall be guaranteed for 10 years from the time that production ceases.
Quality and regulatory requirements for washing machines (excerpt)	
Quality of the white good	The licensee must guarantee that the quality of the Nordic Ecolabelled washing machine is maintained throughout the validity period of the licence. Verification: Procedures for collating and, where necessary, dealing with claims and complaints regarding the quality of the Nordic Ecolabelled white goods.

1.3.2.2. Germany: Blue Angel Environmental Label for Household Washing Machines (RAL-UZ 137)

Basic criteria for the award of the German environmental label “Blue Angel” for household washing machines have been published in January 2013 and they will expire in December 2015.

The detailed resource related criteria are as follows (Ral gGmbH 2013b):

Spare Parts Provision

The applicant undertakes to make sure that the provision of spare parts for appliance repair is guaranteed for at least 10 years following the termination of production and that the customer is informed about this guaranteed availability of spare parts, e.g. by means of corresponding notes in the product manual.

Spare parts are those parts which, typically, may break down within the scope of the ordinary use of a product - whereas those parts which normally exceed the average life of the product are not to be considered as spare parts.

Also, the applicant undertakes to provide an after-sales services or hire a company to do on-site repair work at customer's premises. The product manual shall include information on the above requirements.

Material Requirements for the Plastics used in Housing and Housing Parts

The plastics must not contain as constituents any substances classified as

- carcinogenic in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/2008,
- mutagenic in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/2008
- toxic to reproduction in category 1 or 2 according to Table 3.2 of Annex VI to Regulation (EC) No 1272/2008
- being of very high concern for other reasons according to the criteria of Annex XIII to the REACH Regulation, provided that they have been included in the List (so-called "Candidate List) set up in accordance with REACH, Article 59, paragraph 1.

Halogenated polymers shall not be permitted. Neither may halogenated organic compounds be added as flame retardants. Moreover, no flame retardants may be added which are classified pursuant to Table 3.1 or 3.2 in Annex VI to Regulation (EC) 1272/2008 as very toxic to aquatic organisms with long-term adverse effect and assigned the Hazard Statement H 410 or Risk Statement R 50/53.

The following shall be exempt from this rule:

- Process-related, technically unavoidable impurities;
- Fluoroorganic additives (as, for example, anti-dripping agents) used to improve the physical properties of plastics, provided that they do not exceed 0.5 weight percent;
- Plastic parts less than 25 grams in mass.

Insulation Materials

If fibrous insulation materials are used, such as mineral, glass or rock wool, the applicant shall present a test report showing that the carcinogenicity index (C_I) of the products concerned is ≥ 40 and, hence, the material need not be classified as carcinogenic or suspected of causing cancer in accordance with the classification scheme of TRGS 905. Ceramic mineral fibres, i.e. glassy (silicate) fibres with an alkali metal oxide and earth alkali metal oxide content (Na_2O + K_2O+ CaO + MgO + BaO) of less than or equal to 18 weight percent may not be used.

Systems using Biocidal Silver

The use of systems using biocidal silver shall not be permitted.

Recyclable and Easy-to-Maintain Design

The appliance shall be so designed as to allow quick and easy disassembly with a view to facilitating repair and separation of valuable components and materials. This means that:

- It must be possible to separate the connections concerned by the use of ordinary tools and the points must be easily accessible,
- Plastics should consist of only one polymer or plastic parts greater than 25 g in mass must be marked according to ISO 11469 to allow for a sorting of plastics by type and
- Disassembly instructions must be made available to end-of-life recyclers or treatment facilities in order to recover as many valuable resources as possible.

Consumer Information with regard to resource efficiency

The energy, water and detergent consumption of washing machines greatly depends on the user behaviour (above all, by the user's way of loading and cleaning program selection). The operating instructions/product manual as well as manufacturer's website shall at least include the following basic user information/instructions:

- Instructions for cleaning and care of the appliance (e.g. regular cleaning of the lint filter, use of the detergent depending on soiling and water hardness);
- Information on the 10-year provision of spare parts as well as a contact address/phone number for information on where to obtain spare parts for the appliance.

1.3.2.3. Asian Ecolabel criteria with regard to material and resource efficiency

China (Mainland) – China Environmental Labelling

The following resource-related criteria are required by the China Environmental Labelling:

- The requirement on lifetime of machines shall comply with the provisions of GB/T 4288-2003 Grade A, requiring a minimum number of operating cycles/hours (depending on the type of machine).
- Environmental design of products:
  - Exchangeability, upgradeability design
  - The products should have modular structure.
  - Detachment and module exchange of the products should be done with conventional tools
  - Design of the product should take modular upgradeability and exchangeability into consideration
  - Plastics and metals used in the products should be 90% (by weight) recyclable technically.
  - In the product, independent plastic components should be made from one type of polymer (homopolymer or copolymer) or from recycled plastics
  - Products shall not contain metals that could not be separated from plastic (>25g)
  - Except plastic with <25g weight or <200mm^2 area, plastic components should be marked according to ISO 11469
- Regarding reuse and recycling, the manufacturers should recover and recycle waste products or components by free as well as reuse them.
- Hazardous substances

- Components which contain hazardous substances must be marked and easily be found and detached.
- Regarding plastic parts:
- Plastic parts weighing over 25g shall not contain lead or cadmium added artificially.
- Plastic parts weighing over 25g shall not contain flame retardants containing polybrominated biphenyls (PBBs), polybrominated diphenylethers (PBDEs) and chlorophenol
- Any plastic component exceeding 25g in products could contain maximum 5% organofluoride
- Any of the following softeners shall not be used in plastic component exceeding 25g (this requirement takes not account of recycled components): Diisononylphthalate (DINP); Di-n-octylphthalate (DNOP); Di(2-ethylhexyl)phthalate (DEHP); Diisodecylphthalate (DIDP); Butylbenzylphthalate (BBP); Dibutylphthalate (DBP)
- Packing materials: No CFCs, HCFC, 1,1,1-Trichloroethane or carbon tetrachloride shall be used in the production of packing materials and packing materials themselves.

- Production
  - CFCs, HCFC, 1,1,1-Trichloroethane or carbon tetrachloride is not allowed to be used in the production of products
  - CFCs, HCFC, 1,1,1-Trichloroethane or carbon tetrachloride is not allowed to be used as cleaning agent in producing process of printed circuit boards

China (Hong Kong) – The Hong Kong Green Label Scheme

The following resource-related criteria are required by the Hong Kong Green Label Scheme:

- Plastic parts shall have no lead or cadmium added by the manufacturer and plastic parts weighing over 25g shall not contain flame retardants containing polybrominated biphenyls (PBBs), polybrominated diphenylethers (PBDEs) and chloroparaffins with 10-13 carbon atoms per molecule and chlorine content of greater than 50% by weight.
- Surface Treatment: Paints shall not contain pigments or additives based on cadmium, lead, chromium, mercury or their compounds. Metals shall not be coated with cadmium, chromium, nickel or their compounds.
- The product shall have clear volumetric markings on the detergent dispenser to allow adjustment according to degree of soiling.
- Packing requirements: Packaging materials shall not contain chlorine-based plastics. General packaging requirements according to the Hong Kong labelling criteria for packaging materials.

China (Taiwan) – Green Mark

- The following resource-related criteria on materials, accessories and components are required by the Taiwanese Green Mark:For the product's surface coating material, its content of cadmium, lead, hexavalent chromium, and mercury shall be below the regulatory limits.
- The product shall meet the requirements of ISO 11469, in labelling all major plastic components weighing more than 25 g in prominent areas to indicate the composition code.

- Product's plastic parts weighing more than 25 g shall meet the following requirements:
- Content of cadmium, lead, hexavalent chromium and mercury shall be below the regulatory limit. If recycled materials are used in the plastic components, or safety regulations require the addition of glass fibre to the components located in the high temperature area, the lead content of such components shall be less than 20 ppm.
- Content of the following flame-retardants shall be below the regulatory limit:
- Polybrominated biphenyls (PBBs);
- Polybrominated diphenylethers (PBDEs): monobrominated diphenylether, dibrominated diphenylether, tribrominated diphenylether, tetrabrominated diphenylether, pentabrominated diphenylether, hexabrominated diphenylether, heptabrominated diphenylether, octabrominated diphenylether, nanobrominated diphenylether, decabrominated diphenylether; and
- Chloroparaffins with 10-13 carbon atoms per molecule and chlorine content of greater than 50% by weight.

Korea Ecolabel

The following resource-related criteria are required by the Korean Ecolabel:

- Use of chemical substances
- Recycling capability of product during the recycling or disposal stage of production process: Marking on each part of synthetic resin used for the product; material requirements for shock-absorbing materials in packaging; establishment, implementation and operation of a collecting and recycling system of products to be disposed

1.3.2.4. Ecolabels and other voluntary initiatives regarding the use of detergents

Ecolabel for detergents

The EU Ecolabel criteria for laundry detergents were adopted in 2011 (Commission Decision 2011/264/EU). The aim of these criteria documents was to promote laundry detergents that corresponded to the best 10-20% of the products available on the Community market in terms of environmental performance considering the whole life-cycle of production, use and disposal. These criteria are due to expire in 2016. Currently, these criteria are under review (for more details, cf. http://susproc.jrc.ec.europa.eu/detergents/index.html).

The "Preliminary report for the revision of ecological criteria for laundry detergents" building the basis for revision of European Ecolabel criteria for laundry detergents also provides an extensive overview of other European national as well as international voluntary labelling schemes and standards for laundry detergents including their detailed requirements, cf. (JRC IPTS 2014b), p. 18-46.

PEF process: Development of product environmental footprint category rules (PEFCRs) for "Heavy Duty Liquid Laundry Detergents (HDLLD) for Machine Wash"

The European Commission, working closely with the Joint Research Centre, has developed a proposed methodology for the calculation of the environmental footprint of products. In the spring of 2013, the Commission launched a call for pilots to test this methodology (over the period 2013-2016) with specific product sectors, in order to develop workable product environmental footprint category rules (PEFCRs), test the verification objectives and test different communication options. The International Association for Soaps, Detergents and Maintenance Products (A.I.S.E.) was selected in October 2013 to lead one of the pilot studies, focusing on household liquid laundry detergents.

The procedure for the development of a PEFCR according to the “Guidance for the implementation of the EU PEF during the EF pilot phase” considers a number of steps (A.I.S.E. [n.d.]):

- Definition of PEF product category and scope of the PEFCR documents
- Definition of the product “model” to analyse based on representative product(s)
- Screening of the Product Environmental Footprint (PEF)
- Draft PEFCR
- PEFCR supporting studies
- Confirmation of the benchmark(s) and determination of performance classes
- Final PEFCR

In April 2015, the Technical Secretariat of the PEF pilot project on “Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash” provided a first draft PEFCR together with a PEF screening report to stakeholders which can be downloaded under (European Commission 2015d).

The draft PEFCR (A.I.S.E. 2015) provides rules for the product category “Heavy Duty Liquid Laundry Detergents (HDLLD) for Machine Wash,” including 100% Liquid tablets (unit-dose). Other products such as “Light Duty Liquid Laundry Detergents”, “Powder Laundry Detergents” and “Powder Tablets” are part of the same category; but they were not chosen to be covered by the PEFCR, since the different product types vary in their functional units. However, A.I.S.E. plans to evaluate these other categories in order to assess if and how to apply the HDLLD PEFCR also to these categories.

According to A.I.S.E. (2015), the unit of analysis for the HDLLD Product Category was chosen to be the following (based on or in conformance with the Detergent Regulation (EC 648/2004)): “Wash 4.5 kg of dry fabric with the recommended dosage for

- a 4.5 kg load;
- normally soiled fabric;
- with a medium water hardness;
- in a 6 kg capacity machine wash at 75% loading."

The standard use scenario calculations were chosen to be based on the following data (A.I.S.E. 2015):

- Specific dosage recommended to the consumer (in ml): 75 ml
- Specific location of the consumer (country scale)
- Wash temperature: 40 °C
- Water consumption: 50 litres/wash
- Electricity consumption calculated based on the following formula developed by A.I.S.E. (“A.I.S.E. laundry energy model 2014”).

Equation 1.17:

Electricity consumption (kWh) = -0.1342 + 0.0193 x washing temperature (°C)

According to A.I.S.E. (2015), the equation is based on fundamental thermodynamic principles. In this assessment, the sum is made of the mechanical energy for a wash (drum rotation, spinning) plus the amount of energy consumed in the water heating cycle, as a function of temperature. The efficiency of the washing machine is neglected. Other parameters required for the calculation are the amount of water assumed to be heated (21 l/wash); the average seasonal inlet water temperature for a series of countries (average = 12.98 °C); the specific heat capacity of water.

Based on variations in consumer habits, the following parameters at the use stage can be varied: Product dosing; wash temperature; and water used by the machine.

This is the last update at May 2015. Additional information on the project can be found on: www.aise.eu/pef.

The A.I.S.E. Charter for Sustainable Cleaning

The A.I.S.E. Charter for Sustainable Cleaning (see: http://www.sustainable-cleaning.com/en.home.orb) is a voluntary initiative of the European cleaning and maintenance products industry established since 2005 sets high level standard to drive sustainable progress and standard in the detergent industry. More than 200 companies have joined the project, representing over 95% of the total production output for Europe. The Charter stipulates a set of Charter Sustainability Procedures for companies to implement in their management systems. It also defines a set of key performance indicators (KPIs) linked to the sustainability procedures and covering the whole lifecycle. Companies signed up to the Charter must report annually on these KPIs to measure their progress towards sustainable cleaning. The data collected is independently verified by an international audit firm.

Since 2010, the Charter also incorporates a product dimension, enabling companies to offer sustainability assurance for individual products, by complying with Charter Advanced Sustainability Profiles (ASPs). The Advanced Sustainability Profiles cover following aspects: Ingredient’s safety (if applicable), product formulation, packaging weight and recycled content as well as end-user information.

Products which meet the requirements of these ASPs may then use a differentiated 'ASP' logo on pack which signifies not only that the manufacturer is committed to certain sustainability processes at the manufacturing level, but also that the product itself meets certain advanced sustainability criteria. ASPs are specific to product categories. The following criteria for laundry detergents exist.

Criteria for household Solid Laundry Detergents (including tablets)

The following requirements in each of these domains (i.e. product formulation, packaging and end-use information) should be fulfilled in order to reach Advanced Sustainability Profile (ASP) status (A.I.S.E. 2012).

Table 1.28: Advanced Sustainability Profile (ASP) requirements for household Solid Laundry Detergents (including tablets); source: A.I.S.E. (2012)

Criteria category	Requirements
Product formulation	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage g/job(*): ≤ 75 g AND Dosage ml/job(*): ≤ 115 ml (*) job (i.e. washing cycle): following the Detergent Regulation EC 648/2004 the “standard washing machine loads are 4,5 kg dry fabric for heavy-duty detergents and 2,5 kg dry fabric for low-duty detergents”
Overall packaging weight	Total (primary + secondary but excluding tertiary) packaging g/job: ≤ 6.5 g
Board packaging –	Minimum requirement: ≥ 60%

Criteria category	Requirements
recycled content	OR Where 100% of the board used is certified made from fibre sourced from sustainable forests under an endorsed certification standard such as FSC, SFI or PEFC: no minimum.
Materials other than board – recycled content	No minimum, but any recycled plastic content may be excluded from the calculation of overall packaging weight per job
Wash temperature	Ability to wash at ≤ 30 °C indicated on pack
End user information	End-user info on-pack: Laundry Cleanright (former Washright) Panel Safe Use tips
Performance	Evidence has to be provided (in case of external verification organised by A.I.S.E.) that the product has been performance tested and reached a level acceptable to consumers consistent with claims made.

<u>Criteria for household Liquid Laundry Detergents Products</u>

The following requirements in each of these domains (i.e. product formulation, packaging and end-use information) should be fulfilled in order to reach Advanced Sustainability Profile (ASP) status (A.I.S.E. 2011b).

Table 1.29: Advanced Sustainability Profile (ASP) requirements for household Liquid Laundry Detergents; source: A.I.S.E. (2011b)

Criteria category	Requirements
Product formulation	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage ml/job*: ≤ 75 ml (*job: following the Detergent Regulation EC 648/2004 the "standard washing machine loads are 4,5 kg dry fabric for heavy-duty detergents and 2,5 kg dry fabric for low-duty detergents")
Packaging weight per job	Total (primary + secondary but excluding tertiary) packaging g/job: ≤ 7.0 g
Packaging – recycled content	Primary packaging: No minimum, but any recycled plastic content is excluded from calculation of packaging weight per job Secondary packaging: Board: ≥ 60%
Wash temperature	Ability to wash at ≤ 30 °C indicated on pack
End user information	End-user info on-pack: Washright panel or alternative
Performance	Evidence has to be provided (in case of external verification organised by A.I.S.E.) that the product has been performance tested and reached a level acceptable to consumers consistent with claims made.

<u>Criteria for household Fabric Conditioners</u>

The following requirements in each of these domains (i.e. product formulation, packaging and end-use information) should be fulfilled in order to reach Advanced Sustainability Profile (ASP) status (A.I.S.E. 2011a)

Table 1.30: Advanced Sustainability Profile (ASP) requirements for household Fabric Conditioners; source: A.I.S.E. (2011a)

Criteria category	Requirements
Product formulation	Pass successfully Environmental Safety Check (ESC) on all ingredients AND Dosage ml/job*: ≤ 35 ml (*job: following the Detergent Regulation EC 648/2004 the “standard washing machine loads are 4,5 kg dry fabric for heavy-duty detergents and 2,5 kg dry fabric for low-duty detergents”)
Packaging weight per job	Total (primary + secondary but excluding tertiary) packaging g/job: ≤ 4g
Packaging – recycled content	Primary packaging: No minimum, but any recycled plastic content is excluded from calculation of packaging weight per job Secondary packaging: Board: ≥ 60%
End user information	End-user info on-pack: Washright panel or alternative
Performance	Evidence has to be provided (in case of external verification organised by A.I.S.E.) that the product has been performance tested and reached a level acceptable to consumers consistent with claims made.

The products also carry on a voluntary basis some best use advice to promote the sustainable use of detergents (dosage, low temperature washing, filling of the machine etc.) whether laundry or automatic dishwashing detergents, which are featured on all packs of products (see: http://www.aise.eu/library/artwork.aspx; www.cleanright.eu).

A.I.S.E. "Product Resource Efficiency Projects”

All over Europe, powder detergents are becoming more concentrated, meaning that according to A.I.S.E. there are less raw materials and less packaging needed, which leads to less waste and reduced CO_2 emissions from transport. This voluntary industry initiative shall inform consumers to pay careful attention to the new dosing instructions, as they will need to use less detergent from now on for the same washing.

Product Resource Efficiency Project for Laundry Powder Detergents “PREP-P3”:

The product scope covers Heavy Duty Low Suds (HDLS) powder detergents used for household laundry. Participating companies commit:

- To compact / concentrate their laundry powder detergents, reaching a recommended dosage ≤75 g/wash and ≤115 ml/wash for a normal washing machine load, delivering at least the same performance as before
- To optimize the usage of packing materials, committing to a reduction by ensuring a high fill level, remaining at least overall in line with current filling levels. In particular, for individual rigid containers, effective filling ratios should continue to be no less than 70% of the maximum filling ratio
- To communicate to consumers about the correct use of compact products through on-pack communication, using the A.I.S.E. non-branded material

By end of June 2014 participating companies must have started "placing on the market" the new products with the on-pack communication material and must have stopped producing pre-PREP products.

Product Resource Efficiency Project for liquid Fabric Conditioners “PREP-FC”:

The product scope covers Liquid Fabric Conditioners (FC) used for household laundry. Participating companies commit:

- To concentrate their liquid Fabric Conditioners, reaching a recommended dosage ≤35 ml/wash for a normal washing machine load, delivering at least the same performance as before
- To optimize the usage of packing materials, committing to a reduction by ensuring a high fill level, at least overall in line with current filling levels
- To communicate to consumers about the correct use of concentrated products through on-pack communication, using the A.I.S.E. non-branded material

By end of June 2014 participating companies must have started "placing on the market" the new products with the on-pack communication material and must have stopped producing pre-PREP products.

Multi-stakeholder campaign called "I prefer 30°"

Recently, a specific multi-stakeholder campaign called "I prefer 30°" (for laundry low temperature washing) has been conducted, in a multi-stakeholder way, as it is opened to retailers, appliance manufacturers, fashion manufacturers/retailers, authorities, NGOs and other corporate supporters. The aim is to raise awareness of the benefits and support consumers in lowering their wash temperatures.

More information can be available via www.iprefer30.eu

1.3.3. Test standards for resource efficiency, durability and recyclability

NOTE: This section only presents resource related standards for washing machines and washer-dryers. Standards related to ecodesign, energy efficiency and other performance criteria are presented separately in section 1.2.2.

In the following, an overview of existing test standards and measurement methods for resource efficiency with regard to the aspects durability (maintenance, repair, re-use) and recyclability is given.

Table 1.31 shows an overview of the standards discussed in this section.

Table 1.31: Overview of the standards for resource efficiency, durability and recyclability

	Standards for resource efficiency, durability and recyclability
All	European Commission Mandate M/543 (2015) on horizontal requirements on material efficiency aspects for ecodesign and energy labelling
Durability	**Austrian standard ONR 192102:2014 on durable, repair-friendly designed electrical and electronic appliances**
	British PAS 141 re-use standard
	Durability test standards and measurement methods applied in EU ecodesign and ecolabel regulations International IEC 60068-1 ed7.0 Environmental testing
	Safety standards for products and components, indirectly addressing durability
Recyclability and	European Commission's Mandate M/518 for standardisation in the field of Waste Electrical and Electronic Equipment (WEEE)
	TS 50574-2: Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons - Part 2: Specification for de-pollution
	EN 50574: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons
	EN 50625 standard series: Collection, logistics & treatment requirements for WEEE

Dura	Austrian standard ONR 192102:2014 on durable, repair-friendly designed electrical and electronic appliances
	EN 50614 (under preparation): Requirements for the preparation for re-use of waste electrical and electronic equipment
	IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment
	IEC/TC 111 PT 62824: Guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design. ISO 11469: Plastics - Generic identification and marking of plastics products
	British standard BS 8887: Design for Manufacture, assembly, disassembly and end-of-life processing

Standardization requests are the mechanism by which the European Commission and the EFTA Secretariat request the European Standards Organizations (ESOs) to develop and adopt European standards in support of European policies and legislation. This mechanism evolves through sending a mandate for acceptance to CEN or CENELEC. The Technical Board Members are invited to accept (or reject) the given mandate, with or without restrictions, based on the Technical Body and CEN/CENELEC feedback. In case of acceptance of the mandate, the Technical Body is entrusted with the task of starting expected standardization work within CEN/CENELEC.

On a horizontal level, Mandate M/543 (European Commission 2015a) has as objective to develop generic standards, for any product group covered by Ecodesign, in support of ecodesign requirements related to material efficiency aspects. Standardization bodies CEN and CENELEC shall by end of 2018/ beginning 2019 develop generic methodologies and terminology related to material efficiency, such as durability, reusability, recyclability and recoverability. Related aspects, such as upgradeability, reversible disassembly time, end of life dismantling time, part mass or value, calculation of recycled and re-used content in products, or other relevant characteristics relevant for the product groups under consideration, were asked to be also included if appropriate.

CEN and CENELEC have established a joint technical committee (TC10), which has deployed 6 working groups to deal with the specific aspects of the mandate:

- WG1: Terminology
- WG2: Durability
- WG3: Reparability, upgradability and reusability
- WG4: Ability to Remanufacture
- WG5: Recyclability, recoverability and recycled content, including critical raw materials
- WG6: Provision of information, including critical raw materials

As of June 2017, the work is satisfactorily under development in all working groups

1.3.3.1. Durability

According to stakeholder feedback, there exist only few standards originally designed for durability purposes.

Austrian standard ONR 192102:2014 on durable, repair-friendly designed electrical and electronic appliances

ONR 192102:2014-10-01 with regard to a label of excellence for durable, repair-friendly designed electrical and electronic appliances replaces ONR 192102 from 2006.

This standard describes a label for repair-friendly designed appliances. Manufacturers of electrical and electronic equipment who intend to label their products have to test their products according to the requirements of ONR 192102 verifying compliance with a test report. According to Ricardo-AEA (2015), this standard suggests a labelling system with three levels of achievement (good, very good, excellent) based mostly upon reparability criteria. The standard includes ca. 40 criteria for white goods (such as dishwashers or washing machines), and 53 criteria for small electronics (brown goods). The aim is to consider reparability to ensure products are not discarded sooner than is necessary as the result of a fault or inability to repair a fault.

The 40 criteria for white goods are split into mandatory criteria and other criteria for which a certain scoring can be achieved. To comply, products have to fulfil all mandatory requirements and achieve a minimum number of scores for common criteria and for service documentation.

The types of requirements include criteria such as accessibility of components, ease of disassembly, use of standard components, achievable service life (at least 10 years for white goods), availability of spare parts (at least 10 years after the last production batch), facilitation of regular maintenance, and further service information (inter alia free access for all repair facilities (not only authorized repairers) to repair-specific information). Each requirement is underpinned with some examples of realisation; however, no specific testing procedures and techniques are detailed.

In 2015, a test was undertaken by RUSZ (Vienna, AT) to 28 washing machines. The result was that none of them passed the minimum criteria of the test and would be awarded with the label. The main reason of failing was the restriction of access to information which is essential for repair, for instance manuals for (reversible) disassembly, or access to diagnostics software.

British PAS 141 re-use standard

The PAS 141 specification has been developed by British Standards Institution (BSI) to increase the re-use of electrical and electronic equipment and to ensure that they are tested and repaired to a minimum level. The British non-for-profit company WRAP has developed a set of protocols based on industry experience highlighting tests and procedures to be carried out. The product protocols form a baseline for electrical product assessment and repair for re-use and can be used as a guideline to product assessment and testing (WRAP [n.d.]e).

The PAS 141 Protocol Product Guide for washing machines, tumble dryers and washer/dryers developed by WRAP describes a series of minimum tests that should be performed on those domestic-use appliances when the product shall be considered functional or fit for re-use for auditing purposes. No specific testing procedures and techniques are described as the protocol shall be applied as widely as possible (WRAP 2013c).

According to (WRAP 2013c), the PAS 141 protocol refers only to domestic-use machines that use water as the primary cleaning solution and includes top- and front-loading washing machines, washer/dryers and tumble dryers, as opposed to dry cleaning machines (which use alternative cleaning fluids) or ultrasonic cleaners. It excludes twin-tub machines, which are rarely available.

The following components of a washing machine, tumble dryer or washer/dryer shall undergo a visual inspection, safety or function test:

Table 1.32: PAS 141 Protocol Product Guide for washing machines, tumble dryers and washer/dryers: source: adapted (WRAP 2013c))

Component	Test
Hoses, trims, connector, seals	Visual inspection of condition and for damage
Door or lid hinges and handles and soap trays	Visual inspection of condition
Feet / wheels	Visual inspection of absence or damage

Component	Test
Knobs, switches, and fixings	Visual inspection of absence or damage
Cabinet and back panel	Visual inspection of condition
Plug and lead cables	Safety test regarding condition and connection
Motor	Function test
Drum / spider	Function test of bearings (in place and secure)
Door - locking and unlocking	Function test
Hoses, connectors, seals	Function test for leakage
Programmes	Function test
Internal components, pressure switches, modules and wiring	Presence and function test
Thermostat and heating element	Function test
Detergent dispenser	Function test
Rinse cycle, drain operation, spin operation, drying cycle (including sensor drying, if available)	Function test
Delayed start	Function test
Outlet pipe, sump hose	Function test regarding damage or leaks
Filter	Presence and function test
Timer	Function test
Condenser system	Function test

Durability test standards and measurement methods applied in EU Ecodesign and Ecolabel regulations

In some existing EU Ecodesign regulations requirements with regard to the durability of products or components are specified. The according test procedures are detailed in sections 8.1.1 to 8.1.3.

International IEC 60068-1 ed7.0 Environmental testing

The test procedures described in this IEC standard are used as reference in the draft EU Ecolabel criteria for "Personal, notebook and tablet computers" with regard to durability testing of portable computers (cf. section8.1.5).

IEC 60068-1:2013 includes a series of methods for environmental testing along with their appropriate severities, and prescribes various atmospheric conditions for measurements and tests designed to assess the ability of specimens to perform under expected conditions of transportation, storage and all aspects of operational use. Although primarily intended for electro-technical products, this standard is not restricted to them and may be used in other fields where desired. The IEC 60068 series consists of:

- IEC 60068-1 – General and guidance, which deals with generalities;
- IEC 60068-2 – Tests – which publishes particular tests separately for different applications;
- IEC 60068-3 – Supporting documentation and guidance, which deals with background information on a family of tests. The families of tests comprising Part 2 of the IEC 60068 series are designated by the following upper-case letters:
  - A: Cold
  - B: Dry heat
  - C: Damp heat (steady-state)
  - D: Damp heat (cyclic)

- E: Impact (for example shock and rough handling shocks)
- F: Vibration
- G: Acceleration (steady state)
- H: (Awaiting allocation; originally allotted to storage tests)
- J: Mould growth
- K: Corrosive atmospheres (for example salt mist)
- L: Dust and sand
- M: Air pressure (high or low)
- N: Change of temperature
- P: (Awaiting allocation; originally allotted to “flammability”)
- Q: Sealing (including panel sealing, container sealing and protection against ingress and leakage of fluid)
- R: Water (for example rain, dripping water)
- S: Radiation (for example solar, but excluding electromagnetic)
- T: Soldering (including resistance to heat from soldering)
- U: Robustness of terminations (of components)
- V: (Awaiting allocation; originally allocated to “acoustic noise” but “vibration, acoustically induced” will now be Test Fg, one of the “vibration” family of tests.
- W: (Awaiting allocation)
- Y: (Awaiting allocation)

Safety standards for products and components, indirectly addressing durability

There are some standards which are related to the safety of products and components and seem to address quality and/or durability of those components at least indirectly.

For example, EN 60335 addresses product safety; EN 60335 Part 1 defines general safety requirements on household and similar electrical appliances, whereas Part 2 is divided into specific sub-parts each containing appropriate appliance specific safety requirements inter alia for dishwashers EN 60335-2-5 and washing machines EN 60335-2-7.

Table 1.33: Examples of safety standards for household and similar electrical appliances and their indirect requirements for quality and durability of components to comply with product safety

Standard	Component	Requirement
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, Annex C	Engine	Ageing-check for engines (in device-specific parts are modifications possible)
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 25	Power supply and external cables	(In device-specific parts are modifications possible regarding the number of operating cycles)

Standard	Component	Requirement
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014; section 23	Inner cables	The flexible part is being moved with 30 bends per minute backwards and forwards, so that the conductor is bended by the feasible biggest angle, enabled with this construction. The number of bends accounts: • 10 000 for conductors, which are bended during proper use • 100 for conductors, which are bended during users-maintenance (In device-specific parts are modifications possible, concerning the number of bends)
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 24; standard for switches: IEC 61058-1	Components: Switches	Number of operating cycles have to add up to at least 10 000
Household and similar electrical appliances - Safety - Part 1: General requirements; EN 60335-1:2012/FprAD:2014, section 24; standard for Regulation- and control systems is IEC 60730-1	Components: Regulation and control systems	Minimum number of required operating cycles for example • for temperature controllers: 10 000; • for operating temperature limiter – 1 000 (In device-specific parts are modifications possible regarding the number of operating cycles)
Household and similar electrical appliances - Safety - Part 2-5: Particular requirements for dishwashers (IEC 61/4313/ CDV:2011); FprEN 60335-2-5:2011	Ageing-check for elastomer parts	Test to determine hardness and mass of elastomer parts before and after dipping in detergent and rinse-aid with increased temperature The section (number 18) on endurance is void.
Household and similar electrical appliances - Safety - Part 2-7: Particular requirements for washing machines (IEC 60335-2-7)	Many	This standad contains an array of test protocols to ensure safe operation of washing machines, for application by manufacturers. They deal mainly with electrical risks (e.g. appliances shall be constructed so that foaming does not affect electrical insulation) and management of heating elements. Section 18 on endurance specifies several tests on: door opening cycles (10000, of which first 4000 also with electrical lock; for WD: 13000 cycles, of which 9000 first with electrical lock), and braking mechanism (1000 cycles).
Household and similar electrical appliances - Safety - Part 2-7: Particular requirements for washing machines (IEC 60335-2-7:2008, modified + A1:2011, modified); EN 60335-2-7:2010 + A1:2013 + A11:2013)	Firmness of lid and door	Test with rubber-hemisphere (diameter 70 mm; defined hardness, attached to a cylinder with 20 kg mass) is dropped to the centre of the lid and the door from a height of 1 metre; to be repeated three times.; furthermore, the lid shall have enough firmness to resist deformation
ISO 6804:2009	Rubber and plastics inlet hoses and hose assemblies for washing-	Requirements for three types of rubber or plastics inlet hoses and hose assemblies for washing-machines and dishwashers connected to the domestic water supply at a pressure not exceeding 1 MPa (10 bar). It is applicable to the following types of hose:

Standard	Component	Requirement
	machines	Type 1: rubber hoses for unheated water supply (maximum temperature 70 °C). Type 2: rubber hoses for heated water supply (maximum temperature 90 °C). Type 3: plastics hoses for unheated water supply (maximum temperature 60 °C). The standard foresees performance requirements for finished hoses, such as bending tests, flexing tests, resistance to kinking, resistance to hydrostatic pressure after ageing resistance to ozone or weathering, resistance to hydraulic-pressure impulse test, adhesion and mechanical resistance of thermoplastics coupling nuts.

According to stakeholder feedback, however, those existing safety and endurance / performance standards cannot directly be translated into durability standards. The standards are used by companies to test the safety of their appliances under endurance tests and extreme conditions to ensure consumers' safety during functioning of the appliance, but also in case of incident (stress tests to ensure that people do not get hurt). This is especially true for safety standards to measure components for failure. According to the stakeholders' feedback to the questionnaire (JRC IPTS 2015b), methods for testing failed components have no relation to component durability, although they might be a good starting point for standardisation organisations' investigations in starting up standardisation work for testing durability of appliances and/or components. In this context, the safety standards would have to be checked for details of the testing conditions to make sure that they are applicable for an alternative purpose.

Ricardo-AEA (2015) argued in the same direction, that the adoption of the EN 60335 test requirements into an ecodesign regulation would not affect the durability performance of appliances since these requirements should already be achieved and declared for LVD compliance. However, they could be the basis of tests, potentially with higher minimum standard pass requirements.

Ardente & Talens Peirò (2015) conducted a survey in the websites which revealed that several manufacturers of household dishwashers claim to perform durability tests on sample of devices before putting them in the market. Tests are generally based on intensive use under pre-set conditions, in order to simulate the total number of washing cycles during lifetime. Ardente & Talens Peirò (2015) propose these manufacturers' procedures to be potentially translated into standardised procedures.

Product endurance tests of consumer test magazines (Stiftung Warentest (DE), Test Achats (BE))

Besides tests for durability of components (focus mostly on safety), no widely established test standards for the durability of whole products with regard to their functional quality exist. Some consumer test magazines have developed their own endurance tests. For example, Stiftung Warentest developed and carried out durability tests for washing machines and washer dryers in the last years.

- For washing machines, three machines of each model in the test are run in total 1,840 cycles in different programmes with practice-oriented load and usual heavy duty detergents; this shall correspond to a lifetime of around 10 years with 3.5 wash cycles per week (Stiftung Warentest 2013); (Stiftung Warentest 2015).

- For washer-dryers, three machines of each model in the test are run in total 1,430 cycles in different programmes with practice-oriented load and usual heavy duty detergents; thereof 360 cycles in the programme “wash-dry colour, cupboard dry”; this shall correspond to a lifetime of around 8 years with 3.5 wash cycles per week (Stiftung Warentest 2012b). In its latest test on a washer-dryer (Stiftung Warentest 2015), the durability test was done in accordance to the durability test for washing machines, cf. above.

Also Test Achats in Belgium currently carried out a test on durability and reparability of washing machines.

- For the durability test, two machines of in total 12 models in the test are run in total 2,500 cycles in the “rinse and spin” mode, at their maximum spin speed and a loading of 60%. The test included also 2,500 times opening and closing the door as well as pushing the buttons accordingly. At the end of the test, the abrasion condition is checked.
- For the reparability test, the following criteria based on the Austrian standard ONR 192102 have been checked:
  - Failure indication and machine’s feedback by blocking the wastewater hose, closing down the water supply, disabling the level switches etc.
  - Access to components, dismantlability, availability of spare parts;
  - Cooperation of the manufacturer with independent repair services (e.g. safety information, educational trainings, contact to the manufacturer, availability of information on spare parts and other aspects).

1.3.3.2. Recyclability and end-of-life treatment of electrical and electronic equipment

European Commission’s Mandate M/518 for standardisation in the field of Waste Electrical and Electronic Equipment (WEEE)

In January 2013, the European Commission sent Mandate M/518 to the European standardisation organisations with the purpose to develop one or more European standard(s) for the treatment (including recovery, recycling and preparing for re-use) of waste electrical and electronic equipment, reflecting the state of the art. The European standard(s) requested by this mandate shall assist relevant treatment operators in fulfilling the requirements of the WEEE Directive. (European Commission 2013d)

EN 50625 standard series: Collection, logistics & treatment requirements for WEEE

CENELEC, through its Technical Committee ‘Environment’ (CLC/TC 111X), is leading the development of standards (and other deliverables) that will support the implementation of the EU Directive on Waste Electrical and Electronic Equipment. These standards cover various aspects of the treatment of electronic waste (including collection, treatment requirements, de-pollution and preparing for re-use). TC111X works on standards related to the environment and set up Working Group 6 for the EN 50625 series.

According to SENS/Swico/SLRS (2014), the general standard EN 50625-1 (Collection, logistics & treatment requirements for WEEE - Part 1: General treatment requirements) came into force recently. On 20 December 2013 the voting of the European National Committees on the general WEEE treatment standard EN 50625 resulted in the acceptance of the standard which was finally published in March 2014. It establishes the basis for the standards to follow for individual categories of equipment, such as lamps, monitors and photovoltaic panels and other equipment containing volatile fluorocarbons or volatile hydrocarbons; the latter being also relevant for appliances with heat pumps (dishwashers, washing machines, washer dryers). These more specific standards will contain references to the general standard, and together they will form the EN

50625 series. Additionally, an associated Technical Specification TS 50625-3-1 for de-pollution (general) has been developed in 2014.

The standard on general treatment requirements includes on the one hand administrative and organisational requirements for the treatment operator and the treatment facility such as management, infrastructural pre-conditions, training and monitoring. On the other hand, technical requirements regarding the handling of WEEE, the storage of WEEE prior to treatment, the de-pollution process, the determination of recycling and recovery targets and documentation requirements. The technical specification further details different methodologies for monitoring of de-pollution.

According to SENS/Swico/SLRS (2014), the technical specifications are just as binding as the standards themselves, except that they contain limit values and target values as well as instructions for taking samples of material and specific details for performing tests.

Besides Part 1 on general treatment requirements, further parts are under development:

- EN 50625-2-1: Treatment requirements for lamps plus associated Technical Specification for de-pollution TS 50625-3-2
- EN 50625-2-2: Treatment requirements for WEEE containing CRTs and flat panel displays plus associated Technical Specification for de-pollution TS 50625-3-3
- EN 50625-2-3: Treatment requirements for WEEE containing volatile fluorocarbons or volatile hydrocarbons; according to stakeholder feedback, this standard has currently a draft status and is planned to replace EN 50574:2012. Also for this standard, an associated Technical Specification for de-pollution (TS 50625-3-4**)** will be developed. According to stakeholder feedback, the draft is not yet available, however, will replace TS 50574-2:2014 when adopted.
- EN 50625-2-4: Treatment requirements for WEEE for photovoltaic panels plus associated Technical Specification for de-pollution TS 50625-3-5.

Additionally to these 5 standards and corresponding Technical Specifications (TS), three further TS shall be developed covering horizontal matters:

- TS 50625-4: Specification for the collection and logistics associated with WEEE
- TS 50625-5: Specification for the end processing of WEEE fractions – copper and precious metals
- TS 50625-6: Report on the alignment between Directive 2012/19/EU and EN 50625 series standards

For household dishwashers and washing machines, especially the standard and technical specification regarding the treatment of WEEE containing refrigerants would be applicable in case of appliances operated with heat pumps. If in the future, appliances would be equipped with control panels greater than 100 cm^2, also EN 50625-2-2 and TS 50625-3-3 would apply. Precious metals, for which the technical specification TS 50625-5 is planned, can be found for example in PWBs, containing palladium, silver and gold, and in permanent magnet motors of dishwashers and washing machines.

Whereas the standards and according technical specifications define requirements regarding the removal and further treatment of certain substances, mixtures and components such that they are contained as an identifiable stream or part of a stream by the end of the treatment process, they do not specify requirements for better identification or ease of dismantling of those components to facilitate the end-of-life treatment process itself.

Further national and international standards with regard to end-of-life treatment and facilitating recyclability are listed in the following:

EN 50574: Collection, logistics and treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons

Washing machines and washer dryers, if operated with heat pump, should be covered by standard EN 50574. Discarded appliances covered by this European Standard will have been deposited at a collection facility as domestic WEEE.

Standard EN 50574 was prepared by CENELEC's Technical Committee 111X / Working Group 04, "Environment - End of life requirements for household appliances containing volatile fluorinated substances or volatile hydrocarbons" and published in 2012. It defines requirements for the end of life handling, transportation, storage, sorting and treatment of WEEE household appliances containing volatile fluorocarbons, volatile hydrocarbons, or both; as well as requirements for monitoring and reporting. Furthermore, this European standard only applies to WEEE household appliances that use heat-transfer media other than water e.g. refrigerators, freezers, heat pump tumble dryers, de-humidifiers and portable air conditioners. Also dishwashers and washing machines, if operated with heat pump, are covered by this standard. Discarded appliances covered by this European Standard will have to be deposited at a collection facility as domestic WEEE.

The standard describes requirements for the removal of volatile fluorocarbons and volatile hydrocarbons. These substances can be found as refrigerant in the refrigerating system (partly dissolved in the oil) and as blowing agent in the insulating foam of discarded household appliances.

Further, Annex D of the standard includes sorting requirements for heat pump tumble dryers based on instructions for identifying tumble dryers containing fluorinated refrigerants. According to the European F-gas Regulation (cf. section 1.3.1.5) and the WEEE Directive (cf. section 1.3.1.2), volatile fluorinated hydrocarbons (VFCs) have to be removed when recycling appliances. Special treatment plants are required to recycle appliances containing VFCs. To achieve the right treatment for heat pump tumble dryers with VFCs it is therefore necessary to ensure identification and correct sorting of these appliances. The following procedure should be used to facilitate this identification: Marking according to the requirements of the F-gas Regulation. The information is usually printed on a separate label, placed either near the heat pump element inside the machine, or outside on the back of the machine with a text declaring that the appliance contains fluorinated gases that are covered by the Kyoto protocol. It could also be included in the main rating plate. Other ways of identification, if the information is not provided via F-gas label or the main rating plate is the existence of a compressor and a heat exchanger which can be seen when opening the device.

These requirements shall also be applicable to other household appliances if operated with heat pumps, such as washing machines and washer dryers.

TS 50574-2: Collection, logistics & treatment requirements for end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons – Part 2: Specification for de-pollution

This Technical Specification, published in November 2014, is intended to support EN 50574:2012 (see above) by providing further normative requirements for the measurement of de-pollution for treatment of end-of-life household appliances containing volatile fluorocarbons or volatile hydrocarbons. Any characteristic numbers and target values within this technical specification are based on evidence gathered by technical experts over a time period of more than two years when performing test according to EN 50574:2012.

EN 50574:2012 gives the responsible take-back parties the task of defining target values (e.g. for treatment, and minimum masses of volatile fluorocarbons or volatile hydrocarbons to be recovered). This Technical Specification provides applicable target values, characteristic numbers, sampling and analysis procedures, as well as monitoring and reporting requirements. Furthermore the Technical Specification provides validation methodologies for tests and the daily business of the treatment plants as defined in EN 50574:2012.

IEC/TR 62635: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment

The Technical Report IEC/TR 62635:2012 ed1.0 (IEC 2012) provides a methodology for information exchange involving EEE manufacturers and recyclers, and for calculating the recyclability and recoverability rates to

- provide information to recyclers to enable appropriate and optimized end-of-life treatment operations,
- provide sufficient information to characterize activities at end-of-life treatment facilities in order to enable manufacturers to implement effective environmental conscious design (ECD),
- evaluate the recyclability and recoverability rates based on product attributes and reflecting real end-of-life practices.

Furthermore this technical report includes:

- criteria to describe EoL treatment scenarios;
- criteria to determine product parts that might require removal before material separation and related information to be provided by manufacturers (location and material composition);
- a format for information describing EoL scenarios and the results of EoL treatment activities;
- a method for calculating the recyclability and recoverability rate of EEE. The calculation is limited to EoL treatment and does not cover collection. The recyclability rate is expressed as a percentage of the mass of the product that can be recycled or reused, whereas the recoverability rate in addition includes a portion derived from energy recovery. This techncial report can be applied to all electrical and electronic equipment;
- some example data corresponding to identified scenarios.

IEC/TC 111 PT 62824: Guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design.

Further, under the IEC Technical Committee 111, Project Team 62824 has been established to provide guidance on consideration and evaluation on material efficiency of electrical and electronic products in environmentally conscious design.

ISO 11469: Plastics - Generic identification and marking of plastics products

This International Standard, published in 2000, specifies a system of uniform marking of products that have been fabricated from plastics materials. The marking system is intended to help identify plastics products for subsequent decisions concerning handling, waste recovery or disposal. Generic identification of the plastics is provided by the symbols and abbreviated terms given in ISO 1043, parts 1 to 4:

- ISO 1043-1, Plastics — Symbols and abbreviated terms — Part 1: Basic polymers and their special characteristics.
- ISO 1043-2, Plastics — Symbols and abbreviated terms — Part 2: Fillers and reinforcing materials.

- ISO 1043-3, Plastics — Symbols and abbreviated terms — Part 3: Plasticizers.
- ISO 1043-4, Plastics — Symbols and abbreviated terms — Part 4: Flame retardants.

The standard includes requirements on the marking system and the method of marking. The marking system is subdivided into marking of products, of single-constituent products, of polymer blends or alloys, and of compositions with special additives (fillers or reinforcing agents, plasticizers, flame retardants and products with two or more components difficult to separate).

The standard is often referred to in ecolabels containing requirements on resource efficiency and end-of-life treatment of appliances.

British standard BS 8887: Design for Manufacture, assembly, disassembly and end-of-life processing ("MADE")

The British Standards Institution has developed a design for manufacture standards series BS 8887 (Design for Manufacture, Assembly, Disassembly and End-of-life processing MADE) first in 2006. The series contains of following sub-standards:

- BS 8887-1: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 1: General concepts, process and requirements (01 February 2012, superseding BS 8887-1:2006)
- BS 8887-2: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 2: Terms and definitions (01 July 2014)
- BS 8887-211: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 211: Specification for reworking and remarketing of computing hardware (31 August 2012). This sector-specific standard focuses on the information and communication technology sector and created to provide the vocabulary and procedures for 'remarketed products', i.e. products that cannot be sold as new. It is planned to develop a generic remarketing standard for use by all sectors, using BS 8887-211 as a template (BSI Group [n.d.]).
- BS 8887-220: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 220: The process of remanufacture – specification. It outlines the steps required to change a used product into an 'as-new' product, with at least equivalent performance and warranty of a comparable new replacement product (BSI Group [n.d.]).
- BS 8887-240: Design for manufacture, assembly, disassembly and end-of-life processing (MADE) – part 240: Reconditioning (March 2011)

According to BSI Group ([n.d.]),

> *In 2012, BS 8887-1 was put forward to the ISO and it has been accepted onto the work programme of the ISO committee with responsibility for technical product documentation. A new working group is being set up, which will be led by the UK, and work to convert BS 8887-1 into an international standard.*

The international standard BS ISO 8887-1 Design for manufacture, assembly, disassembly and end-of-life processing (MADE) Part 1: General concepts, process and requirements is currently in development, by the BSI committee TDW/4 'Technical Product Realization' being responsible.

1.3.3.3. Test standards regarding the use and performance of detergents

Basically, the performance standard EN 60456 defines a test procedure for measuring the washing performance of the washing machine under a certain reference detergent (cf. section 1.2.2.1).

For testing the performance of detergents themselves, according to (Center for Testmaterials BV [n.d.]), there have been numerous of test methods which were used for detergent testing. In the last few years there was more movement towards standardisation and consensus. The two main exponents from that are: the AISE-protocol and the Ecolabel-standard which are moving closer together. Especially the AISE-protocol is a base standard that means it leaves a lot of room to add other stains or test materials as well, so that you can better incorporate the protocol into your own protocols. Both protocols incorporate a section on colour management as well.

A.I.S.E. Minimum protocol for comparative detergent performance testing

A.I.S.E., the International Association for Soaps, Detergents and Maintenance Products, developed the first detergent test protocol in 2009 and updated it in 2013. The protocol aims at advising test institutes and consumer organisation about the minimum set of tests for assessing the performance of detergents across Europe, independent from the country under test. The A.I.S.E. working group “Detergent Testing” has published the “Minimum protocol for comparative detergent performance testing” for Heavy Duty, Colour Save and Light Duty Detergents and Stain Removers.

The test protocol includes minimum requirements – free to exceed those but not lower them, and can be adapted to different countries/regions, differences in wash habits, wash temperatures, recommended dosages, etc. Inter alia, the test protocol defines parameter like dosage, soil donator, stain set, dyes for dye transfer inhibition, dyes for colour maintenance, the test execution, statistical evaluation or requirements to the communication of results prior to publication.

For example, dosages should be based on manufacturers’ recommendation. Regarding the wash temperature, the temperature that is most relevant in the country shall be selected; different temperatures may be used if justified by product category. In most countries this is 40 °C for generalist detergents.

The protocol has been developed based on experts' knowledge of major companies manufacturing such products, after a thorough review of existing test protocols used in Western Europe and of existing internal company data. For more information, please refer to

http://www.aise.eu/our-activities/standards-and-industry-guidelines/detergent-test-protocol.aspx

EU Ecolabel Performance Test for Laundry Detergents

In June 2014, the final draft of a revised EU Ecolabel Performance Test for Laundry Detergents has been published (European Commission 2014d).

The test protocol serves as a prove to show compliance with Criterion 6 – Washing performance (fitness for use) of the Commission Decision establishing EU Ecolabel criteria for Laundry Detergents. It detailed describes the test criteria, materials and conditions (such as water hardness, water inlet temperature, ballast load, stains set, soil, dosage, number of cycles etc.), the methods and test procedures including evaluation of stain removal, basic degree of whiteness, colour maintenance and dye transfer inhibition.

For example, the test load for heavy duty detergents (HDD), powder and liquid, contains a clean all cotton ballast load for the normal cotton wash program to reach a total weight of 4.5 kg. The dosage of the detergent to be tested shall be done in accordance to the producer recommendation.

Different wash programmes are used for the Ecolabel performance test, depending on the kind of detergent to be tested (cf. Table 1.34).

With low temperature and cold-water wash products, the washing performance will be determined at the lowest stated temperature at which the detergent is claimed to be effective. The reference detergent must be tested at 30 ºC.

Table 1.34: Different wash programmes for the EU Ecolabel test on detergents; source (European Commission 2014d)

Wash programme	Tª efficient	Wash programme test product	Wash programme reference detergent	Water inlet Tª (test product)	Water inlet Tª (ref. detergent)	Heating element dis-connected
HDD/CSD	30 °C	30 ºC, normal cotton program, 1200 rpm	30 ºC, normal cotton program, 1200 rpm	(20.0±2.0) ºC	(20.0±2.0) ºC	No
HDD/CSD	20 °C	20 ºC, normal cotton program, 1200 rpm	30 ºC, normal cotton program, 1200 rpm	(20.0±2.0) ºC	(20.0±2.0) ºC	No
HDD/CSD	15 °C	20 ºC, normal cotton program, 1200 rpm	30 ºC, normal cotton program, 1200 rpm	(15.0±2.0) ºC	(20.0±2.0) ºC	Yes
LDD	30 °C	30 ºC, delicate program, 600rpm	30 ºC, delicate program, 600 rpm	(20.0±2.0) ºC	(20.0±2.0) ºC	No
LDD	20 °C	20 ºC, delicate program, 600 rpm	30 ºC, delicate program, 600 rpm	(20.0±2.0) ºC	(20.0±2.0) ºC	No
LDD	15 °C	20 ºC, delicate program, 600 rpm	30 ºC, delicate program, 600 rpm	(15.0±2.0) ºC	(20.0±2.0) ºC	Yes

HDD: Heavy Duty Detergent; CSD: Colour Safe Detergent; LDD: Low Duty Detergent

Nordic Ecolabel Performance Test (fitness for use)

The Scandinavian Ecolabel "Nordic Swan" labels products which are environmentally friendly and "fit for use". Beside an ecological evaluation of the ingredients, the product must proof its performance in a so called Nordic Ecolabel Performance Test (fitness for use). The Test is detailed described in Appendix 6 (Nordic Ecolabel Performance Test (fitness for use)) of the Nordic Ecolabelling of Laundry detergents and stain removers, Version 7.7 (Nordic Ecolabelling 2011).

The performance test is categorised into four different parts for Heavy-Duty detergents, Low-duty detergents, Stain removers with subsequent wash and Stain removers without subsequent wash. It clearly defines parameters such as washing machines and wash programmes, water quality, materials, the test procedure, evaluation and sets limit values.

Other performance tests for laundry detergents

Further own or adapted test protocols for performance testing of laundry detergents are applied for example by consumer testing magazines like Que Choisir, Stiftung Warentest, Which? Consumentenbond, Test Achat, AFISE. The report of the EU project MarketWatch "Approaches and priority parameters tested by consumer associations and independent organisations performing tests on energy-using products" provides an overview of the current activities of consumer associations and independent endorsement organisations in Europe with respect to the testing of energy-using products. It is based on a survey conducted among the MarketWatch project partners and their partners/members.

The report is available on:

http://www.market-watch.eu/wp-content/uploads/2014/01/MW_NGO-approaches.pdf

1.3.4. Other studies on material resource efficiency

1.3.4.1. Study "Ecodesign Directive version 2.0 – from energy efficiency to resource efficiency" by Bundgaard et al.

In their study "Ecodesign Directive version 2.0 – from energy efficiency to resource efficiency", (Bundgaard et al. 2015) reviewed 23 currently adopted implementing measures and voluntary agreements under the Ecodesign Directive, criteria for resource efficiency in voluntary instruments such as ecolabels and Green Public Procurement as well as recent Commission projects with regard to implementation of resource efficiency aspects into the ecodesign directive.

In the study, Bundgaard et al. generally include under "resource efficiency" the following measures:

- Reducing materials and energy use in the entire life cycle of products (mining of materials, production / use / final disposal of the product)
- Improving possibilities for maintenance and repair (e.g. guidelines)
- Ensuring re-use or redistribution, i.e. multiple use cycles.
- Increasing the potential for remanufacturing or refurbishment of the product, i.e. multiple use cycles (e.g. improving reparability, access to spare parts)
- Improving recyclability of materials used in the product

The review of existing instruments revealed that resource efficiency is already widely applied in voluntary instruments covering energy related products. The instruments include following criteria which were also assessed by the study team with regard to their transferability to the Ecodesign Directive (Bundgaard et al. 2015):

<u>Declaration and threshold of RRR ratio (reusability, recyclability and recoverability)</u>

According to Bundgaard et al. (2015), transferring declaration and threshold requirements with regard to RRR ratio to the implementing measures and voluntary agreements of the Ecodesign Directive first needs a common methodology to be developed on how to calculate the RRR ratio for products and materials to verify the requirements based on technical information provided by the producers.

However, setting requirements for the RRR ratio of the material or the product only reflects the theoretical potential and will not ensure that the materials or products are in fact reused, recycled or recovered which depends on the infrastructure for collection and treatment and the technologies available.

In case of future requirements to RRR ratio it is recommended to make them according to the waste hierarchy, by prioritising reuse before recycling and recycling before recovery.

<u>Declaration and/or threshold of recycled content</u>

According to Bundgaard et al. (2015), setting criteria for the threshold of recycled materials can help create a market for these materials. The environmental benefits of using recycled materials would depend on the type of material. However, before transferring these requirements to the Ecodesign Directive, it is important to assess if producers of recycled materials can satisfy increased demands on the market that a requirement would create. A possibility could be to begin by setting declaration requirements and then tightening them continuously by setting threshold requirements.

If setting criteria for recycled materials, however, first reliable technologies for an analytical assessment of the recycled content in the products would be needed to enable verification and market surveillance.

Bill of materials (BOMs)

BOMs are an important source of information to conduct LCAs, assess the product's recyclability, recoverability and recycled content and identify priority resources in the product to ensure their reuse and recycling; all of these activities are basis for other requirements to improve resource efficiency.

However, Bundgaard et al. (2015) conclude that due to the complexity of the supply chain of electronic and electrical equipment, a mandatory requirement on providing BOMs would be challenging to comply especially for small producers, as they might not have the ability to force these requirements on to their larger suppliers. Further, the implementation of such a requirement might first need the setup of a system that can ensure the companies' property rights, e.g. with regard to the use of rare metals.

Identification of plastic components

Marking of plastic components according to ISO 11469, at least the main ones, shall help recyclers identifying different plastic types and parts to ensure correct handling during waste recovery or disposal, when the plastic parts are manually sorted. Also, the visual marking of plastics parts according to certain ISO standards might be quite easy to verify visually by market surveillance authorities when dismantling the product.

On the other hand, there are certain drawbacks shown by the literature research of Bundgaard et al. (2015): A certain percentage of the labels were found to be incorrect and, mainly, for automatic sorting systems (currently the large majority of treatment) the ISO labels had no effect as these systems sort according to the plastic's mechanical, optical and electrostatic properties.

Thus, Bundgaard et al. (2015) recommend that before setting criteria for visual marking of plastics in the Ecodesign Directive it should be further examined to what extent the waste is manually sorted for the product group in question, and how the future waste treatment of the product might look like. Furthermore, alternative marking methods should be examined (e.g. Radio Frequency ID),, which could be applied for example in automatic sorting systems.

Contamination of materials / plastics

Requirements regarding contamination of materials are relevant for the recyclability, as the potential for recycling is reduced if incompatible materials are combined, e.g. painting, coating or metallizing large plastic parts making them not compatible with recycling. Depending on the specific requirement, it could be verified visually.

Mono-materials

Using compatible or a reduced number of plastics can improve the recyclability of e.g. thermoplastics, as a mixture of different polymers or a contamination of the plastic fractions can significantly decrease the plastics properties and thereby the use of the recycled materials.

Bundgaard et al. (2015) recommend that setting these types of requirements should be supplemented with a dialogue with the stakeholders from the recycling industry to ensure the effectiveness of these types of requirements which depends on the recycling system that the products enter into.

Efficient use of materials during the use phase

For washing machines, the Ecodesign Regulation 1015/2010 sets specific ecodesign requirements with regard to the water consumption. For dishwashers, no such requirement is yet in place. According to Bundgaard et al. (2015) an example of ecodesign requirements within this category could be to set a requirement to an automatic detergent dosing system for washing machines avoiding over-dosage and overconsumption of detergents. Several manufacturers have already such systems in place, based on the use of liquid detergents. Some manufacturers require the use of a specific detergent, while others can adapt to different detergents. None offers currently the option of using powder detergent, as it is more prone to clogging and requires more maintenance. Therefore, two liquid containers are necessary for cycles where bleaching is required, amaking the system more complex. This limits also the usability of the system for the cycles where powder detergent is necessary, or recommended, including during testing.

Easy disassembly

Easy or manual disassembly can help improve reparability and upgradability of the product improving the durability of the product. Criteria might be detailed with regard to the components to be separated, the type of connections or the tools to be used.

Regarding end-of-life treatment, Bundgaard et al.(2015) conclude that it is not possible based on the finding of their study to assess whether or not requirements for manual disassembly will improve the recyclability and recoverability of electrical and electronic equipment in the future. This is due to the reason that manual disassembly in the waste treatment process of electrical and electronic equipment (EEE) is increasingly being replaced by automatic or destructive disassembly in many developed countries which questions if requirements for easy or manual disassembly will improve the recyclability and recoverability of EEE if they are fed into an automatic or destructive disassembly system. However, manual disassembly is still performed when economically feasible, e.g. components or materials containing valuable resources, or when regulations such as the WEEE Directive require it, e.g by removal for separate treatment of components containing hazardous substances. Requirements in addition to manual disassembly might target automatic or destructive disassembly.

Durability requirements
(incl. extended warranty, upgradability and repair, spare parts, modularity)

All criteria strive to extend the lifetime of the product thereby preventing electronic waste. Durability is also related to the previous category disassembly, where criteria targeting easy disassembly for repair and upgradability were included.

The length of the warranty should be product specific and it is also strongly related to the availability of spare parts, which is also an issue for reparability. Determining how long spare parts should be taking into account both economic and resource efficiency aspects: On one hand components should be available to enable repair, but on the other hand the risk is that a too large inventory of components will be out-dated and never utilized. Modular design and easy disassembly enable upgrading and repair and are thus prerequisites for lifetime extension. Upgradability can potentially reduce the frequency of replacement against the background of rapid technological product developments.

Bundgaard et al. (2015) conclude that durability should be included as possible resource efficiency requirements in the Ecodesign Directive, also due to the requirements being possibly verifiable by market surveillance authorities. However, it is important to ensure that prolonging the lifetime of the product is the environmentally best solution in a life cycle perspective, e.g. that possible environmental benefits are not evened out by increased energy consumption of the older product compared to a new more energy efficient product.

Waste from manufacturing

By including requirements to the manufacturing, the scope would be expanded from a product focus towards a production focus which is applicable to the Ecodesign Directive which mainly sets requirements to the design of the product, however targeting the environmental performance of the entire product life cycle. Therefore, design requirements to the product that might improve the manufacturing process would be highly relevant. However, as many electronic products are produced outside Europe, it might be difficult to enforce these criteria (Bundgaard et al. 2015).

Further requirements

Further requirements on hazardous substances, take-back schemes and packaging identified in voluntary instruments such as ecolabels are not recommended to be transferred to the Ecodesign Directive as there are rather large overlaps with existing legislations such as REACH and RoHS, WEEE and the European Directive on packaging and packaging waste.

Information requirements related to resource efficiency

With regard to information and specific requirements targeting resource efficiency in ecodesign, Bundgaard et al. (2015) recommend in their study the following:

- Information relevant for disassembly, recycling or disposal at end-of-life:
  - Relevant for end-users to know how to correctly dispose the product at its end-of-life
  - Relevant for recyclers to know how to disassemble and recycle the products in the best possible way, for example to ensure that hazardous substances are removed and treated correctly. It is suggested that such information could be made more easily available, by embedding it in the product in e.g. a RFID to benefit the recyclers more compared to information provided on webpages or in user instructions. Furthermore, it could be specified in the Directive which type of information the recyclers may need. This could be done in close collaboration with the recyclers to ensure that the information is indeed relevant for their processes.
- Information and specific requirements on easy disassembly:
  - Relevant for consumers / repair facilities to help improving maintenance and repairs. Generic information requirements for non-destructive disassembly for maintenance could be supplemented by requirements for the producers to make repair and service manuals public. It may also be relevant to set specific requirements to easy disassembly of the product for maintenance purposes.
  - Relevant for recyclers to help improving end-of-life treatment, for example the removal of certain components which have to be treated separately in accordance with the WEEE Directive (batteries, heat pumps etc.).
- Information and specific requirements on durability (e.g. on lifetime of the product as for lamps, or for components, such as minimum loading cycles for batteries in computers)
  - Relevant for consumers to enable them selecting the most durable product
- Information requirements on hazardous substances, precious metals or rare earths
  - Relevant for recyclers to a) avoid contamination of the materials when they are recycled or b) ensure a more optimal recovery of precious materials. As stated above, also for these information it is suggested to make it more easily available, by embedding it in the product in e.g. a RFID.
- Information requirements with regard to resource consumption in the use phase
  - Relevant for consumers: e.g. to stipulate consumers choosing the most efficient programmes in terms of energy and water consumption and the best suitable detergents.

1.3.4.2. Study "Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP)" by BIO Intelligence Service

BIO Intelligence Service (2013) conducted a study to clarify the implications of material efficiency from the pragmatic perspective of its practical application for ecodesign purposes, and the elaboration of recommendations for the MEErP methodology (Part 1); and undertook an update of the MEErP methodology and its component EcoReport tool, to include the necessary means for better analysing material efficiency in MEErP (Part 2). Part 2 also contains a guidance document for analysing material efficiency in ErP; as well as an updated version of the EcoReport Tool and a report of the test of the updated methodology on two case studies.

The project identified from available evidence the most significant parameters regarding material efficiency that may be used in MEErP, in order to analyse the environmental impacts of ErP, and assessed their suitability and robustness for Ecodesign purposes, together with associated information parameters.

The parameters selected as most suitable were:

- <u>Recyclability benefit ratio</u>, describing the "potential output" for future recycling, based on a formula considering the recyclable mass per material and its recycling rate and a down-cycling index. It implies that it is possible to assess the potential benefits of recyclable plastic parts in a product (as metals are already commonly recycled to a large extent). However, due to data constraints only data on recyclability benefit rate for bulk and technical plastic is included.
- <u>Recycled content</u>, describing the "input" of materials with origin on waste, based on new data sets for materials. The dataset makes it possible to model products with recycled material as input material. However, again due to data constraints, only data on paper, PVC, PET and HDPE has been included as additional material inputs in the EcoReport Tool.
- <u>Lifetime</u>, a mechanism to display impacts not only as a total over the whole lifespan, but also per year of use, allowing an easier comparison of products with different lifetimes or analysing the effect of lifetime extension. The product lifetime can refer to:
  - The technical lifetime is the time that a product is designed to last to fulfil its primary function (technical lifetime).
  - The actual time in service is the time the product is used by the consumer (service lifetime). The actual time in service is not a typical parameter in industry and depends more on the user than on the manufacturers of the product design.
- Critical raw materials, a tool to analyse products including critical raw materials to display differences between different product designs and improvement options.

The key end result of this project is the proposal of new features in the MEErP, enabling further analyses of material efficiency aspects in products. These shall be fully functional and ready to be used in future Ecodesign preparatory studies. However, Bundgaard et al. (2015) conclude in their study:

> *The MEErP methodology has not been changed significantly. The alterations made to the EcoReport Tool are minor and to some extent updates of existing elements. Hence, despite the good intentions to include material efficiency into MEErP, the current update and expansion of MEErP will properly not be enough to ensure a focus on material efficiency in future implementing measures and voluntary agreements.*

The study by VHK "Resource efficiency requirements in Ecodesign: Review of practical and legal implications" (2014) provides some additional insights on this. Due to time constraints, it has not been possible to analyse it, but the conclusions will be presented in the next update of the present study.

1.3.4.3. Study "The durability of products" by Ricardo-AEA

Ricardo-AEA, in collaboration with Sustainability Management at Scuola Superiore Sant'Anna di Pisa (SuM) and Intertek, has been commissioned by the European Commission – DG Environment to conduct a study on the durability of products. The purpose of the study is to identify two priority products and develop a methodology for measuring their durability. The study also aims to estimate the benefits and costs of more durable products. The outputs from this work can then be used in relevant product policies (Ricardo-AEA 2014a).

Within the durability study, the authors undertook a literature analysis to develop an appropriate definition of durability. For example, the Ecodesign Directive 2009/125/EC in Annex I, Part 1.3 defines parameters which must be used, as appropriate, and supplemented by others, where necessary, for evaluating the potential for improving the environmental aspects of products. According to (European Parliament 2009a), this includes inter alia

> *"Extension of lifetime as expressed through: minimum guaranteed lifetime, minimum time for availability of spare parts, modularity, upgradeability, reparability."*

The following definition has been developed by Ricardo-AEA (2014a) proposed to be potentially also applied to other policy interventions in Europe aimed at improved durability of products.

> *"Durability is the ability of a product to perform its function at the anticipated performance level over a given period (number of cycles – uses – hours in use), under the expected conditions of use and under foreseeable actions.*
>
> *Performing the recommended regular servicing, maintenance, and replacement activities as specified by the manufacturer will help to ensure that a product achieves its intended lifetime."*

The authors further discussed the possibility of creating an extended definition of durability that encompasses repair, design for repair and remanufacturing, and that such an extended definition of durability could be developed for inclusion within for example the EU Ecolabel and GPP criteria requirements.

> *"A product to maintain its functions over time and the degree to which it is repairable before it becomes obsolete."…. "In other words, a product should not cease to function after relatively little usage and its reparability should not be hindered by its design."*

It is thus worth considering that, within this context, extended durability is the aim to extend the life of a product past its first life by ensuring a product can be easily repaired, upgraded, remanufactured and, at end of life, dismantled and recycled.

Beyond the above definitions on durability, Ricardo-AEA (2014a) listed the following definitions for a number of relevant terms:

- Design for durability: considering the product's longevity, reparability and maintainability; considering environmental improvements emerging from new technologies (ISO/TR 14062 2002).
- Operating time: average time frame during which the product is supposed to be used. Operating time can be derived from product statistics or from estimating models.
- Extension of operating time: estimated time frame extension of the operating time that can be achieved due to specific design and maintenance actions.

Within the study of Ricardo-AEA (2014a), domestic refrigerators and freezers, and ovens were selected for further analysis. The selection is based on the assumption, that they might also be applicable to other products with similar components. For washing machines and washer dryers the study results are expected to be transferable to a large extent as following components are similar:

- Outer casing
- Pumps
- Filters
- Heating elements
- Mechanical elements such as hinges and catches
- Electronics, including controls and displays

1.3.4.4. Study "Investigation into the repairability of Domestic Washing Machines, Dishwashers and Fridges" by RReuse

The Reuse and Recycling EU Social Enterprises network (RREUSE) is a European umbrella organisation for national and regional networks of social enterprises with re-use, repair and recycling activities. They cover 42,000 Full Time Equivalent (FTE) employees and over 200,000 volunteers working throughout 22 member organisations across 12 EU Member States.

In 2013, RReuse has conducted an investigation into some of the main obstacles its members encounter when repairing products, inter alia for washing machines and dishwashers, to provide part of the basis for setting requirements within implementing measures to improve the reparability of products, and thus their material and resource efficiency. Based on a questionnaire sent out through their network, the findings are answers from 9 individual reuse and repair centres from four national networks of social enterprises namely AERESS (Spain), Repanet (Austria), Réseau Envie (France) and the Furniture Reuse Network (UK) (RReuse 2013).

The study identifies obstacles for repair and maintenance of washing machines can be found in section 3.3.3. Examples of common causes of break downs as well as suggestions for product design to help improve reparability of washing machines are provided in section 4.5.5.2.

Based on the study results, the following horizontal measures within Ecodesign Implementing Measures are suggested by (RReuse 2013):

- The product should be able to be disassembled non-destructively into individual components and parts without the need for special proprietary tools to do this. If special tools are required however, these must be readily and freely available to all approved reuse and repair centres/networks (not just to the after sales service providers of the manufacturers).
- The availability of replacement parts must be guaranteed for a minimum period of 10 years following the last product batch. Critical spare part components should be available at a reasonable price (with no reference to what is a reasonable price)..
- Free of charge access to repair service documentation of the after sales service providers of the manufacturers for all reuse and repair centres, not only those of the after sales service providers, together with any relevant fault diagnostic software and hardware.
- Simplification of specific components and potential standardisation of certain components across different brands would significantly increase the efficiency of repair as it would allow greater interoperability of components across different machines

1.3.4.5. "Study on Socioeconomic impacts of increased reparability" by BIO by Deloitte

DG Environment has commissioned a study to BIO by Deloitte to analyse the socioeconomic impacts of increased reparability (Bio by Deloitte 2015). A second part of the study deepening the analysis on some aspects is underway in 2017.

With this study, DG Environment strives to gather information about the mechanisms of the solutions in order to increase reparability. To assess the viability of the requirements, they must be tested in order to measure the benefits of their impacts on economic growth, job creation and resource efficiency under the perspective of the Roadmap to a Resource Efficient Europe and the Green Employment Plan. Thus, within the study case studies on possible reparability requirements are performed on 4 product groups (domestic washing machines, dishwashers, coffee machines and vacuum cleaners) in order to get a global and complementary vision of the repair sector. These case studies enhance the mechanisms barriers and drivers in the perspective of their potential integration of generic or product-specific requirements in product policy instruments (either mandatory or voluntary). The operational objectives of the project are stated as follows:

- Perform case studies on four product groups;
- Review existing barriers and identify suitable reparability requirements;
- Quantify the job creation, economic and resource-savings potential of the selected reparability requirement policy scenario and its individual elements, including impact on SMEs;
- Describe the characteristics of possible job creation potential in terms of skills requirements, private/public, entrepreneurship and self-employment, entry to labour market and global mobility; and
- Describe mechanisms under which such a policy framework would develop in a scientifically sound way building on empirical studies, literature studies or economic modelling or others as best suited.

Each case study was performed in order to assess the job creation potential, the resource savings potential and the net cost and benefits for society. The results are compared in order to identify an EU policy scenario.

In April 2015 a first questionnaire has been sent out to stakeholders. For domestic washing machines, Bio by Deloitte (2015) asked about the importance of certain barriers to repair:

- Availability of technical documentation, diagnosis software
- Availability of spare parts
- Cost of spare parts
- Labour cost
- Difficulty of access and replacement of control boards
- Non-replaceable components (e.g. ball bearings, door hinges, drum casing)
- Low consumer awareness about repair possibilities

Additionally, stakeholders have been asked about their opinion regarding possible reparability requirements and their effectiveness to increase the repair of products by being voluntary or mandatory tools (Bio by Deloitte 2015):

- Provision of instructions for troubleshooting, diagnosis software, diagrams of the Printed Circuit Board

- Ensure accessibility in the switched on position for the purpose of troubleshooting during the repair work
- Ensure accessibility to inner parts (e.g. large and easily accessible back and top covers, cable lengths, space for mounting, screw orientation, scale of design)
- Ensure the possibility of breaking down the product (e.g. components can be tested separately)
- Provision of information relevant for disassembly (e.g. instructions, break down plan
- Avoidance of non-reversible adhesives
- Ensure the separation of the connections by a limited number of ordinary tools
- Ensure the possibility to exchange or upgrade critical components (e.g. ball bearings, door hinges)
- Use of standardised designs to allow compatibility of spare parts
- Ensure the availability of compatible spare parts for a determined period of time
- Offer to consumers an optional extension of warranty time at purchase
- Provision of information to consumers about reparability in product Energy Labels, brochures, etc. (e.g. similar to Austrian rating Standard ONR 192102).

Within the final report of the “Study on socioeconomic impacts of increased reparability” (Deloitte 2016), several public policy instruments at European and national level, such as Ecodesign, EU Ecolabel, ecolabels at Member State level as well as the French law and the Austrian standard on durability of products have been analysed in a desk research with regard to existing reparability requirements. The detailed criteria with regard to reparability have been clustered into three general types:

- Information requirements;
- Requirements on product design and;
- Requirements on the provision of services, e.g. the accessibility to spare parts.

Based on this thorough list, stakeholders were consulted on the selection of reparability requirements with 16 stakeholders providing input to the discussion. As a result, the following five rather generic policy measures were chosen as input for the subsequent scenario-based impact analysis, however, not setting out the product scope of technical details of the various scenarios:

1. Measures to ensure the availability of spare parts for at least a certain amount of years from the time that production ceases.
2. Measures to ensure provision of information to consumers on possibilities to repair the product.
3. Measures to ensure provision of technical information to repair professionals to facilitate repair.
4. Measures for the provision of technical information to consumers to facilitate simple self-repairs.
5. Measures to enable an easier dismantling of products.

According to the study results, it was not feasible due lack of data or limited geographical representativeness to make a clear conclusion on which scenario is the most beneficial one. The scenarios 1 (spare parts) and 5 (easier dismantling) seem to provide the highest benefits e.g. in terms of resource savings, but also impose the highest negative impacts for example on the reduction of turnover and jobs for manufacturers and producers. The scenarios 2 to 4 with regard to information requirements seem to be easier to be implemented but with certain difficulties such as concerns over possible intellectual property rights (no. 3) or health and liability issues (no. 4). The study concluded with the recommendation that the most promising policy scenarios 1 and 5 should be analysed case-by-case during the specific Ecodesign preparatory studies.

Furthermore, in this study the main barriers and drivers for repair are presented and analysed. The authors classified them into economic, organisational and technical ones.

Appliances are often not repaired for economic reasons. The low prices difference between the repair and the purchase of a new product may make repair and reuse economically unattractive. In addition, there are some uncertainties regarding the guarantee of the repair service. At a macroeconomic level, increased reparability and durability could reduce the dependence of the EU on imports and increase the activity in recycling and the industrial sectors that use valuable materials such as rare earths, platinum group elements or other precious metals

Regarding the organizational aspects, the most relevant barriers for repair are closed markets of spare parts and monopolies. Some producers deliver spare parts only to their partners which hinders competition. Finally regarding the technical aspects, manufacturers and retailers are not always obliged to provide consumers or the repair market with technical instructions.

1.3.4.6. Study "Addressing resource efficiency through the Ecodesign Directive. Case study on electric motors" by Dalhammar et al.

Dalhammar et al. (2014) conducted a case study in 2012 on the potential inclusion of permanent magnet (PM) motors in the Ecodesign Regulation for electric motors. The objective was to see how the Ecodesign Directive could promote eco-innovation for resource use in PM motors, and to:

- Investigate what kind of requirements related to resource use of rare earth elements (REE) are of relevance for permanent magnet electric motors, and
- Obtain input from experts on the feasibility of outlined potential requirements, and the most important drivers for eco-innovations.

Against the background of increased demand for REE, combined with global supply imbalances and unavailable post-consumer recycling options for REE, their substitution in the magnets is currently being investigated in several pilot projects. Replacing REEs with other materials however can come with a performance loss in the PM motor (i.e. reduced energy efficiency due to a reduced energy density in the magnet and more material use). Therefore, increasing the recyclability of PMs is of interest, if technically and economically feasible at the point in time of interest, as it could provide a stable supply of REEs and thus, enhances their continued use to achieve more energy-efficient motors.

Based on interviews with material experts, Dalhammar et al. (2014) outline potential implementing measures facilitating recycling of REE.

- Generic requirements that producers should show how they take design for recycling into account in the design process.
- Design for dismantling, e.g. modularisation; or preventing that permanent magnets are for instance covered by plastic, which would ease recycling practices.
- BOMs providing information about key materials and their positions to promote future recycling (when new technologies may allow for profitable recycling if the motors are easy to disassemble).
- Additional information to recyclers that are relevant for allowing cost-effective recycling.

- Take-back obligation; it might provide incentives to design a motor from which materials can more easily be recycled.

Dalhammar et al. (2014) conclude that it appears as if a more developed set of requirements cannot be set under the Ecodesign Directive until pilot projects and ongoing research have provided more insights on the technical and economic viability of REE recycling. The long-time scales involved (i.e. time before the motors are at the EoL stage) however mean that future recycling options and associated costs and benefits are rather uncertain compared to products with shorter life spans, e.g. laptops or cell phones.

1.3.4.7. VHK study "Resource efficiency requirements in Ecodesign: Review of practical and legal implications" (2014)

This study for the Dutch Ministry of Infrastructure and Environment explores the potential role of material resource efficiency, except energy efficiency during use, in the Ecodesign of Energyrelated Products (ErP) Directive. The study analysed the results of the DG JRC research on resource efficiency parameters like Reusability/Recyclability/Recoverability (RRR rates), Recycled Content, Use of Priority Resources (RRR Benefit Rates), Use of Hazardous Substances (as a barrier to end-of-life treatment) and Durability. These calculation methods are theoretically largely applicable in Ecodesign and have recently been added to the generic methodology for preparatory studies (MEErP), cf. section 1.3.4.2. The VHK study analysed whether the list of resource efficiency parameters is complete and if and how these parameters would be enforceable. The VHK study concludes on the role of resources (VHK 2014):

> *In principle, the Ecodesign directive can regulate almost any resource efficiency*
>
> *parameter of energy-related products, provided that*
>
> *a) the parameter can be measured and*
>
> *b) there is a significant impact and improvement potential.*

(VHK 2014) further recommends to strengthen the role of material resource efficiency in Ecodesign, beyond energy efficiency, the following actions on short, medium and long term:

- Short term: To build and expand on what already appears to be enforceable within Ecodesign:
    - Regulation of the consumption of direct and indirect resources during product use (beyond energy efficiency) and
    - Durability (technical life, spare part availability)
- Medium term: Resource efficiency parameters that can be measured on the product are easier to implement than those that require a 'paper trail' of declarations or certain obligations. Thus according to (VHK 2014) it would seem logical to start investigating parameters that can be derived from
    - Product weight and/or weight fractions that are an indication for resources use in production and distribution (light-weighting, miniaturisation, critical raw materials)
    - Physical/chemical characteristics like purity, surface quality or key mechanical properties for which there are test standards and that are indicative – even only approximate – of recycled content.
- Long term: After considerably more research and capacity building than what is available today, according to (VHK 2014) it may be appropriate to use Ecodesign through those parameters that cannot be directly measured on the product but where there is an expectation for the future that certain related parameters might be beneficial. This would

include Reusability, Recyclability, and Recoverability. Also, for those parameters related to end-of-life, there is the additional problem of a 5 to 25 year time gap between the manufacturing of the product and the moment these parameters can prove their effectiveness.

(VHK 2014) concludes that the recently developed RE parameters are mainly oriented to end-of-life of products and are not complete. Waste prevention, i.e. the first priority in the EU waste hierarchy and currently an important contributor to diminishing the waste stream, is the most important RE parameter missing. Waste prevention includes

- Minimal materials use through miniaturisation and light-weighting of the product, affecting all life-cycle-phases, and
- Minimal (non-energy) resources consumption during the use-phase, e.g. direct use of water, paper and refrigerants, but possibly also indirect ('related') resources impacts e.g. linked to food preservation (in fridges), textile wear (in laundry equipment), etc.

Regarding practical implementation and enforceability, (VHK 2014) summarizes that Ecodesign measures regarding savings on non-energy resources consumption in the use-phase have proven to be enforceable, at least for directly consumed resources, legally and in practice; however, methodology and measures regarding weight-saving measures in Ecodesign would need to be developed. Further, measures on product durability (life time extension) have proven to be enforceable when formulated in terms of minimum technical life of the product or components according to harmonised test and calculation procedures. Also minimum warranty times and the time period during which spare parts are available can be enforced.

On the other hand, to use specific RRR measures in legislation, requires that they should be technically and economically feasible and preferably relate to parameters that can be assessed with an accurate, reliable and reproducible test and calculation methods at product-level. If they would depend on input from upstream actors (suppliers) or downstream (end-of-life) processes, the administrative burden would be considerable and still the accuracy and reproducibility of measurements would require robust test standards to be in place to guarantee a level playing field.

2. Task 2: Markets

This chapter provides information on generic economic data, market and stock data, market trends and consumer expenditure for washing machines and washer-dryers. Each of these sections is explained in detail in the following.

2.1. Generic economic data from official European statistics

This section presents market and economic data based on official European statistics provided by Eurostat concerning production and trade data. Based on these data, the apparent EU-28 consumption of household washing machines including washer-dryers is calculated in section 2.1.3.

It has to be noted, however, that the statistical data have to be interpreted with care as there are some data gaps, especially for the domestic production. However, the statistical analysis can very well complement the general market analysis which is presented in subsequent sections as they do represent the official source for EU policy.

<u>Classification of household washing machines and washer-dryers in Eurostat statistics</u>

Prodcom (EU statistics on the production of manufactured goods, (Eurostat [n.d.])) and the European trade statistics (Eurostat 2015a) use different classifications for household washing machines and washer-dryers:

- Prodcom database: Clothes washing and drying machines, of the household type (Prodcom code 27511300)
- Trade database:
  - Fully-automatic household or laundry-type machines, of a dry-linen capacity ≤ 6 kg: (CN code 84501110)
    - Fully-automatic household or laundry-type front-loading washing machines, of a dry-linen capacity ≤ 6 kg: (CN code 84501111)
    - Fully-automatic household or laundry-type top-loading washing machines, of a dry-linen capacity ≤ 6 kg: (CN code 84501119)
  - Fully-automatic household or laundry-type washing machines, of a dry-linen capacity > 6 kg but ≤ 10 kg: (CN code 84501190) (top and front load)

The Prodcom category includes clothes washing machines, combined washer-dryers, but also clothes dryers altogether in one single code.

In the EU-28 trade statistics, the so called Combined Nomenclature codes (CN8) are used. The trade statistics differentiates by specifying washing machines only and further categorising according to capacity (≤ 6 kg or 6-10 kg) and/or format (front- or top loading). It is assumed, that these categories of the trade database also include combined washer-dryers (which do not have an own category, but also do not fall under “drying machines” for which other CN codes apply).

Please, note that the presented data may contain some inherent inconsistencies (e.g. when comparing Tables 2-3, 2-4 and 2-5) due to the different nature of the databases, methods used for data collection, and to some limitations existing in such statistics (e.g. precision, completeness).

This information and these inconsistencies will be analysed critically. Nevertheless, this is only one of the sources considered for describing the market and further input will be taken into due account if available.

2.1.1. EU Production of clothes washing and drying machines of the household type

2.1.1.1. Volume of EU production of clothes washing and drying machines of the household type

The following table shows data on the units of household clothes washing and drying machines produced, in the EU28 from 2007 to 2013 (Eurostat 2015a).

According to the Prodcom data, Poland, Italy and Germany are the main Member States (for which data are available) producing 'clothes washing and drying machines', followed by Spain and France. Besides Poland, all other production sites have declining production volume whereas Poland doubled the production between 2007 and 2013. In total, the volume of produced household clothes washing and drying machines in EU28 declined from 27.7 million units in 2007 by 26% to 20.5 million units produced in 2013.

However, it is important to note that data is missing for some producing Member states like Czech Republic or Germany. For UK, for example, production data are available until 2009 only, for Germany production data are not displayed in the statistics from 2012 on. This leads to a data gap of around 7 million units in 2013 of the listed production in single Member States compared to the EU 28 totals production volume.

Table 2.1: Volume (number of units) of 'Clothes washing and drying machines, of the household type' produced in the EU28 between 2007 and 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	0	0	0	0	0	0	0
Belgium	0	:	:	:	:	:	:
Bulgaria	0	:	:	:	:	:	:
Croatia	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0
Czech Republic	:	:	:	:	:	:	:
Denmark	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0
Finland	2	:	:	0	0	0	0
France	0	1,659,943	1,424,648	1,377,689	1,067,727	1,220,365	1,007,213
Germany	2,661,139	:	2,574,867	2,419,348	2,477,977	:	:
Greece	0	:	:	:	:	:	:
Hungary	:	:	:	:	:	:	:
Iceland	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0
Italy	9,681,266	8,495,725	5,407,054	5,098,767	4,782,322	4,524,574	4,315,817
Latvia	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0
Luxem-bourg	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0
Nether-lands	0	0	0	0	0	0	0
Norway	0	0	0	0	0	0	0

Declarant	2007	2008	2009	2010	2011	2012	2013
Poland	3,706,613	4,152,683	5,027,864	5,924,203	6,264,679	6,711,326	7,495,935
Portugal	0	0	0	0	0	0	0
Romania	0	:	:	14,701	:	:	:
Slovakia	0	:	:	:	:	:	:
Slovenia	0	:	:	:	:	:	:
Spain	2,470,484	2,002,840	1,689,876	1,272,514	:	1,300,123	1,013,725
Sweden	55,812	:	:	:	:	:	:
United Kingdom	1,477,174	2,538,108	2,244,032	:	:	:	:
EU28 TOTALS	27,736,546	24,812,568	21,163,985	21,046,139	20,645,799	20,305,038	20,516,768

":" means data not being available

2.1.1.2. Value of EU production of clothes washing and drying machines of the household type

The following table provides an overview of the value corresponding to the number of units produced in certain Member States and EU28 totals (cf. Table 2.1). It can be resumed that the total value of produced household washing machines in EU28 declined from 6.4 billion Euros in 2007 by 29% to 4.5 billion Euros in 2013; i.e. the production value decreased slightly more than the production volume.

Table 2.2: Value (in Euros) of 'Clothes washing and drying machines, of the household type' produced in the EU28 between 2007 and 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	0	0	0	0	0	0	0
Belgium	0	:	:	:	:	:	:
Bulgaria	0	:	:	:	:	:	:
Croatia	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0
Czech Republic	:	:	:	:	:	:	:
Denmark	0	0	0	0	0	0	0
Estonia	0	0	0	0	0	0	0
Finland	1.254.084	1.375.653	366.121	0	0	0	0
France	0	364.507.000	303.655.000	279.585.000	217.897.000	259.569.000	231.871.000
Germany	1.267.224.082	:	1.238.742.793	1.151.713.896	1.127.944.004	886.774.455	:
Greece	0	:	:	:	:	:	:
Hungary	:	:	:	:	:	:	:
Iceland	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0
Italy	1.866.729.000	1.635.573.000	1.099.828.000	1.071.993.000	989.943.000	951.759.000	899.542.000
Latvia	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0
Luxem-bourg	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0
Nether lands	0	0	0	0	0	0	0
Norway	0	0	0	0	0	0	0
Poland	790.942.649	912.843.541	1.012.044.205	1.182.905.575	1.136.946.755	1.290.793.701	1.391.240.095
Portugal	0	0	0	0	0	0	0

Declarant	2007	2008	2009	2010	2011	2012	2013
Romania	0	:	:	1.190.633	:	:	:
Slovakia	0	:	:	:	:	:	:
Slovenia	0	:	:	:	:	:	:
Spain	476.001.395	393.598.900	329.556.008	265.978.058	:	285.340.520	225.284.053
Sweden	19.011.470	:	:	:	:	:	:
United Kingdom	206.710.115	434.737.781	389.900.554	:	:	:	:
EU28 TOTALS	6.372.604.475	5.696.900.447	4.948.867.062	4.890.074.180	4.663.341.489	4.623.900.016	4.526.493.195

":" means data not being available

2.1.2. EU imports and exports of clothes washing and drying machines of the household type

The following tables provide an overview of the *value* of imports and exports of clothes washing and drying machines of the household type in the EU for the year 2013. Unfortunately, since 2008 no data regarding the *quantities* of exports and imports is available any more so that the following overviews only represent the MS specific values of exports and imports.

Based on value, Germany, UK and France appear to be the largest importing countries of household clothes washing and drying machines, followed by Italy, Netherlands, Sweden, Spain and Belgium.

A clear trend of rising or declining import values cannot be seen; for many Member States, the values have been more or less stable over the years, for some MS they have been declining (e.g. Sweden, Spain or Netherlands) whereas the value of imports has been increasing for others (e.g. Belgium, Germany or Italy, as well as EU28 totals).

Table 2.3: Value of imports of clothes washing and drying machines of the household type from 2007 to 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	107.859.640	107.658.210	115.979.120	127.402.350	121.206.540	115.218.510	119.229.380
Belgium	171.775.340	174.906.480	178.752.840	192.668.530	191.909.040	211.912.630	211.812.840
Bulgaria	49.164.930	41.246.580	31.094.920	32.425.720	26.100.650	29.461.990	31.309.390
Croatia	32.135.110	27.529.460	21.655.490	23.039.770	22.050.210	20.502.560	22.730.340
Cyprus	12.402.220	12.909.680	10.447.470	9.608.430	9.193.470	7.271.380	5.047.330
Czech Republic	77.157.990	80.712.660	80.967.560	77.314.410	83.233.660	85.979.860	91.479.250
Denmark	119.541.300	110.215.100	97.415.060	98.539.710	103.529.750	97.764.410	97.581.580
Estonia	11.175.840	9.386.070	6.265.920	8.416.690	8.265.820	1.456.360	11.537.130
Finland	101.798.270	92.777.380	61.494.880	65.432.840	70.059.750	65.286.130	59.319.750
France	566.309.800	531.191.420	552.783.200	556.897.430	576.550.160	580.437.220	554.764.620
Germany	800.016.110	786.040.090	782.266.790	914.464.020	924.941.040	943.852.650	914.545.660
Greece	98.270.46	103.078.920	93.877.000	86.004.910	65.867.420	51.977.720	57.327.010
Hungary	98.700.230	70.815.940	61.169.320	74.465.340	50.692.000	38.761.250	42.751.12
Ireland	72.826.250	61.996.680	49.694.600	43.806.050	47.571.520	48.238.560	49.890.600
Italy	255.810.230	234.360.790	250.174.420	299.309.970	284.097.020	273.179.260	263.282.570
Latvia	16.150.650	13.035.960	7.572.680	10.400.750	11.630.190	15.021.390	16.567.440
Lithuania	28.494.310	21.299.580	11.285.490	15.500.630	15.271.840	18.983.410	21.676.710
Luxembourg	13.032.380	15.846.980	17.203.870	15.366.850	11.981.500	11.193.900	12.277.640
Malta	4.153.660	4.903.630	4.337.740	3.634.640	4.559.050	4.235.330	5.195.060
Netherlands	304.879.330	280.315.610	282.544.330	291.557.800	267.105.290	272.342.390	245.352.590
Poland	228.684.900	193.395.510	144.887.940	146.589.630	165.053.520	166.303.830	156.110.400
Portugal	84.106.330	81.465.980	73.567.940	86.622.370	65.292.260	49.652.840	55.383.950
Romania	96.339.760	98.575.690	58.517.510	63.895.100	58.302.360	61.926.230	66.475.350
Slovakia	42.297.080	34.377.290	26.847.930	29.701.780	34.141.740	37.095.150	30.725.190
Slovenia	18.263.750	18.773.520	17.103.120	19.345.160	19.758.360	17.392.520	18.713.000
Spain	308.663.840	246.592.300	219.158.410	261.233.500	255.864.850	214.170.180	216.672.850
Sweden	245.134.670	226.409.700	224.250.950	209.551.590	202.005.380	209.001.960	218.492.390
United Kingdom	505.556.820	499.484.540	519.208.920	558.480.340	613.039.580	642.464.020	672.794.200
EU28 TOTALS	681.833.790	705.407.100	818.403.860	1.008.006.810	1.035.474.150	1.002.704.270	972.250.450

Table 2.4 provides an overview of the export values. Based on value, Poland by far, Italy and Germany appear to be the largest exporting countries of household clothes washing and drying machines, followed by Slovakia, Czech Republic, Spain and Sweden.

A clear trend of rising or declining export values cannot be seen; for many Member States, the values have been more or less stable over the years, for some MS they have been declining (e.g. France, Germany, Italy or UK) whereas the value of exports has been increasing for others (e.g. Czech Republic or Poland). Within EU28 totals, the value of exports has declined significantly from 1.8 billion Euros in 2007 to 0.8 billion Euros in 2013.

Table 2.4: Value of exports of clothes washing and drying machines of the household type from 2007 to 2013; source: (Eurostat 2015a)

Declarant	2007	2008	2009	2010	2011	2012	2013
Austria	7.509.580	6.310.690	6.302.520	11.286.900	11.906.610	10.912.830	12.493.000
Belgium	47.366.140	43.597.000	36.874.530	39.625.020	47.732.400	64.173.050	63.787.000
Bulgaria	3.199.030	2.671.090	3.014.860	5.006.750	3.783.240	3.024.390	2.590.230
Croatia	1.804.460	1.686.370	643.930	770.540	596.090	296.900	541.700
Cyprus	76.230	35.340	7.350	18.140	16.410	4.410	15.130
Czech Rep.	154.798.010	164.420.950	136.957.870	136.731.600	148.938.520	170.879.650	199.598.760
Denmark	11.506.480	11.371.740	9.032.290	7.539.820	9.847.170	21.673.280	18.954.130
Estonia	852.710	799.110	484.470	1.733.210	1.673.000	2.618.940	2.227.420
Finland	59.408.380	45.442.910	9.653.950	2.643.230	2.070.630	781.260	970.390
France	323.679.330	257.699.320	198.166.840	179.114.010	174.779.630	155.953.860	130.089.920
Germany	1.550.471.120	1.327.164.830	1.067.034.750	967.399.990	937.818.410	732.118.300	647.578.070
Greece	6.761.080	7.151.220	6.779.760	6.257.360	7.023.750	6.524.350	5.829.410
Hungary	44.468.850	24.421.720	21.477.890	21.272.980	8.499.440	8.964.110	9.945.940
Ireland	2.669.610	2.916.630	1.938.940	1.137.820	1.309.060	2.582.400	3.066.640
Italy	1.533.267.020	1.290.392.720	899.571.400	881.954.450	802.108.670	791.576.780	791.399.880
Latvia	1.419.010	1.860.770	1.965.870	5.731.900	6.458.280	8.293.450	8.965.880
Lithuania	5.189.710	2.552.430	2.630.850	5.874.670	6.087.240	7.419.130	8.980.620
Luxem-bourg	4.503.030	5.973.180	6.749.840	6.214.800	3.872.010	2.645.190	3.698.310
Malta		3.970	1.350	170		1.450	6.910
Nether-lands	65.154.660	74.507.260	47.087.470	77.255.580	67.235.160	72.265.330	67.845.520
Poland	756.202.550	621.666.130	918.957.190	1.133.065.950	1.156.333.880	1.232.965.330	1.355.472.630
Portugal	3.260.290	3.164.330	4.608.450	2.620.760	2.992.030	3.300.570	2.939.270
Romania	594.920	309.390	2.027.710	2.734.350	2.343.840	3.309.370	2.452.550
Slovakia	313.703.870	314.892.940	274.111.440	250.192.210	246.496.770	235.572.350	284.206.930
Slovenia	127.192.490	124.284.820	121.249.390	128.468.440	119.962.970	113.439.670	139.681.190
Spain	269.707.570	216.564.440	174.345.750	158.557.520	204.594.660	265.386.030	193.046.240
Sweden	156.105.110	151.557.520	153.334.700	192.061.390	190.243.600	199.591.340	183.253.200
United Kingdom	173.375.490	110.219.120	77.806.880	85.251.730	96.378.620	87.636.760	96.240.900
EU28 TOTALS	1.847.347.600	1.541.836.330	1.078.843.670	1.009.109.470	957.913.390	879.885.450	830.778.490

2.1.3. Apparent consumption of household washing machines

Apparent consumption of EU Member States generally can be calculated as follows:

Apparent consumption = Production + Imports – Exports

Unfortunately, since 2008 no data on quantities of exports and imports are available, only on values. In addition, also clothes drying machines are included in the data shown so far.

A rough estimation of the apparent consumption will be made by taking the average EU unit values of produced appliances (value, cf. Table 2.2, divided by volume, cf. Table 2.1) and apply them to the values of the import and export data (cf. Table 2.3 and Table 2.4) to derive an estimated import and export volume with the restrictions to the data quality as stated above.

Table 2.5: Estimated calculation of the apparent consumption of clothes washing and drying machines of the household type from 2007 to 2013; source: own calculation based on (Eurostat 2015a)

Clothes washing and drying machines, EU28 TOTALS	2007	2008	2009	2010	2011	2012	2013
Production Volume (cf. Table 2.1)	27,736,546	24,812,568	21,163,985	21,046,139	20,645,799	20,305,038	20,516,768
Production Value (cf. Table 2.2)	6,372,604,475	5,696,900,447	4,948,867,062	4,890,074,180	4,663,341,489	4,623,900,016	4,526,493,195
Calculated average unit value (prod.)	230	230	234	232	226	228	221
Value of imports (cf. Table 2.3)	681,833,790	705,407,100	818,403,860	1,008,006,810	1,035,474,150	1,002,704,270	972,250,450
Calculated volume of imports	2,964,495	3,066,987	3,497,452	4,344,857	4,581,744	4,397,826	4,399,323
Value of exports (cf. Table 2.4)	1,847,347,600	1,541,836,330	1,078,843,670	1,009,109,470	957,913,390	879,885,450	830,778,490
Calculated volume of exports	8,031,946	6,703,636	4,610,443	4,349,610	4,238,555	3,859,147	3,759,179
Calculated apparent consump-tion (prod+imp-exp)	22,669,095	21,175,919	20,050,994	21,041,386	20,988,988	20,843,717	21,156,913

Note: Volume expressed in number of units; Value expressed in EUR

The calculated apparent consumption of clothes washing and drying machines based on the estimations stated above has been rather stable with around 20 to 22 million units within the past years. It has to be noted that also clothes dryers and washer-dryers are included in this number, i.e. the volume of clothes washing machines solely is lower. An alternative method of estimation will be used in further phases of the study for quantifying the apparent consumption (cf. Task 5.1.3).

2.1.4. EU sales and Intra/Extra-EU28 trade of household washing machines

The following tables show the Intra- and Extra-EU trade of EU Member States with household washing machines (front-loaders ≤ 6 kg; top-loaders ≤ 6 kg, and machines > 6 but ≤ 10 kg) in 2014 according to (Eurostat 2015b).

The trade data suggest that for nearly all Member States, the Intra-EU trade is greater than the Extra-EU trade. Sales with top-loading washing machines ≤ 6 kg, especially the Extra-EU trade, is rather small compared to the front-loading machines. Slovakia, Poland and France have the largest number of exports from their country to other EU Member States (exports to Intra-EU); France, Germany and Poland also import most of top-loading machines from other EU Member States. Exports to extra-EU countries are very small at all, with France having the largest number of export.

Within the front-loading machines, appliances ≤6 kg and >6 to 10 kg have a comparable trade volume with differences in single Member States. For example, in some countries the trade with the smaller appliances is higher (e.g. Italy, Czech Republic, Slovakia or Poland; in Poland, however exports of appliances >6 – 10 kg to other EU Member States surpass the exports of smaller appliances). In other Member States, the trade with larger appliances is in a similar range or higher (e.g. Germany, Netherlands, France, Greece, or Sweden).

Table 2.6: Intra- and Extra-EU28 trade of Member States with household washing machines (front-loaders ≤ 6 kg) in 2014; source: (Eurostat 2015b)

	EU28_EXTRA		EU28_INTRA	
Country	Imports (units)	Exports (units)	Imports (units)	Exports (units)
Austria	19.009	1.584	116.824	38.132
Belgium	65.905	244	0	0
Bulgaria	28.368	508	43.056	4.321
Croatia	22.490	274	19.551	1.046
Cyprus	1.328		7.675	
Czech Republic	39.565	2.503	94.138	20.815
Denmark	9.808	6.027	42.564	8.709
Estonia	2.168	310	13.974	2.012
Finland	2.195	122	25.015	53
France	290.076	19.142	450.657	9.954
Germany	199.567	29.532	517.580	124.147
Greece	34.455	35	23.346	5.474
Hungary	20.054	1.636	63.599	7.351
Ireland	13.602		92.196	4.060
Italy	204.939	262.876	312.598	1.401.295
Latvia	3.981	3.908	17.801	7.208
Lithuania	11.753	5.162	24.446	3.622
Luxembourg			8.354	65
Malta	4.509		2.642	
Netherlands	28.327	564	131.009	35.928
Poland	191.690	243.524	134.594	1.302.757
Portugal	25.277	605	65.937	2.255
Romania	82.557	808	101.707	5.210
Slovakia	7.604	44.012	42.599	625.072
Slovenia	8.418	36.578	5.859	146.457
Spain	320.309	5.304	107.426	24.986
Sweden	53.086	34.045	92.321	44.993
UK	243.378	1.355	885.544	36.817

Table 2.7: Intra- and Extra-EU28 trade of Member States with household washing machines (top-loaders ≤ 6 kg) in 2014; source: (Eurostat 2015b)

PARTNER	EU28_EXTRA		EU28_INTRA	
Reporter	**Imports (units)**	**Exports (units)**	**Imports (units)**	**Exports (units)**
Austria	365	130	9.993	593
Belgium	257	873	0	147
Bulgaria		10	2.913	81
Croatia	133	356	4.585	417
Cyprus			43	
Czech Republic		21	50.204	32.265
Denmark	85	71	14.433	59
Estonia	1	709	7.753	292
Finland	73	0	35.338	34
France	27.558	19.883	368.497	102.804
Germany	703	12.736	154.706	15.058
Greece	37		15.828	22
Hungary	0	1.226	58.193	4.638
Ireland			365	1
Italy	2.354	57.189	65.132	89.845
Latvia	9	228	3.674	978
Lithuania	179	1.872	6.625	62
Luxembourg			446	115
Malta			183	
Netherlands	1.467	5	10.048	2.398
Poland	547	53.746	115.285	298.675
Portugal	21	1	509	18
Romania	1	368	19.618	125
Slovakia	1	107.679	13.735	569.887
Slovenia	2	887	2.275	473
Spain	3.309	8.900	23.387	58
Sweden	1.077	18.772	34.866	20.246
UK	62	51	2.344	187

Table 2.8: Intra- and Extra-EU28 trade of Member States with household washing machines (> 6 but ≤ 10 kg) in 2014; source: (Eurostat 2015b)

PARTNER	EU28_EXTRA		EU28_INTRA	
Reporter	Imports (units)	Exports (units)	Imports (units)	Exports (units)
Austria	19.284	1.114	96.587	9.993
Belgium	106.471	1.649	0	134
Bulgaria	11.762	262	27.806	2.078
Croatia	8.786	297	28.185	200
Cyprus	1.084		3.591	
Czech Republic	15.293	2.080	52.287	12.776
Denmark	8.175	1.599	94.465	3.590
Estonia	263	1.555	6.447	496
Finland	9.329	607	73.901	289
France	275.623	4.214	439.486	6.990
Germany	176.676	246.283	846.176	601.618
Greece	48.983	534	63.718	6.360
Hungary	9.361	4.389	37.285	9.382
Ireland	5.674		52.511	1.982
Italy	148.648	106.796	210.525	215.483
Latvia	3.991	913	19.087	11.549
Lithuania	1.011	3.428	15.468	608
Luxembourg			18.380	6.710
Malta	2.949	1	3.031	
Netherlands	49.127	309.815	412.940	231.526
Poland	100.145	131.344	83.163	1.977.542
Portugal	23.619	1.239	89.571	1.517
Romania	35.171	50	49.960	2.540
Slovakia	6.343	3.963	20.823	15.972
Slovenia	6.008	139.062	16.875	117.568
Spain	117.521	30.727	249.377	275.758
Sweden	56.418	75.097	287.950	104.417
UK	255.923	633	533.245	27.849

2.2. Market, stock, sales and trends

Different approaches did allow getting some insight into the market and understanding, how it developed in the past and how it may develop in future.

A picture of the stock and sales of washing machines is provided in a study conducted under the supervision of the European Commission in order to assess the impacts of already existing ecodesign regulations (2.2.1). A deeper analysis of the market of washing machines and washer-dryers is also provided in the subsequent sections. In particular, key information from the testing of 50 models of washing machines on the market in 2012-2013 is reported (2.2.4). These data will be used to derive the Life Cycle Cost inputs later in Task 5.

2.2.1. Market structure of the European white goods industry

According to (Europe Economics 2015), across the EU28 there were over 3,600 firms that manufactured “domestic appliances” in 2012. This included large original equipment manufacturers (OEMs) such as Electrolux AB, BSH Hausgeräte GmbH and Indesit SpA, all of which are among the ten largest firms in the world. However it also includes a much larger number of smaller firms working in the sector. The share of SMEs is accounting for 19 per cent of turnover in the domestic appliances sector. The number of direct employees in the domestic appliances sector in the EU28 was some 211,000 in 2012, down from around 231,000 in in 2009. The country where the most people are directly employed in the manufacture of domestic appliances was Germany, at nearly 50,000. Of the major manufacturers, domestic appliances represented a greater share of total employment in Italy and – outside the EU – Turkey, reflecting the presence of major OEMs such as Indesit SpA in Italy and Arcelik in Turkey. There are other, smaller economies, where the number of employees as a share of total employment is larger, particularly Slovenia and Hungary. (Europe Economics 2015).

Manufacturers

The European white goods industry in 2012 was dominated by seven major players, as shown in Table 2.9. BSH Hausgeräte was ranked number one in Europe, and number 3 globally. Electrolux was ranked number 2, at both European and global level. Indesit and Whirlpool were number 3 and 4, respectively, in Europe. They are followed by Samsung, LG and Miele. Globally, Whirlpool was number 1 player in 2012. Other important players are Haier, Amica and Fagor (Capgemini Consulting 2012). Indesit has been recently bought by Whirlpool (Livesey 2014).

Table 2.9: Major players 2010 in the in European white goods industry; source: (Capgemini Consulting 2012)

Company	Main brands (non-exhaustive)	Total turnover* in Europe (2010, bln €)	European ranking	Total turnover* (2010, bln €)	Global ranking
BSH	Bosch, Siemens Gaggenau, Neff	6.7	1	8.4	3
Electrolux**	Electrolux, AEG, Zanussi	4.8	2	11.5	2
Indesit (meanwhile belonging to Whirlpool)	Hotpoint, Indesit, Scholtès	2.7	3	2.9	
Whirlpool**	Whirlpool, Bauknecht, Ignis, KitchenAid	2.2****	4	13.0	1
Samsung**	Samsung	1.7***		7.5	

LG**	LG	1.2***		6.1	
Miele	Miele	--		2.8	
* Not all turnover is white goods related. Figures most of the time concern the overall home appliance turnover, including small home appliances.					
** Converted to €, based on June 2010 currency rates.					
*** High level estimate, based on published European Turnover share for all product groups.					
**** EMEA figure, assuming that turnover in Middle East and Africa is small compared to Europe					

Leading manufacturers operate numerous production locations in different European countries, mainly in Italy, Poland, Germany, Spain, Hungary and Turkey. Each production location is specialized in one product group and supplies whole of Europe.

With respect to washing machines and washer-dryers only, stakeholders involved in the elaboration of this preparatory study have indicated the key players for the European market as shown in the table below.

Table 2.10: Major European manufacturers of washing machines and washer-dryers (Own elaboration based on stakeholder feedback)

Washing machines	Washer-dryers
Arcelik Group BSH Group Electrolux Group Whirlpool-Indesit Group	BSH Group Candy Group Electrolux Group LG Group Whirpool-Indesit Group
Other key players: LG Group, Samsung Group, Candy Group. Some of them have also production in Europe.	

Retail sector

Retail channels for white goods are diverse: there is a large number of smaller retailers specialized in white goods and household appliances, large grocery chains, kitchen manufacturers and resellers, mail-order companies and online shops. (Capgemini Consulting 2012) Data of the importance of e-commerce when purchasing washing machines and washer-dryers have not been found. Generally, the e-commerce of white goods (category “Electronics and Appliances”) is supposed to differ widely throughout the European countries, as shown for the example of Germany and Great Britain in 2012 (see Figure 2.17). As in Great Britain 42.3% of Electronics and Appliances were bought online, in Germany only 25.5% were sold by this purchase channel.

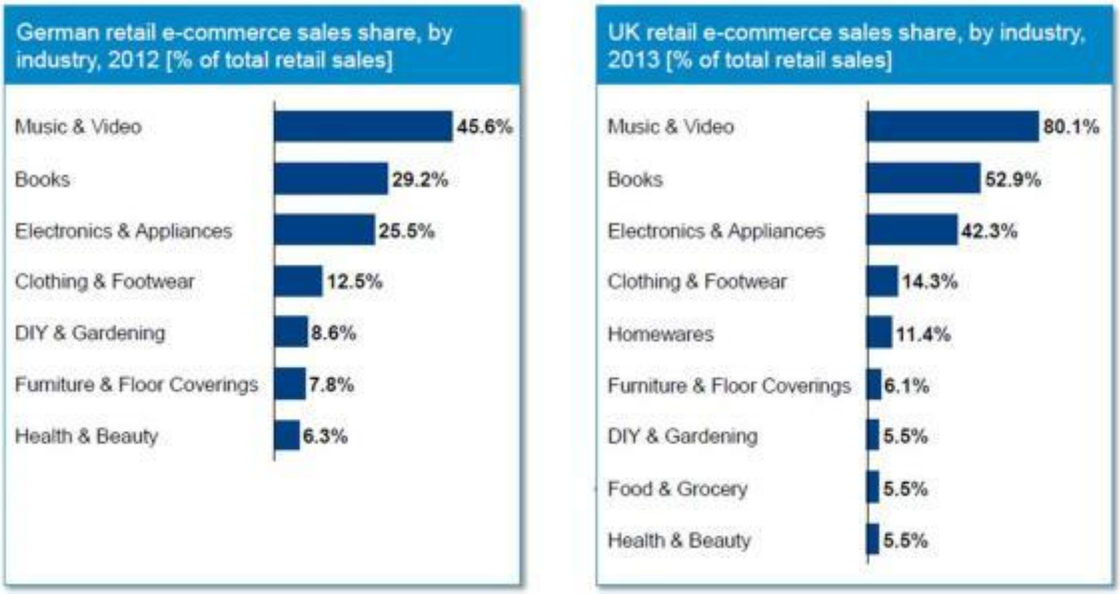


Figure 2.1: E-commerce with household Electronics and Appliances in 2012; source: (Bachl & Koll 2013)

2.2.2. Penetration rates of washing machines and washer-dryers

Penetration rate of washing machines

Based on data from Euromonitor International Passport database (http://www.euromonitor.com/passport), cited by (JRC IPTS 2014a), in 2013 92% of households in Europe had a **washing machine**, in 19 countries the ownership rate was 90% or over. Sweden (79%) and Denmark (81%) have the lowest known washing machine ownership rates due to the way laundry is typically carried out in the Nordic countries. In apartment buildings, student residences, etc. there are typically communal laundry rooms available for use by residents which limits the need for household washing machines. However, many countries are nearing (or may have already reached) saturation in terms of washing machine ownership. In countries such as Spain, Austria and the Czech Republic, ownership of washing machines is 99%. According to the "Omnibus" study (VHK et al. 2014), it is not expected that ownership will increase to 100% as a certain share of households use common laundry rooms.

Penetration rate of washer-dryers

Penetration of **washer-dryers** in European countries is very different from country to country (Figure 2.2). In many European countries, less than 4% of households possess a washer-dryer. Lowest penetration can be observed in Turkey, Romania, Czech Republic and Germany; the highest share of washer-dryers with around 11% is in United Kingdom, followed by Portugal (around 8%) and Austria (around 7%). In Denmark, France and Netherlands, the penetration is between 5 and 6%. Overall, an increase of the penetration of washer-dryers is to be observed. According to market observations by Topten, for example, there are more and more manufacturers offering and promoting them which is expected to lead to an increasing demand in the near future (TIG 2015b).

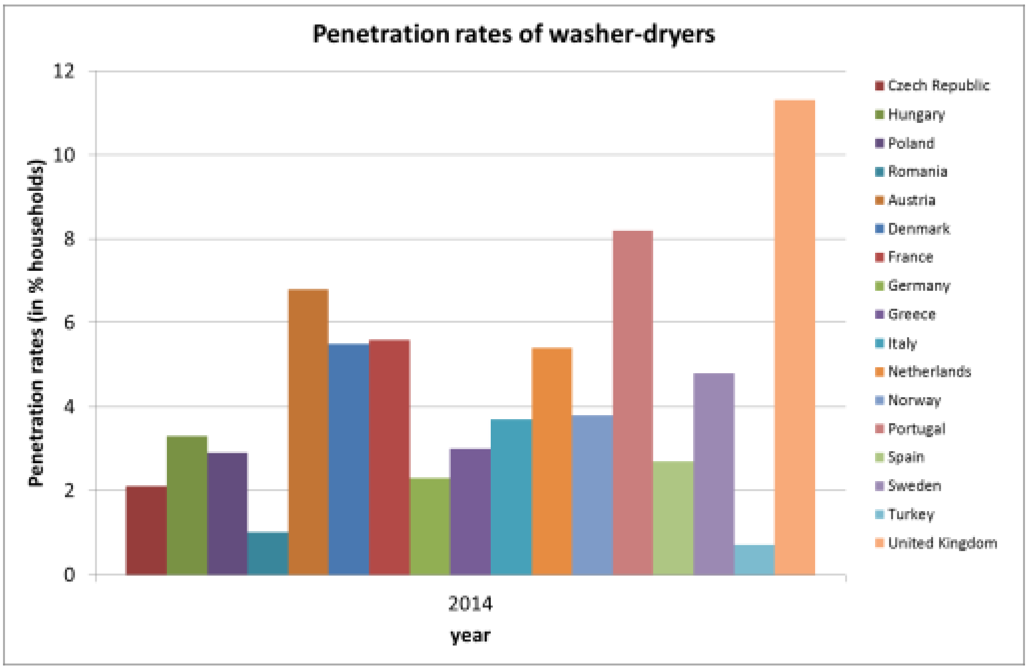


Figure 2.2: Washer-dryer penetration rate in households of various European countries; source: (Euromonitor International 2014)

To sum up, it could be assumed that about 92% of families in Europe have a washing machine in their household, while the EU average share of owners of washer-dryers is only about 4%. This would mean that 6-8% of families rely on a different system to wash their laundry.

Stakeholders involved in the elaboration of this study have reported that the penetration for washing machines is constant to slightly growing, and that the indicated saturation level seems realistic. A penetration of as much as 4% for washer-dryers also seems realistic according to stakeholders' feedback. The ratio washing machines to washer-dryers would thus be 23 : 1 or, in other words, washer-dryers would represent 4% of the total number of washing machines and washer-dryers.

2.2.3. Stock and sales data for washing machines and washer-dryers

2.2.3.1. Study "Ecodesign Impact Accounting"

The European Commission has identified a need to systematically monitor and report on the impact of Ecodesign, Energy Labelling, Energy Star and Tyre Labelling measures, including potentially new forthcoming actions, with a view to improve its understanding of the impacts over time as well as its forecasting and reporting capacity. With contract no. ENER/C3/412-2010/FV575-012/12/SI2.657835 DG Energy has contracted Van Holsteijn en Kemna B.V. (VHK) to undertake this exercise (VHK 2014 / Status 2013). The accounting method developed in this study (ECODESIGN IMPACT ACCOUNTING; Part 1 – status Nov. 2013) provides a practical tool to achieve those goals.

The accounting covers projections for the period 2010-2050, with inputs going as far back as 1990 and earlier. Studies of 33 product groups (including Lot 14 on washing machine and dishwashers) with over 180 base case products were harmonised and complemented to fit the methodology. For the period up to 2025-2030 inputs were derived from the available studies. The period beyond 2025-2030 is an extrapolation of the existing trend without any new measures, i.e. it is not in the scope of this study to develop new policies.

Projections use two scenarios: a 'business-as-usual' (BAU) scenario, which represents what was perceived to be the baseline without measures at the moment of the decision making, and an ECO scenario that is derived from the policy scenario in the studies which come closest to the measure taken. The BAU scenario is not a 'freeze' scenario; it is derived from extrapolating historical trends at the time of the preparatory study analysis, including possible ongoing trends in energy efficiency improvement and emission abatement. The ECO scenario is the scenario with the impact of known Ecodesign, Energy Labelling, Energy Star, and Voluntary Agreements. Up to 2020-2030 it is derived from Impact Assessment and preparatory study scenarios for the selected/proposed measures. Longer term scenarios are extrapolations of the trends, but do NOT assume that new measures will be introduced (it was not within the study scope to predict new long-term measures). All prices, rates and Euro values are in 2010 Euros, i.e. inflation corrected (at 2%) to 2010.

For **washer-dryers**, the study on Impact Assessment by (VHK 2014 / Status 2013) (VHK et al. 2014) did not provide separate data. As the study is based on ENER Lot 14 data where washer-dryers were excluded from the scope, they are also not included in the set of data presented above. Data on stock and sales of washer-dryers thus will be derived from other sources (cf. following sections) to be taken as Life Cycle Cost inputs for further calculations (cf. Task 5.1.3)

Regarding **washing machines**, this study reports some increase related to the inclusion of new member states in the late 90's and beginning of the 00's, but foresees a relative constant level for the period from 2015 to 2050 (Figure 2.3) reflecting almost 100% penetration in European households. VHK does not give data on penetration, and uses sales and lifetime information to calculate the stock.

Regarding stock data, (VHK 2014 / Status 2013) assumes for the year 2015 a stock of 196.8 million units of washing machines; the sales are projected to be around 13 million units in 2015 (cf. Figure 2.3).

For calculating the expected change in energy consumption and related greenhouse gas emissions the study makes some essential assumptions (Table 2.11). While the size of the washing machine is seen as rather constant after 2020 (in terms of rated capacity and used capacity measured per cycle), the average washing temperature is assumed to decrease almost uniformly by about 20 Kelvin between 2020 and 2050 down to about 17 °C in 2050. However, according to stakeholder feedback, having on average 17 °C programme temperature in 2050 seems to be very low, Taking these basic input parameters and the data about BAU and ECO scenarios from Lot 14 the consumption of washing machine per cycle and per year can be calculated for a washing machine on sale for all years (Figure 2.4).

Using the stock model as developed by (VHK 2014 / Status 2013) with the assumption of constant 15 years life time the energy used for a washing machine on stock in all years can be calculated (Figure 2.5). These calculation prognoses a significant difference of the total amount of energy used per year between the BAU and the ECO scenario for about 75 kWh per year. This is mainly caused by the reduction in average wash temperature. Following these calculations for the ECO scenario a total energy consumption for automatic laundry washing in EU is estimated to be at 15 TWh elec. in 2050 causing 8 MtCO2 eq./a greenhouse gas emissions (cf. Figure 2.6 and Figure 2.7). Notably, this is half as high as it is calculated for automatic dishwasher use.

All data is summarised in Table 2.11.

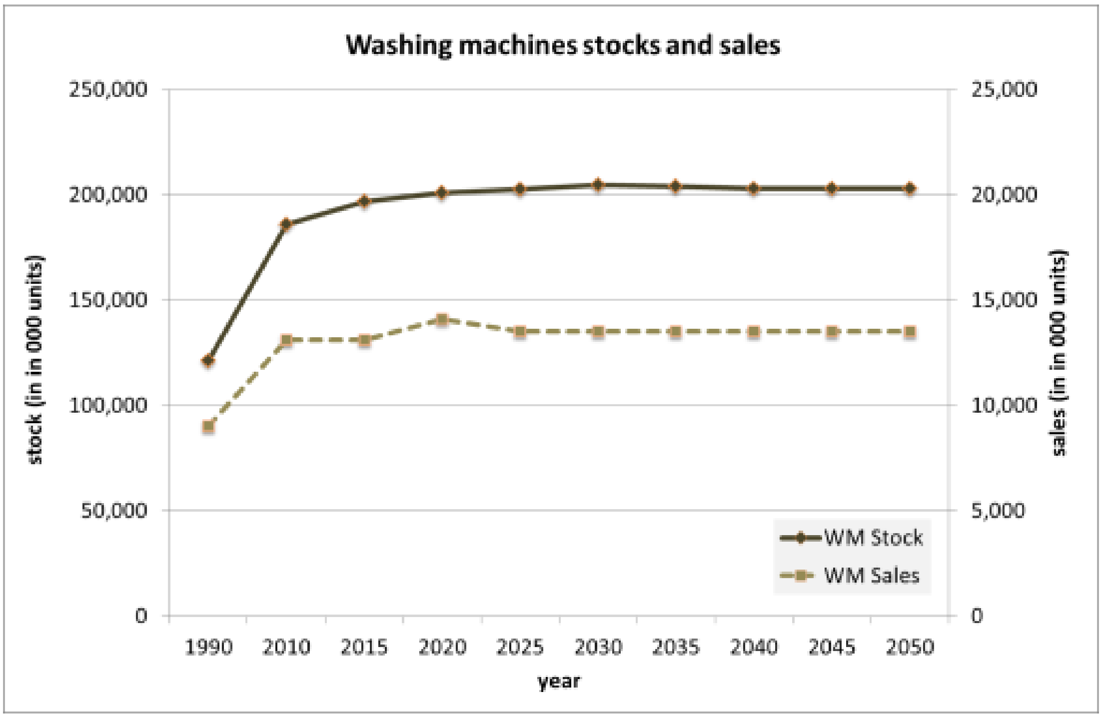


Figure 2.3: **Sales and stock of washing machines in the European market from 1990 to 2050 – please note that the interval 1990-2010 is not represented proportionally in the horizontal axis (data from (VHK 2014 / Status 2013))**

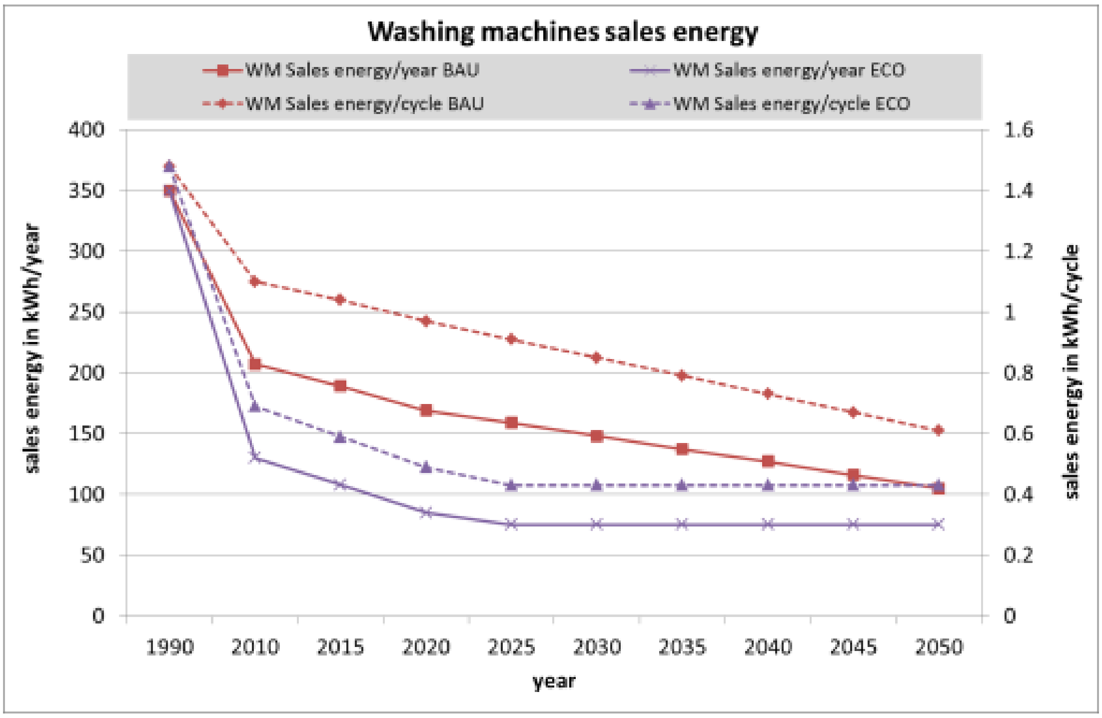


Figure 2.4: Energy consumption of the washing machines on sale in the European market from 1990 to 2050 – please note that the interval 1990-2010 is not represented proportionally in the horizontal axis (data from (VHK 2014 / Status 2013))

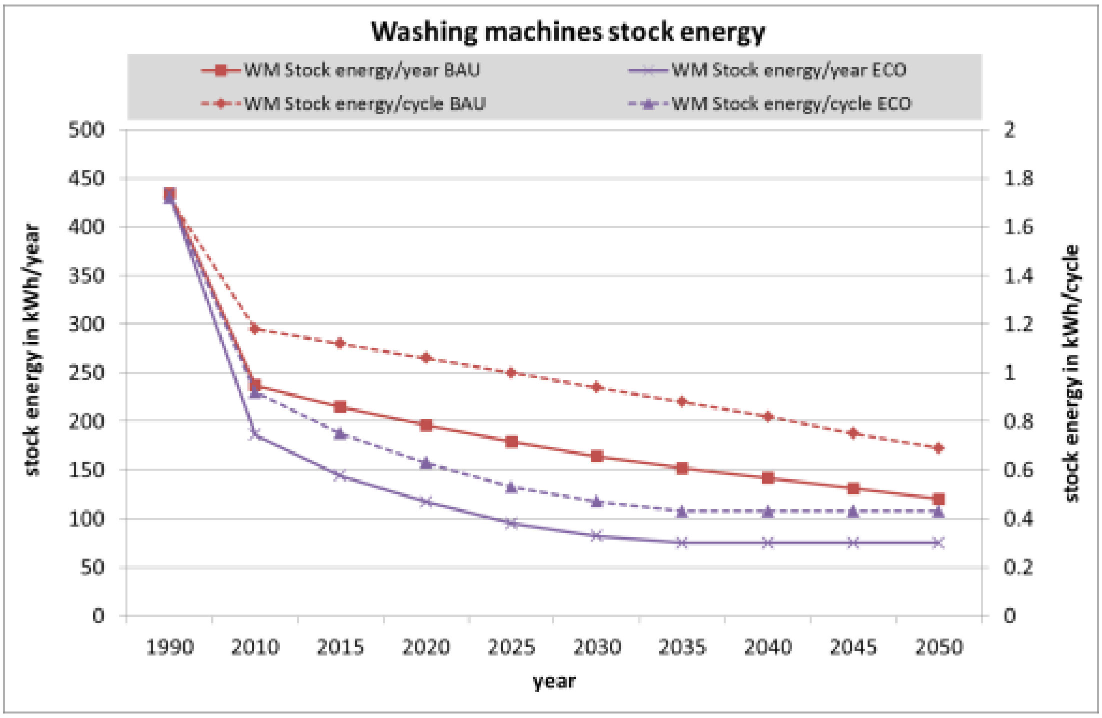


Figure 2.5: Energy consumption of the stock of washing machines installed in the European market from 1990 to 2050 – please note that the interval 1990-2010 is not represented proportionally in the horizontal axis (data from (VHK 2014 / Status 2013))

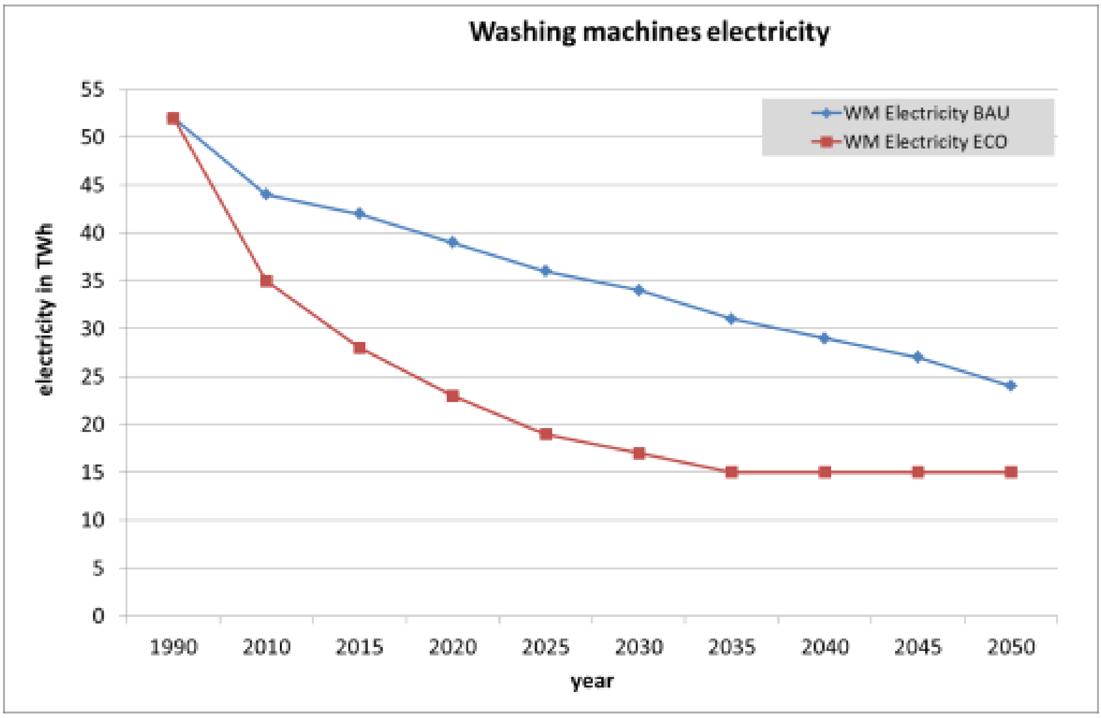


Figure 2.6: Total electricity consumption of installed washing machines in the European market from 1990 to 2050 – please note that the interval 1990-2010 is not represented proportionally in the horizontal axis (data from (VHK 2014 / Status 2013))

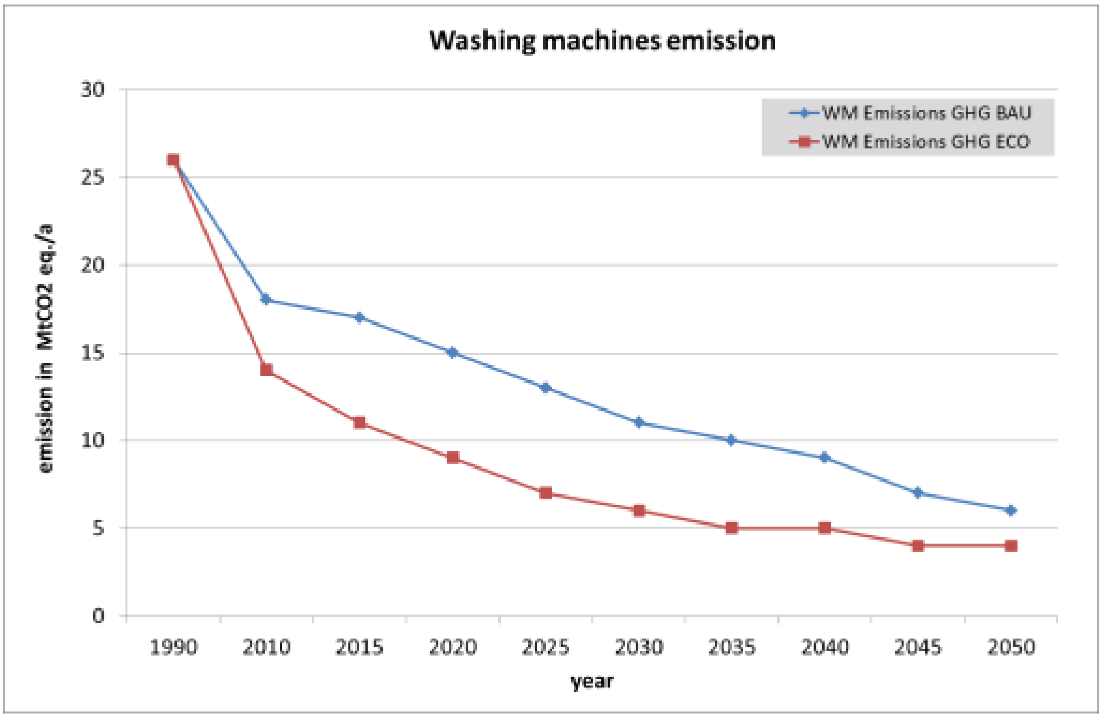


Figure 2.7: Total greenhouse gas emissions of washing machines installed in the European market from 1990 to 2050 (data from (VHK 2014 / Status 2013))

Table 2.11: Summary of data regarding washing machines from ECODESIGN IMPACT ACCOUNTING (VHK 2014 / Status 2013)

Data Washing machines	unit	year									
		1990	2010	2015	2020	2025	2030	2035	2040	2045	2050
Stock	in 000 units	121,000	185,828	196,821	200,805	202,648	204,744	203,893	202,766	202,766	202,766
Sales	in 000 units	9,000	13,099	13,099	14,081	13,518	13,518	13,518	13,518	13,518	13,518
Programme temperature	°C	56	43	39.7	36.4	33.2	29.9	27	23	20	17
Rated capacity	kg/cycle	4.1	6.8	7.1	7.6	7.6	7.6	8	8	8	8
Real (rated) load	kg/cycle	2.9	3.7	3.8	4	4	4	4	4	4	4
Cycles/year per unit (estimated)	cyc/a	237	189	182	174	174	174	174	174	174	174
SAEc (EEI=100)	kWh/a	246	371	387	410	410	410	410	410	410	410
Laundry washed per year	Mt	83	131	138	140	141	142	142	141	141	141
Sales energy/cycle BAU	kWh/cycle	1.48	1.1	1.04	0.97	0.91	0.85	0.79	0.73	0.67	0.61
Sales energy/year BAU	kWh/a	350	207	189	169	159	148	137	127	116	105
Sales energy/cycle ECO	kWh/cycle	1.48	0.69	0.59	0.49	0.43	0.43	0.43	0.43	0.43	0.43
Sales energy/year ECO	kWh/a	350	130	108	85	75	75	75	75	75	75
Stock energy/cycle BAU	kWh/cycle	1.72	1.18	1.12	1.06	1.00	0.94	0.88	0.82	0.75	0.69
Stock energy/year BAU	kWh/a	434	237	215	196	179	164	152	142	131	120
Stock energy/cycle ECO	kWh/cycle	1.72	0.92	0.75	0.63	0.53	0.47	0.43	0.43	0.43	0.43
Stock energy/year ECO	kWh/a	434	186	144	117	95	82	75	75	75	75
Electricity BAU	TWh elec	52	44	42	39	36	34	31	29	27	24
Electricity ECO	TWh elec	52	35	28	23	19	17	15	15	15	15
Emissions GHG BAU	MtCO2 eq./a	26	18	17	15	13	11	10	9	7	6
Emissions GHG ECO	MtCO2 eq./a	26	14	11	9	7	6	5	5	4	4
Unit price BAU	€ (2010)	449	474	466	459	449	449	449	449	449	449
Unit price ECO	€ (2010)	449	541	559	574	565	537	511	486	463	449
Revenue Wholesale BAU	m€ (2010)	121	186	183	194	182	182	182	182	182	182
Revenue Wholesale ECO	m€ (2010)	121	213	220	242	229	218	207	197	188	182
Revenue Industry BAU	m€ (2010)	1628	2503	2461	2606	2445	2445	2445	2445	2445	2445
Revenue Industry ECO	m€ (2010)	1628	2858	2952	3258	3078	2929	2787	2651	2523	2445

2.2.3.2. Sales data of washing machines and washer-dryers – topten.eu / GfK data 2014

In June 2015, topten.eu published a study "Energy efficiency of White Goods in Europe: monitoring the market with sales data" (Michel et al. 2015). The study reports about 'Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014'. Inter alia, GfK-data on washing machines sales 2014 in Europe (covering 21 European countries) as well as selected countries (France, Portugal, and partly Switzerland) are presented.

<u>Total washing machine sales</u>

In 2014, 15.2 million washing machine units were sold in EU-21. Sales numbers increased from 13.5 million to 15.1 million units from 2004 to 2007 in the EU-21 considered in that study, then fluctuated around 15 million units per year (cf. Figure 2.8).

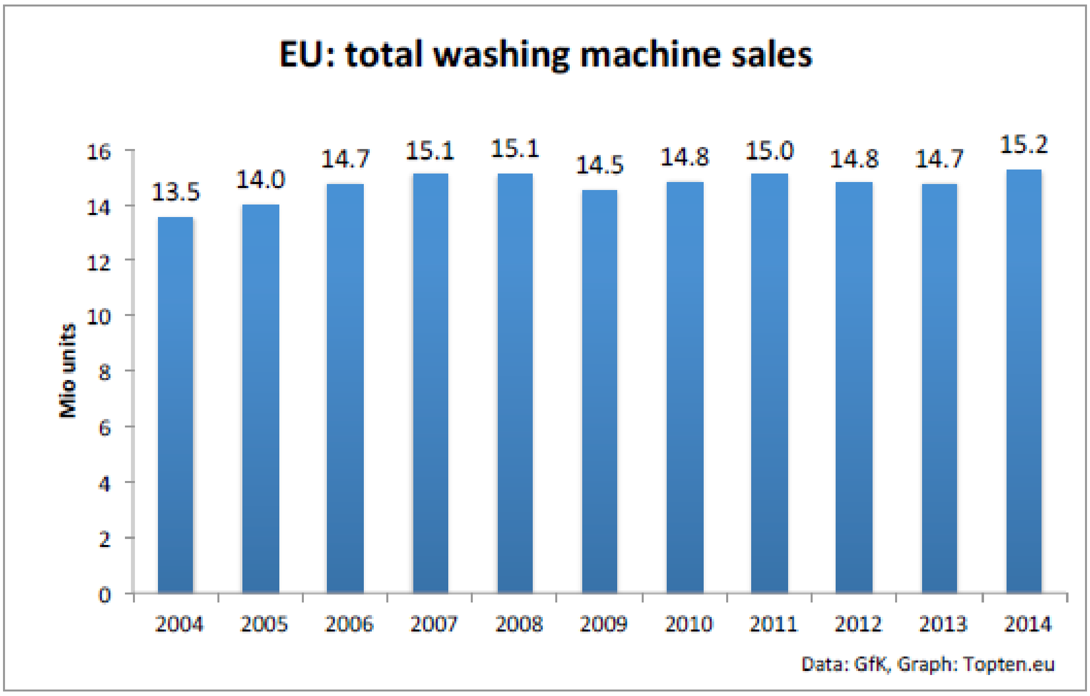


Figure 2.8: EU: total washing machines sales; source: (Michel et al. 2015)

<u>Energy efficiency classes of EU washing machine sales</u>

In detail the data show that in 2014, 43% of the sales across the EU were in the top class A+++ (cf. Figure 2.9), meaning that three years after the current energy label became compulsory, close to half of the sold washing machines were in the top class.

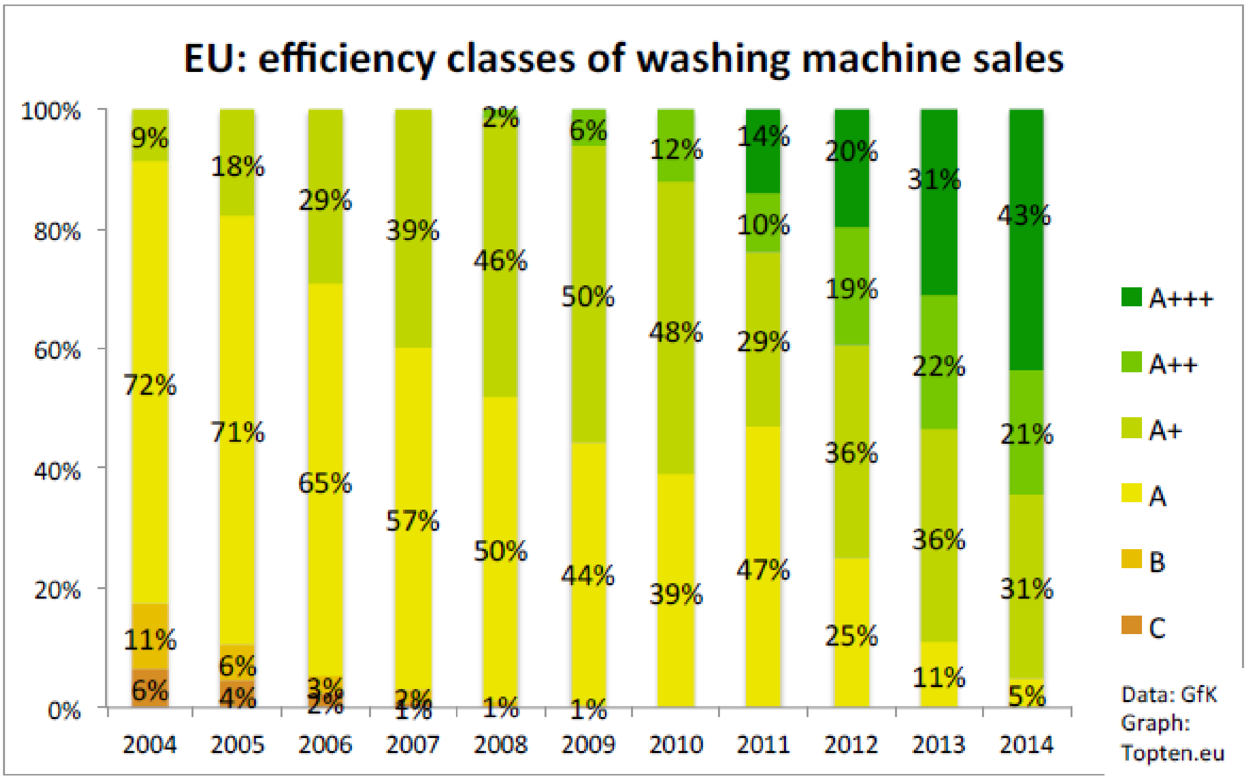


Figure 2.9: **EU: energy efficiency classes of washing machine sales; source: (Michel et al. 2015)**

<u>Average energy and water consumption of washing machine sales</u>

In 2014, average declared annual energy consumption of the sold washing machines was 185 kWh per year in the EU-21; the average water consumption for EU-21 is reported to be 9.9 kL per year (cf. Figure 2.10 and Figure 2.11). However, the exact values have to be read with caution, as for the energy and water consumption the declaration changed from litres / cycle (multiplied with 220 cycles per year for this figure) to annual consumption with the introduction of the new Energy Label in December 2011 and also the measurement standard changed. Thus, the values are not fully comparable, but can show trends before and after 2011.

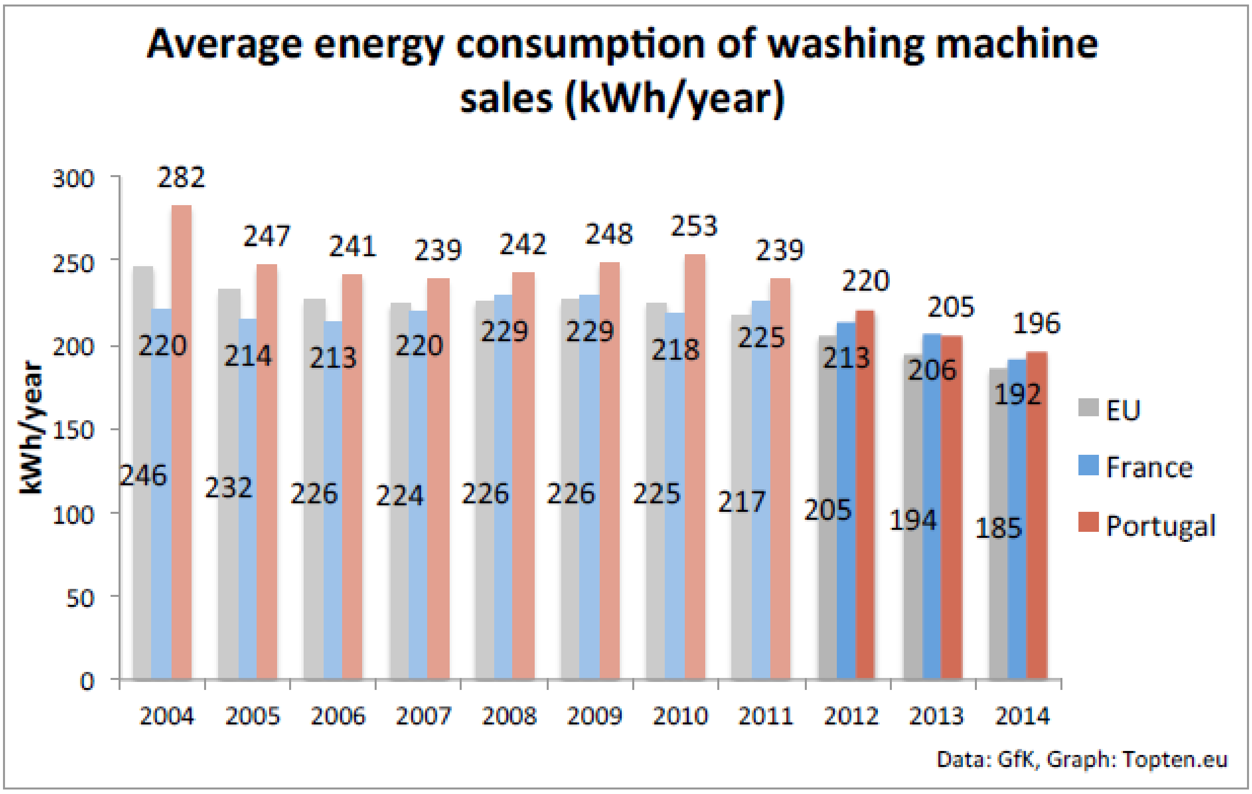


Figure 2.10: **Average energy consumption of washing machine sales; source: (Michel et al. 2015)**

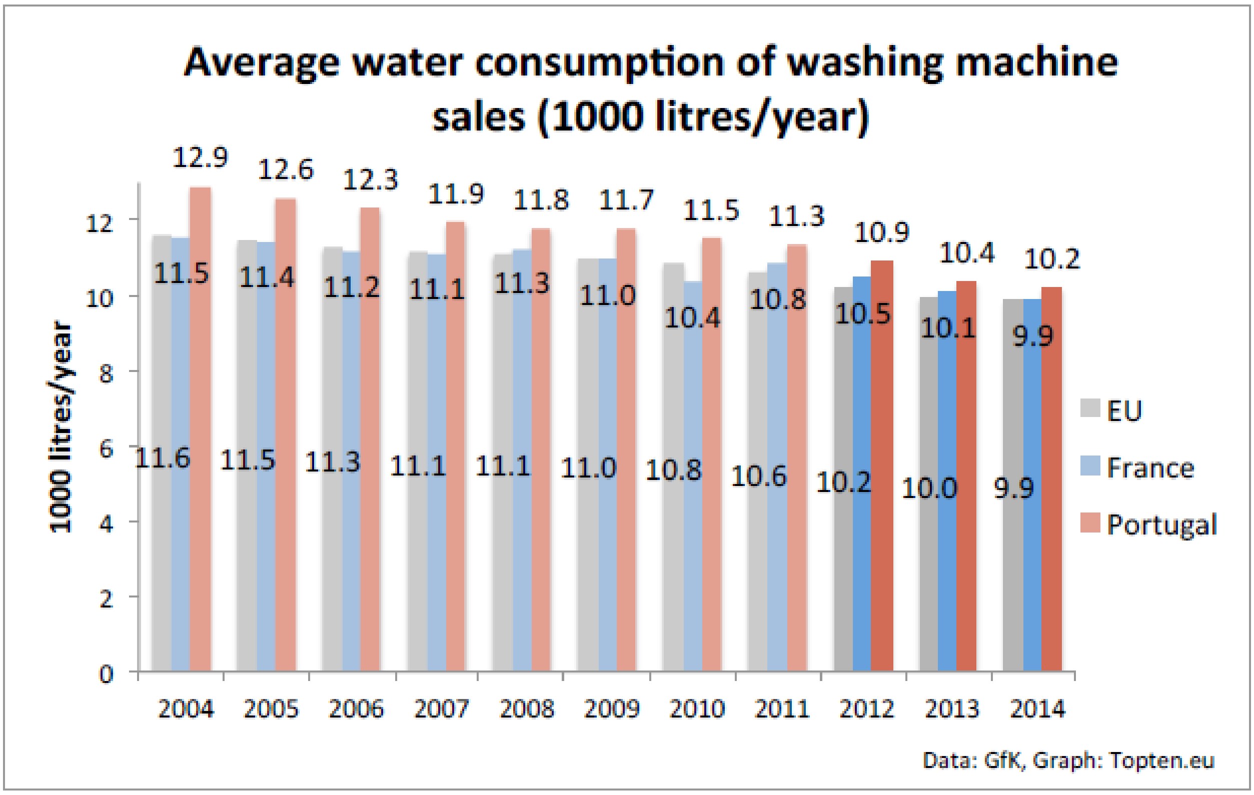


Figure 2.11: **Average water consumption of washing machine sales; source: (Michel et al. 2015)**

The following Figure 2.12 and Figure 2.13 show the average declared energy and water consumption between efficiency classes. According to (Michel et al. 2015), the reduction in declared energy and water consumption between the classes is small to nearly non-existent. The average declared energy consumption of all class A+ and A++ washing machines that were sold in 2014 is virtually the same. The average declared water consumption of A++ and A+++ washing machines is even identical.

(Michel et al. 2015) see the size correlation shown Figure 2.15 below as the probable reason for the negligible reduction in resource consumption by efficient washing machines.

Washing machines sold in the two top efficiency classes are sold for clearly larger capacities than A+ (and A) models. While A+ washing machines are mainly sold for washing 6 kg and less laundry, most A++ and A+++ sales are for 7 kg. 41% of the sold A+++ washing machines are sold for washing 8 kg or more laundry.

Calculations made by topten.eu show that a difference of four classes (A to A+++) results in a reduction in energy consumption of 23%.

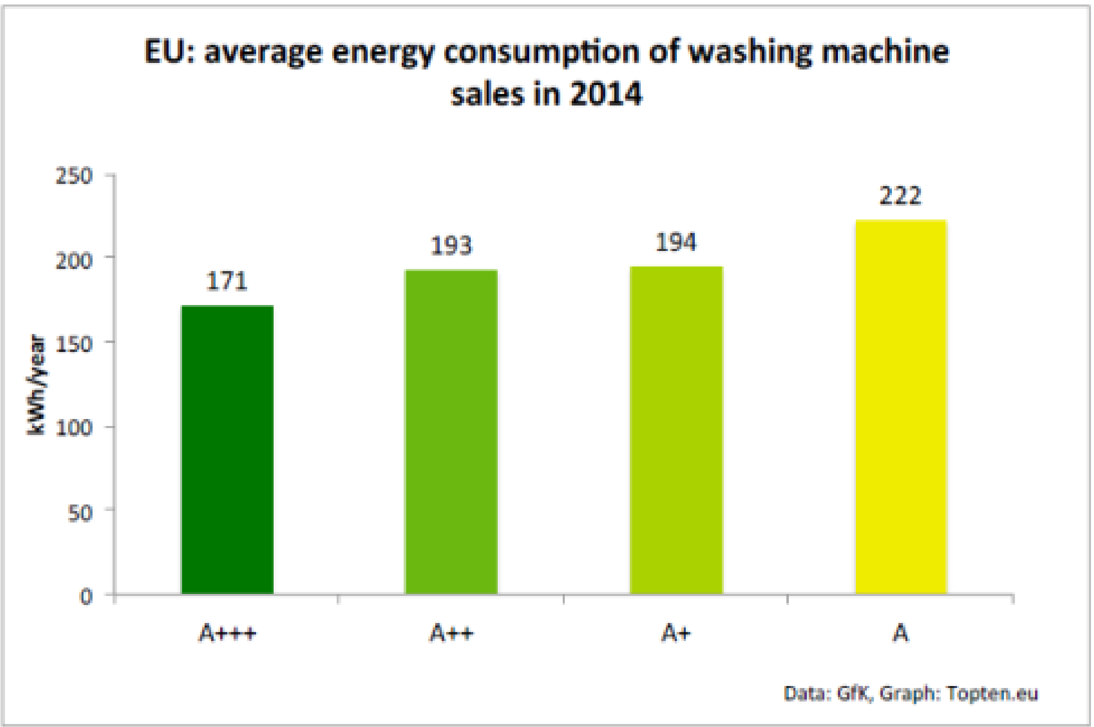


Figure 2.12: **EU: average declared energy consumption of washing machine sales according to classes, 2014; source: (Michel et al. 2015)**

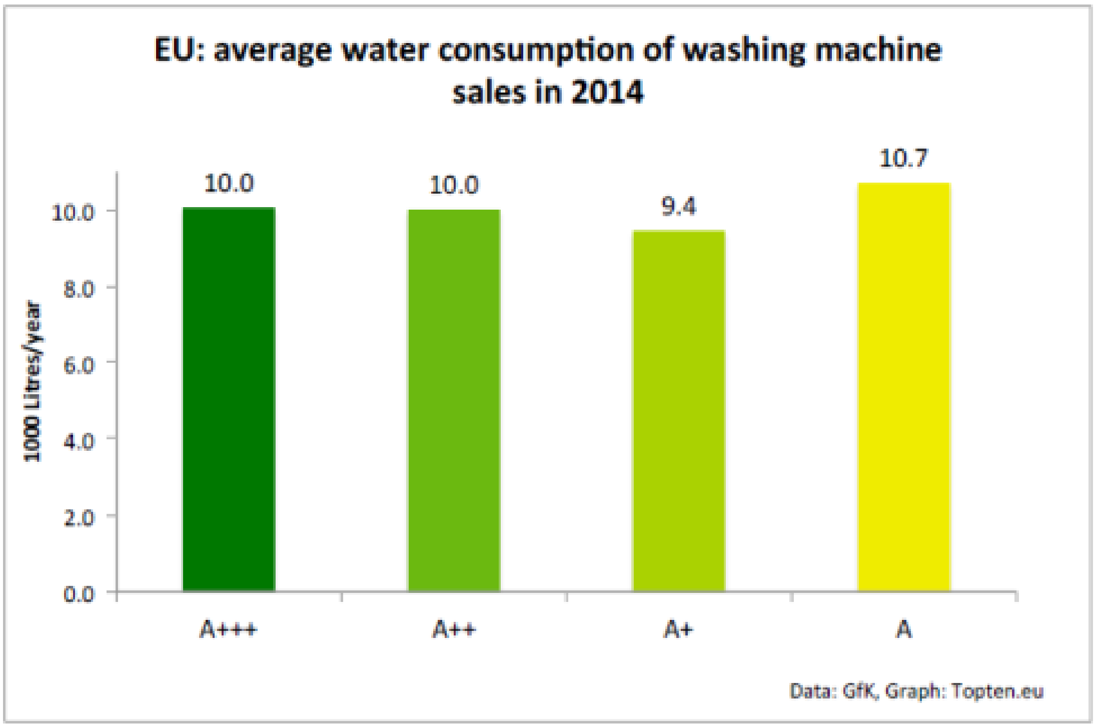


Figure 2.13: **EU: average declared water consumption of washing machine sales according to classes, 2014; source: (Michel et al. 2015)**

<u>Capacities of EU washing machine sales</u>

In 2014, nearly 60% of all washing machines sold across the EU-21 were declared to be designed for washing 7 kg laundry and more (35% at 7 kg, 19% at 8 kg and 6% > 8 kg).

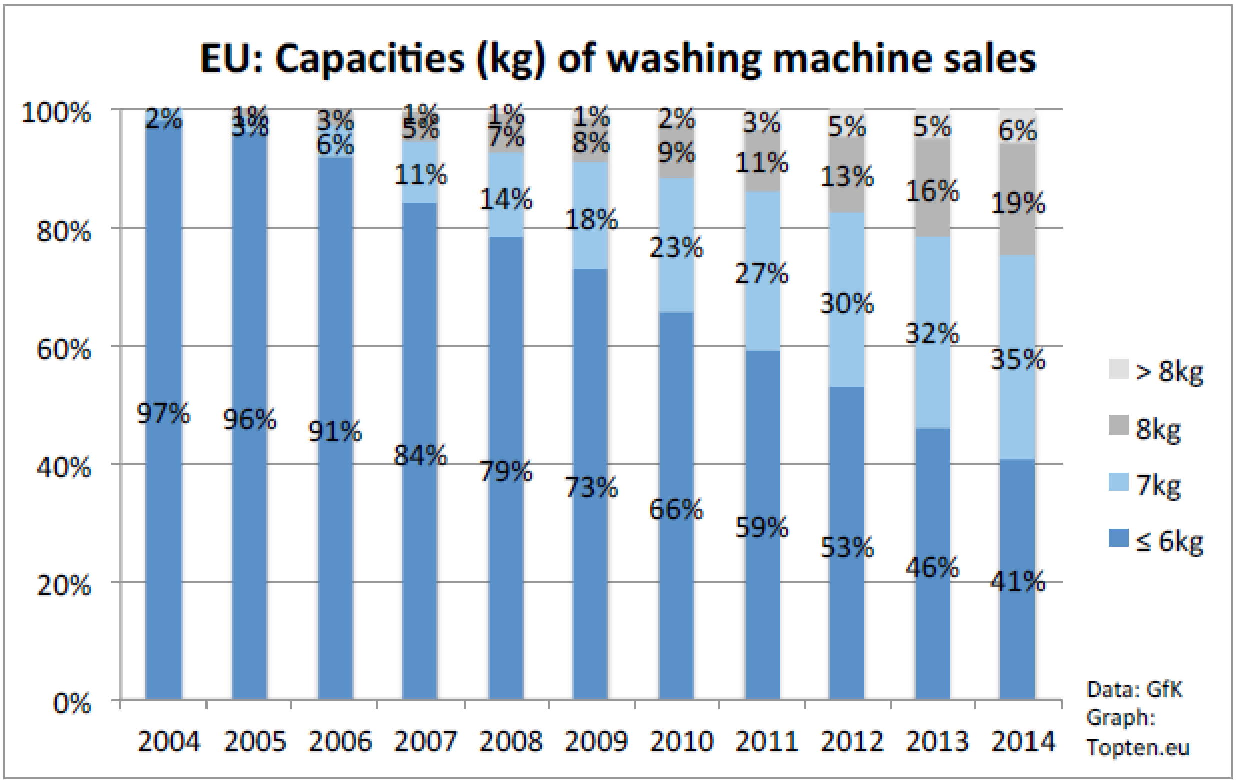


Figure 2.14: **EU: Capacities of washing machine sales; source: (Michel et al. 2015)**

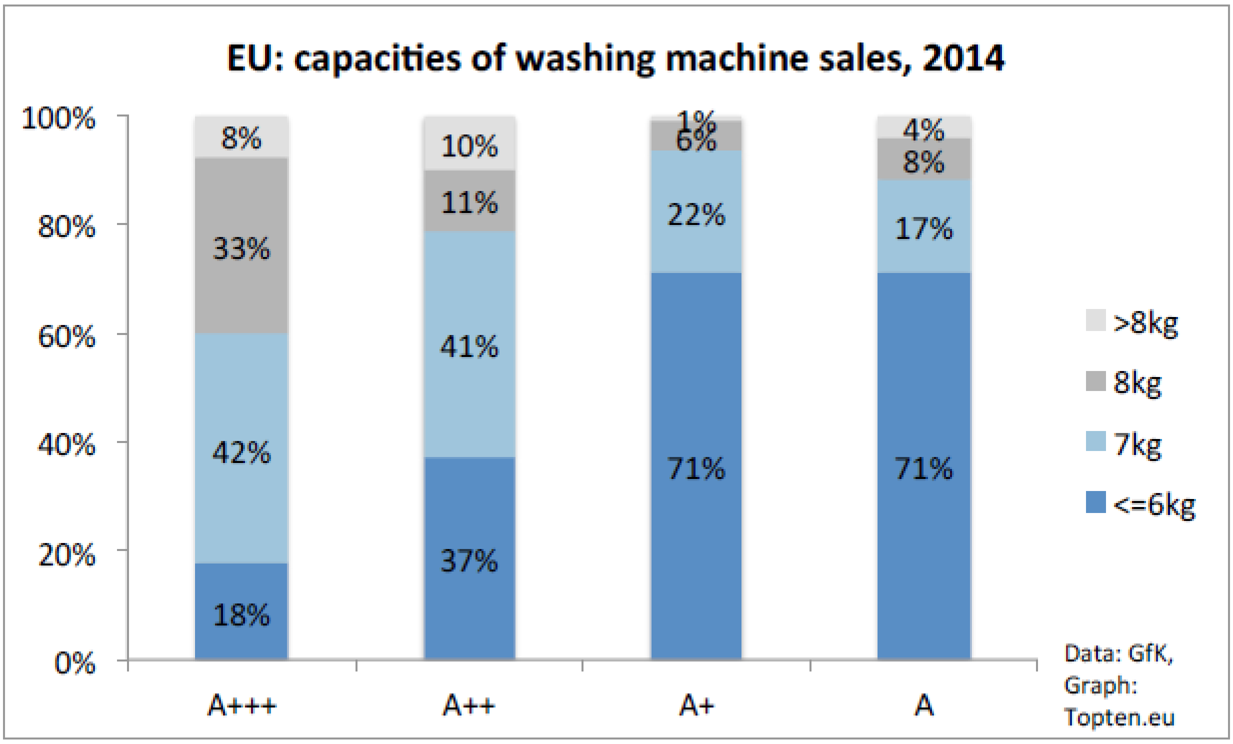


Figure 2.15: **EU: declared capacities of washing machine sales according to classes, 2014; source: (Michel et al. 2015)**

The summary about washing machines reads:

> *'The picture for washing machines is more complex. Good energy efficiency classes have been well taken up by the markets since the introduction of the new Energy Label, but the link to low energy consumption is unclear. The differences in declared energy and water consumption between the classes are minimal, and Portugal, with the highest share of energy efficient washing machines, has the highest average declared energy consumption at the same time. The reason is the large size of the washing machines sold in Portugal. Washing machines in better efficiency classes are larger, and the trend to larger appliances is on-going. High efficiency in washing machines today means rather large capacity than low energy consumption.'*

However, declared values relate to operating washing machines with standard programmes at full/partial load. Lower consumption values might be registered under real life conditions, as a consequence of operating the machine at partial loads and selecting also low temperature programmes.

2.2.3.3. Sales data of washing machines and washer-dryers – further information

GfK data 2013

The German market analysis company Gesellschaft für Konsumforschung (GfK) analysed the relative distribution of sales of **washing machines** of certain energy efficiency classes from 2004 to 2012 in 14 European countries (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE), cf. Figure 2.16 (GfK, personal communication 2013). The data mostly correspond to the more current data provided by topten.eu in the previous section.

According to (GfK, personal communication 2013), the share of sold washing machines with an energy efficiency class A+ steadily increased up to 44% in 2010 and decreased afterwards. On the other hand, a gradual decline in sale of the lower energy efficiency classes is seen, particularly for energy efficiency class A.

Since new energy efficiency classes were introduced in December 2011 by Regulation (EU) 1061/2010, the share of sold washing machines with energy efficiency classes A++ and A+++ increased. By having closer look to data related to the sales percentage of the washing machines in 2011 and 2012, it can be seen that the amount of sales for washing machine with A+++, A++ and A+ energy efficiency class has a slight rise while the percentage of sales for washing machine with an A energy efficiency class has a noticeable decrease. The sales of washing machine with B and C energy efficiency class have remained almost constant.

According to these data it is noticeable that since 2006, almost no sales for energy efficiency classes below C have reported and share of washing machine sales with B energy efficiency class has reduced continuously.

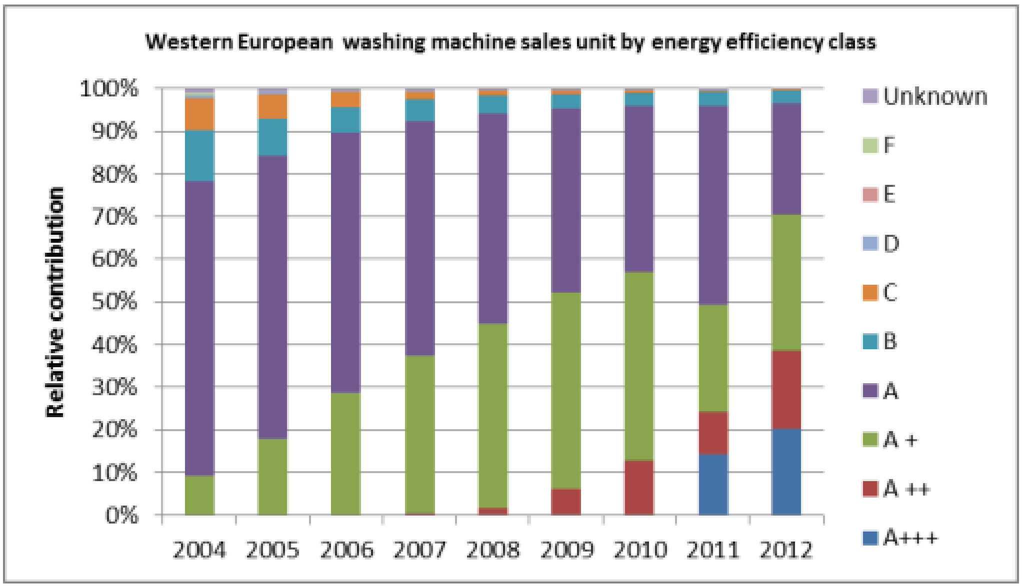


Figure 2.16: **Relative distributions of energy efficiency classes on total washing machine sales from 2004 - 2012 in 14 European countries (AT, BE, DE, DK, ES, FI, FR, GB, GR, IE, IT, NL, PT, SE), (GfK, personal communication 2013, personal communication 2013)**

Figure 2.17 gives information about the percentages of sales of washing machines in six western European countries based on their energy efficiency classes in 2012. It can be detected that Germany, among the six European countries listed, has the highest sale of washing machines with the energy efficiency class A+++ whereas France has the lowest share of sales of washing machine with the same energy efficiency class which is around 40 percent and 9 percent respectively. Belgium by having 5.5 percent difference with Germany has the second rank for the sales of washing machines with the energy efficiency class A+++ and first rank for the sales of washing machines with the energy efficiency class A++ which is around 30 percent. Great Britain has the highest rank of sales of washing machine with the energy efficiency class B and C among these six analysed European countries.

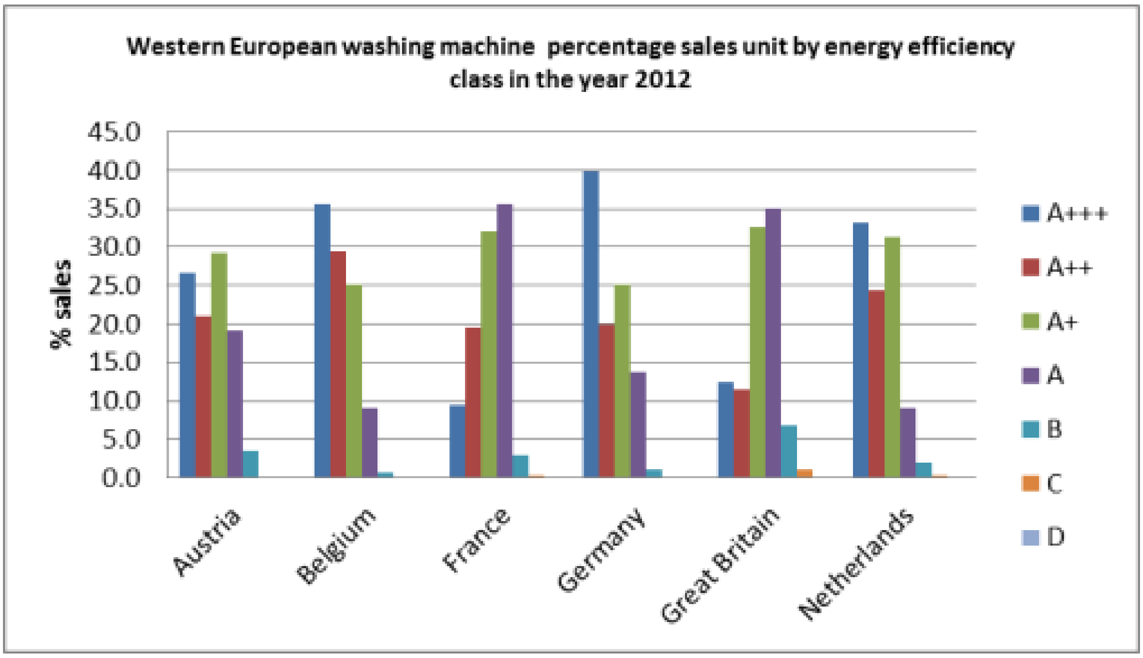


Figure 2.17: **Relative distribution of percentages of sales of different energy efficiency classes on total washing machine sales 2012 (GfK, personal communication 2013)**

Figure 2.18 illustrates the percentage of washing machines sales units based on their capacities for 14 western European countries from 2004 to 2012. It is evident that the amount of washing machine sales with the capacity of 6 kg or smaller has reduced remarkably from 97.2 percent to 47.8 percent during this period.

On the contrary, the amount of washing machine sales with capacities larger than 6 has soared noticeably. Moreover, among the washing machines with the capacity larger than 6 kg, the highest sale belongs to the group of washing machines with the capacity between 6.1 to 7 kg. The sales of this group of washing machines have increased from 2.1% in 2004 to 32% in 2012.

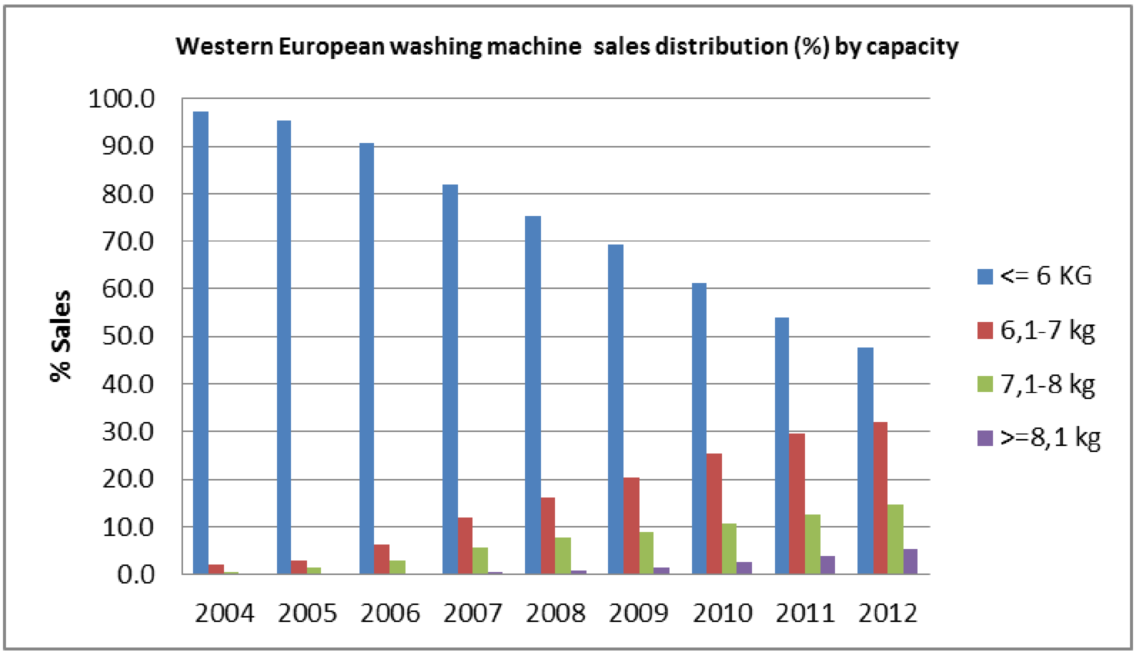


Figure 2.18: Sales of western European washing machines based on capacity (GfK, personal communication 2013)

"Omnibus study"

According to the "Omnibus study" (VHK et al. 2014), sales data for washing machines are reported to be 15.9 (2011) and 15.6 (2012) million units based on GfK data for EU-23 which is higher than the data provided in the previous sections by topten.eu or the Ecodesign impact accounting.

Sales of **washer-dryers** in the EU were above 700,000 in 2012 based on GfK data. According to (VHK et al. 2014), this corresponds to about 4% of the 16 million unit washing machine market used as market data in that study. It is further noted that this is an average figure and the sales vary considerably depending on the country. The market for washer-dryers is growing as there is a higher consumer acceptance due to higher rated capacities for washing and/or drying (VHK et al. 2014).

Stakeholder information

The following information on sales has been provided by stakeholders (Table 2.12) in the context of this revision study. The EU sales data, however, are considerably higher compared to the data provided in the previous sections.

Table 2.12: Information on sales data for washing machines and washer-dryers provided by stakeholders

Information	Washing machines	Washer-dryers
Sales	Europe, 2013: • 25 M units, 5,5 B EUR (220 EUR/unit)	Europe, 2013: • 1,0 M units, 0,4 B EUR (400 EUR/unit)
	Germany (1): • About 2.5 million units (front loading) sold (1 each 322 persons) • Scale-up to Europe = 25 million (2.5 x 742.5 / 80.6)	Germany (1): • About 50 000 units sold (1 each 1610 persons) • Scale-up to Europe = 460 600 (50 000 x 742.5 / 80.6) • Ratio WM to WD = 50 : 1 • Share of WD = 2%
	Switzerland: • 200 000 (1 each 410 persons) • Ratio Germany to Switzerland = 12.5 : 1 (9.83 by population)	Switzerland: • 10 000 (1 each 820 persons) • Ratio Germany to Switzerland = 5 : 1 (9.83 by population)
Trends	Stable in Europe In Switzerland the number of sold units is increasing every year since 2002	Increasing number of sold units in Europe
(1) source: https://www.test.de/thema/waschmaschinen/		

The table below shows the market segmentation by Energy Efficiency Class in Europe based on information provided by stakeholders.

Table 2.13: Market segmentation by Energy Efficiency Class in Europe based on information provided by stakeholders

Product	Current shares in terms of Energy Efficiency class (%)
Washing Machines (A+++; A++; A+)	• Europe, 2014: 35% A+++, 20% A++ 30% A+ (including Washer-dryers). 15% missing are washer-dryers in lower energy label classes and wrong declarations) • Switzerland, 2013: 60% A+++, 15% A++, 17% A+ Switzerland, 2015: 75% A+++, 15% A++, 10% A+ • 44% of the WM sold in the EU in 2013 were already rated in the two highest energy efficiency classes only one year after the introduction of these classes (22% in A+++, 22% in A++). This share is estimated to be clearly higher by today (Source: http://www.topten.eu/uploads/File/Topten_recommendations_Washing_machines.pdf)
Washer-dryers (A; B; C)	• Europe, 2014: 55% A, 40% B, 5% C • Switzerland, 2013: 47% A, 53% B, 0% C

The table below shows the market segmentation by capacity in Europe based on information provided by stakeholders.

Table 2.14: Market segmentation by capacity in Europe (2015) based on information provided by stakeholders

Washing Capacity (kg)	Indicative shares for Europe	
	Washing machines	Washer-dryers
< 5 kg		
5 kg	15%	2%
6 kg	30%	20%
7 kg	30%	30%
8 kg	18%	25%
9 kg	5%	18%
> 9 kg	2%	5%
Additional information on capacities of high efficiency washing machines can be found on: < 8 kg: http://www.topten.eu/english/household/washing-machines/8kg.html 8 kg: http://www.topten.eu/english/household/washing-machines/8kg-2.html > 8 kg: http://www.topten.eu/english/household/washing-machines/8kg-3.html Information on capacities of high efficiency washer-dryers can be found on http://www.topten.eu/english/household/washer-driers.html		

2.2.4. Models offered on the market – analysis based on the CECED database

The following analysis of washing machines and washer-dryer models available on the European market from 1998 to 2013 is based on the CECED database. It is noticeable that during this period, the European Union has been enlarged from 15 countries to 28 countries and from 380 million inhabitants to over 500 million inhabitants.

2.2.4.1. Washing machine data up to 2013

Total number of washing machine models available on the market

Figure 2.19 shows that number of washing machine models has increased from 4,392 in the year 1997 to 7,745 in the year 2013. This trend can be ascribed to the continuously increasing market with its need to offer a larger variety of models due to different consumer needs and preferences and the invention and implementation of new product features.

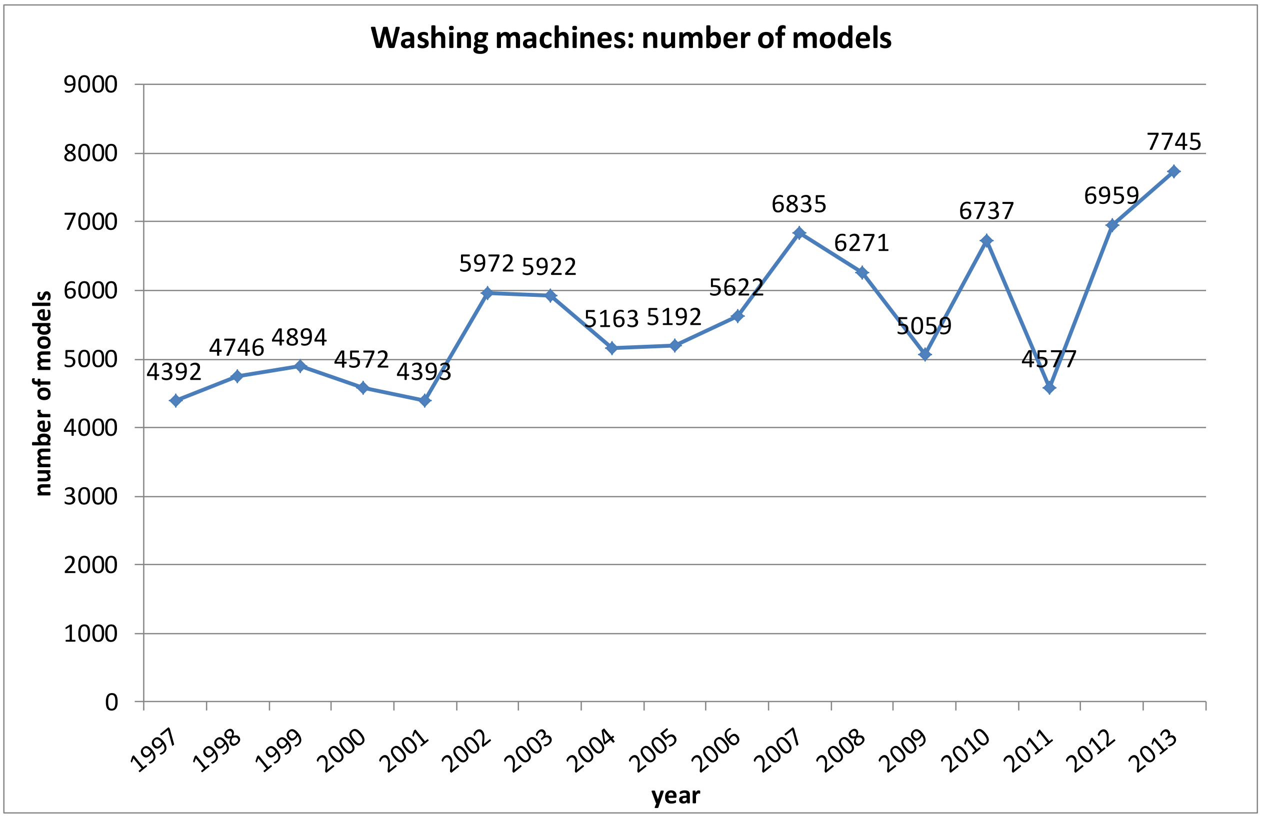


Figure 2.19: Development of number of models of washing machines on the European market from 1998 to 2013 (CECED 2014)

Capacities of washing machine models available on the market

The development of washing machine capacities on the European market is shown in Figure 2.20.

The average capacity of the machines (in kg cotton) has increased from about 4.8 kg in 1997 to 7.04 kg in 2013. This tendency seems to have just started in 2002 (Figure 2.20) and is increasing its trend. As average household size is getting smaller, there must be other demographic explanations for this development.

Distribution of rated capacity for the 7,745 washing machine in the year 2013 shows that around 31 percent of washing machines models have 6.5 to 7 kg capacity followed by 24 percent for 7.5 to 8 kg and 23 percent at 5.5 to 6 kg (Figure 2.21). In 2013, the 5 kg models (the former base case of Lot 14) only constitute to a share of around 8%. On the contrary, there are already some models with 9, 10 and 11 kg capacity on the market.

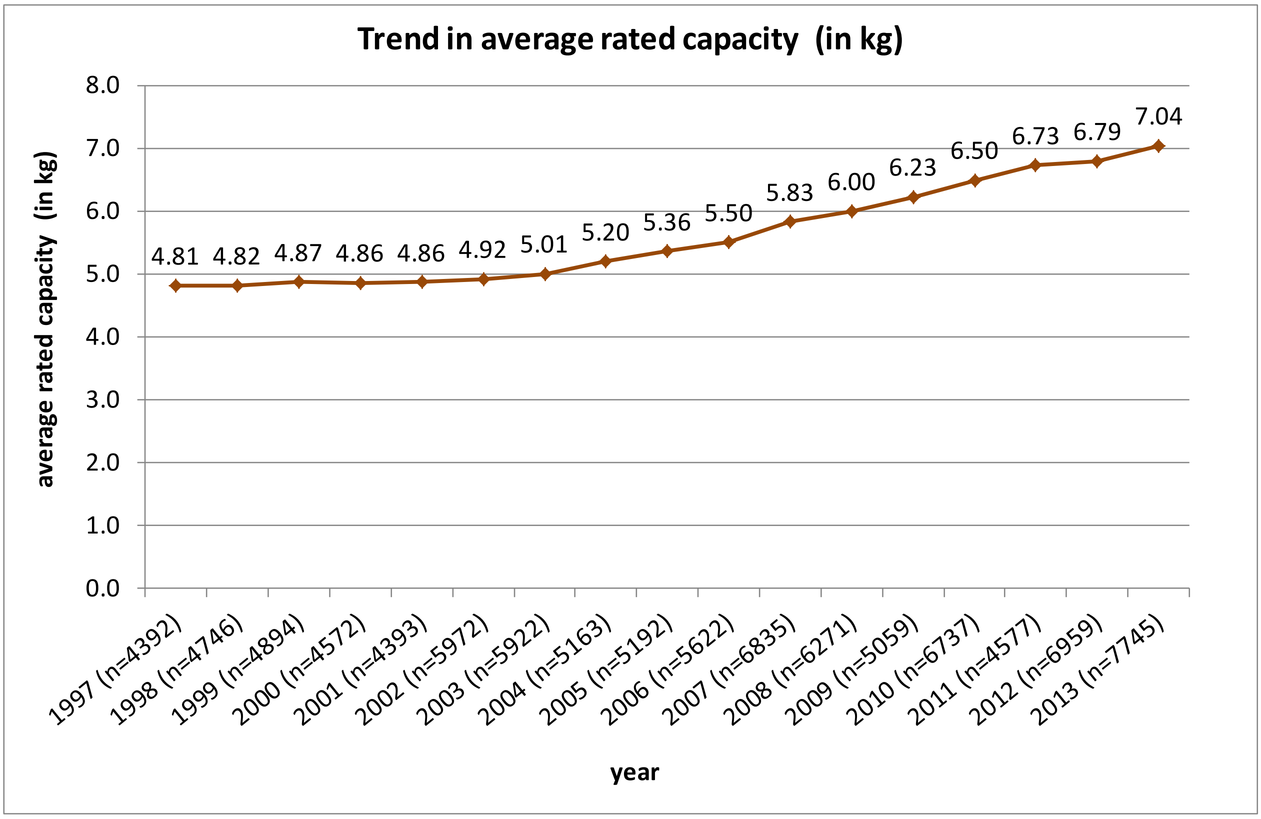


Figure 2.20: **Average rated capacity (kg cotton) of washing machine models (CECED 2014)**

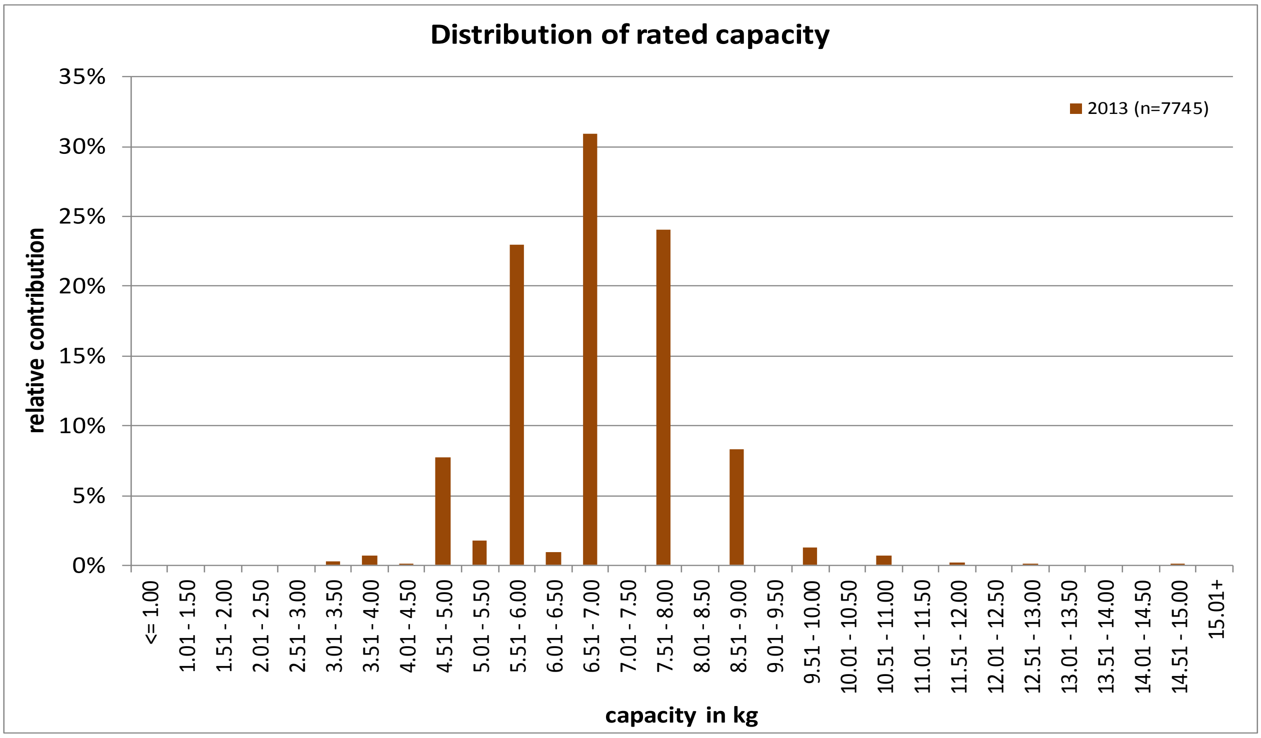


Figure 2.21: **Distribution of rated capacity (kg cotton) of washing machines models in 2013 (CECED 2014)**

Energy consumption of washing machine models available on the market

Concerning the development of the energy efficiency in terms of average energy consumption per kg of capacity a continuous and almost linear improvement can be observed (Figure 2.23).

The average specific energy consumption has been halved from 0.245 kWh/kg in the year 1997 to 0.120 kWh/kg in the year 2013. However, it has to be noted that the reference for the declaration of the energy consumption has changed in 2011. From 2011 onwards energy consumption has been measured in a combination of programmes at 40 and 60 °C with half and full load compared with before where energy was measured only at 60 °C full load. When comparing the distribution of the average specific energy consumption per cycle (Figure 2.22) of year 1997 with 2013, it is evident, that industry has optimised the washing machines models to comply with the energy consumption requirements of the energy efficiency class thresholds.

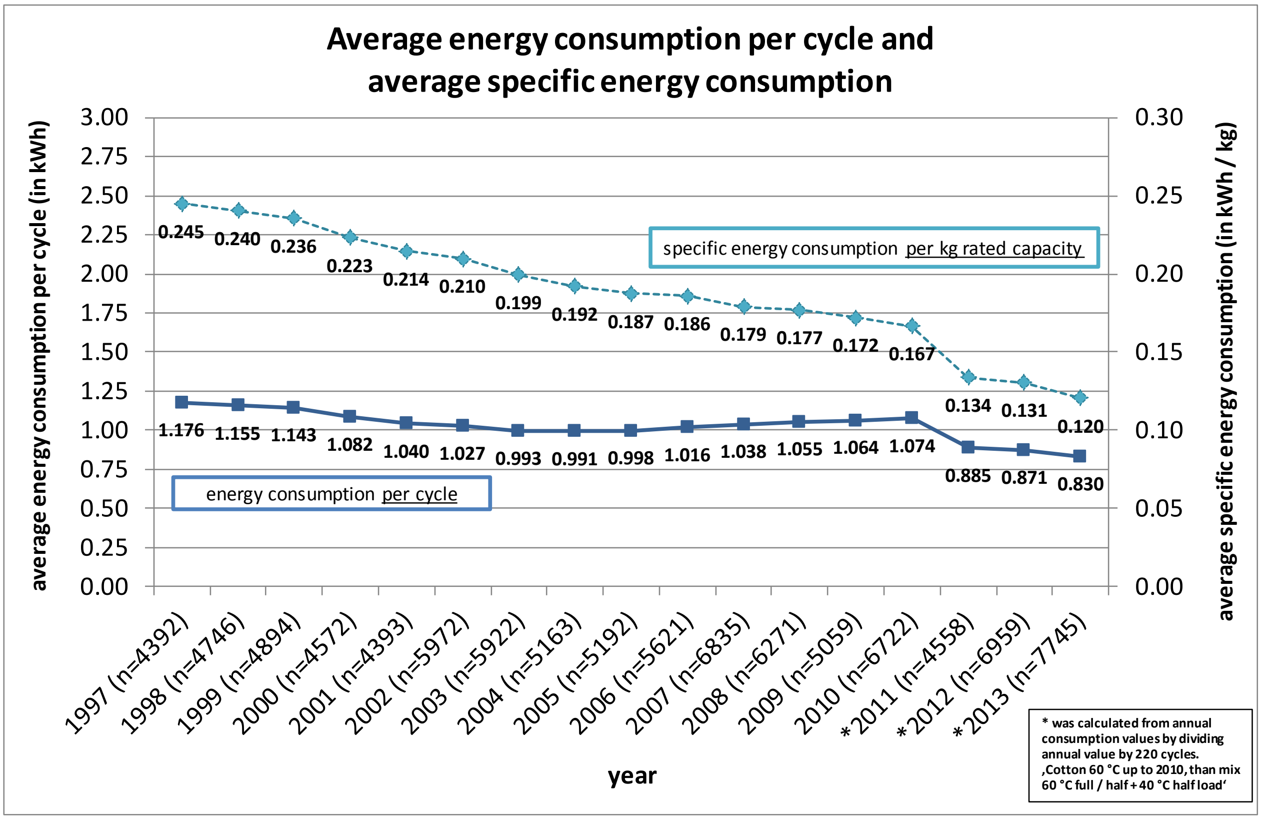


Figure 2.22: **Average energy consumption per cycle and average specific energy consumption per kg (CECED 2014)**

In Figure 2.23, the distribution of energy consumption per cycle of 7,745 washing machine models in the year 2013 is shown. The energy consumption per cycle has been calculated by dividing annual consumption values by 220 cycles. The range of energy consumption per cycle is broad among the washing machine models available on the market in 2013, starting from less than 0.50 kWh per cycle to 1.46 kWh per cycle and more. The average of this energy consumption per cycle is 0.83 kWh. Most of the washing machine models have energy consumption between 0.86 to 0.90 kWh per cycle, followed by 0.76 to 0.80 kWh per cycle.

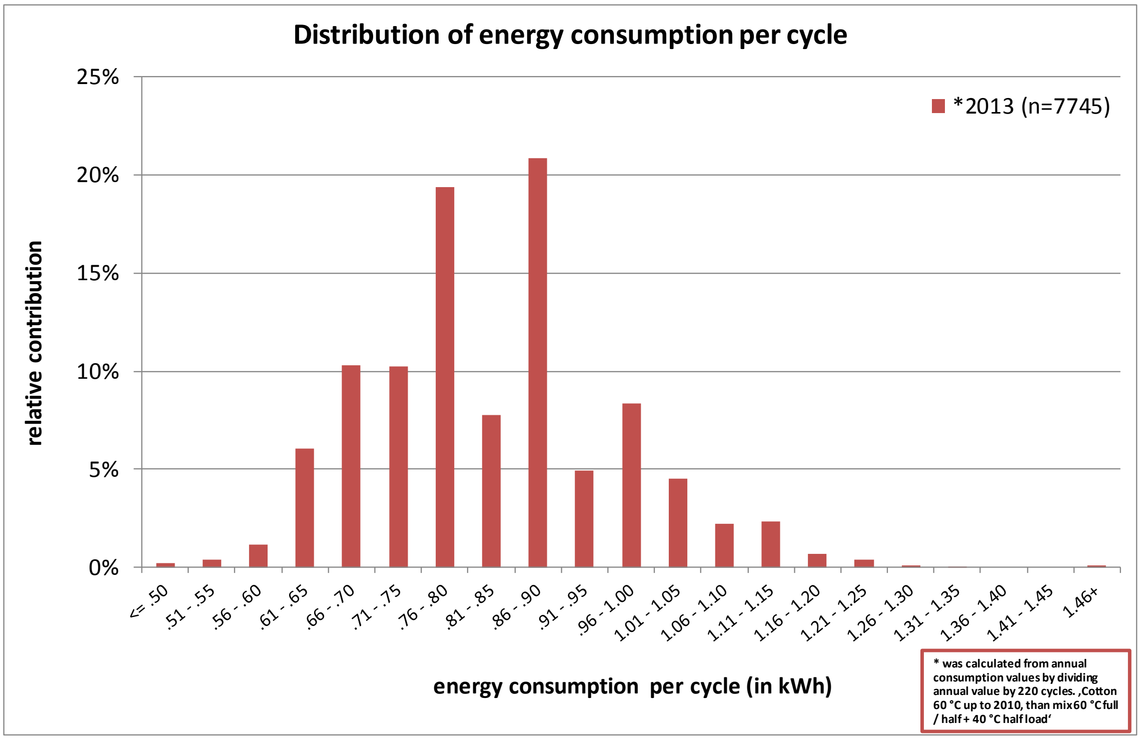


Figure 2.23: **Energy consumption of washing machine models per cycle for the year 2013 (CECED 2014)**

In Figure 2.24, the distribution of the specific energy consumption in kWh per kg load of 7,745 washing machine models in the year 2013 is shown. These values have been calculated by dividing the average total energy consumption per cycle of each machine by its nominal load mass (equals rated capacity). As it can be seen around 72 percent of the tested washing machines have a specific energy consumption of 0.11 to 0.15 kWh/kg. The average of specific energy consumption is 0.12 kWh/kg.

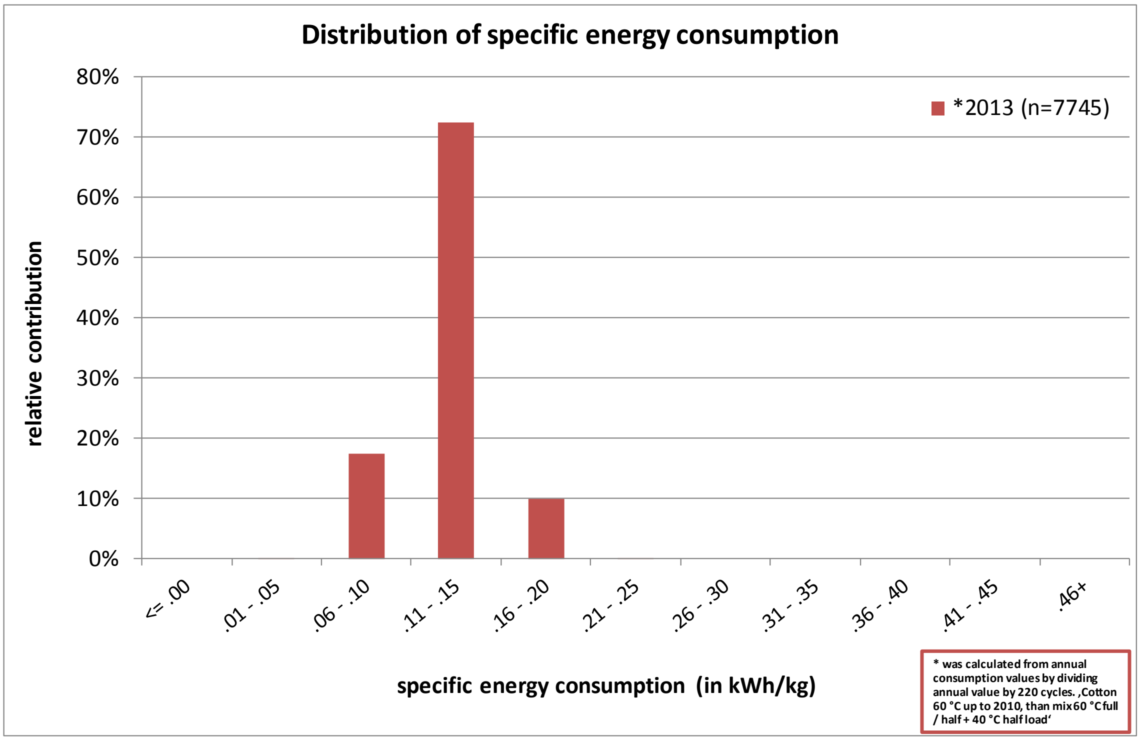


Figure 2.24: **Specific energy consumption of washing machine models in kWh/kg for the year 2013 (CECED 2014)**

Energy efficiency classes of washing machine models available on the market

The current Energy Label for washing machines entered into force by the end of 2010 based on Regulation (EU) 1061/2010 and is mandatory since December 2011. The new energy efficiency classes A+, A++ and A+++ were filled up quickly. Distribution of the energy efficiency classes from year 1997 till 2013 reveals the continuous improvement in energy efficiency classes (Figure 2.25).

As it can be seen the share of energy efficiency classes below the A energy efficiency class has decreased significantly during this period. In 2013 no washing machines worse than class B has registered in the database, showing the Ecodesign Regulation is properly followed. Thus, in 2013 all of the washing machine models registered in the database had energy efficiency class A or better, whereof already 50 percent of the models had energy efficiency class A+++. This class is somehow driving the development of washing machines towards more efficient models.

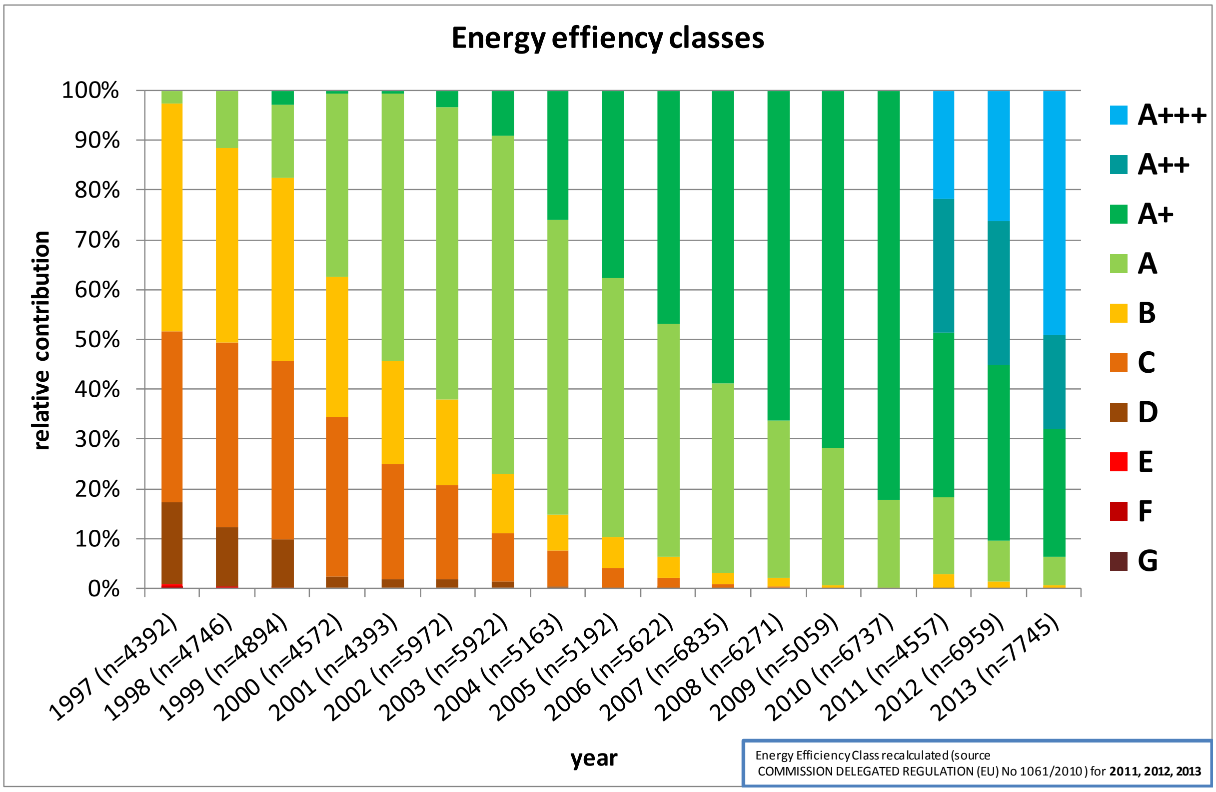


Figure 2.25: Distribution of energy efficiency classes for washing machines in 1997-2013 (CECED 2014)

Distribution of energy efficiency classes according to capacity of washing machine models

As it can be seen in Figure 2.26, the most common capacity class of the 7,745 registered washing machine models in the CECED database in 2013 was 7 kg with 31 percent. Within these 7 kg washing machine models, the distribution of energy efficiency classes is 48.7% A+++, 24.7% energy efficiency A++, 23.4% energy efficiency class A+, and 3.2% with energy efficiency B. In general it can be seen that washing machines with larger capacity also have a better energy efficiency class; this is also clearly shown in Figure 2.26.

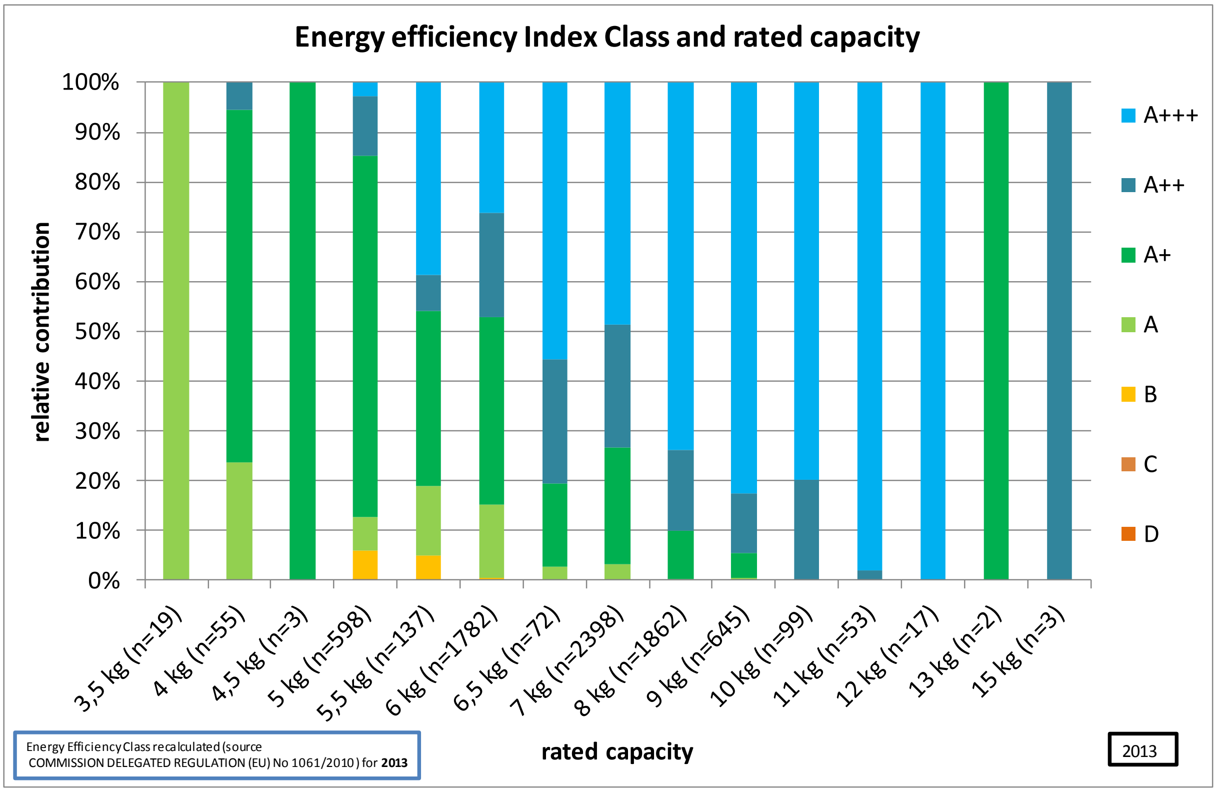


Figure 2.26: Energy efficiency index class and rated capacity 2013 (CECED 2014)

Figure 2.27 attempts to model the relationship between two variables including rated capacity and energy efficiency index by fitting a linear equation to observed data. In general one can say that washing machines with a low energy efficiency index (EEI) more often have a higher capacity than machines with a higher EEI.

Further research is needed to assess whether larger machines have higher energy performances and whether larger machines are used less often due to consumers washing more laundry in one cycle.

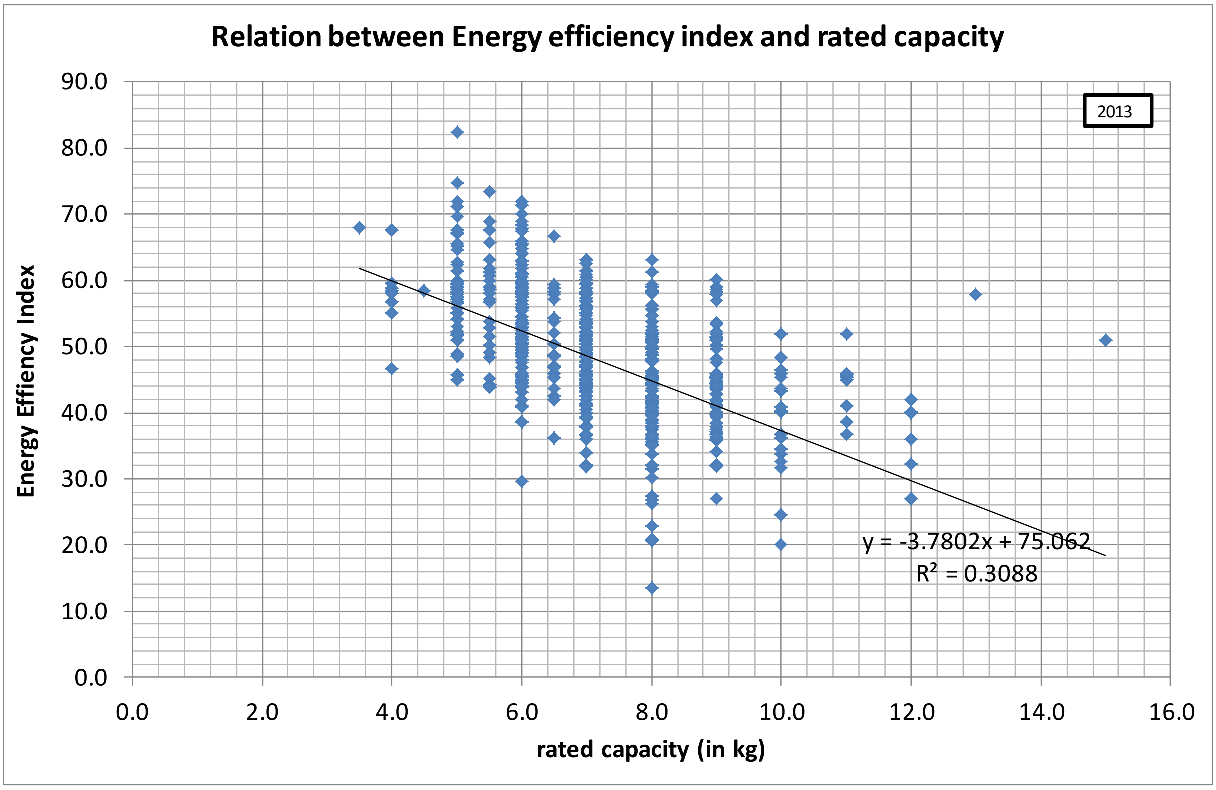


Figure 2.27: **Relation between energy efficiency index, energy label class and rated capacity (CECED 2014)**

Figure 2.28 illustrates the distribution of washing machine models in terms of their energy efficiency index.

It can be seen that most of the registered washing machine models in the CECED data base in 2013 had an energy efficiency index below 59, including the A+++, A++ and A energy efficiency class. Furthermore, the majority of models had an energy efficiency index that complies with the lower limitation of the corresponding energy efficiency class. For instance about 1,000 washing machine models had an energy efficiency index of 59, which is the lower limit of energy efficiency class A+ (52 ≤ EEI < 59), whereas only around 100 models were in the upper limit of the energy efficiency class.

The distribution of the number of models indicates that manufacturers seem to adjust the energy performance of the label programme to the minimum requirements of a desired energy efficiency class. At the present time, following EU Ecodesign requirements for Energy Efficiency Index (EEI) apply for washing machines sold on the EU market (Commission Regulation (EU) No 1015/2010 and Corrigendum): For all washing machines ≥ 4 kg the EEI has to be < 59, which equals the energy efficiency classes A+, A++ or A+++ on the Energy Label. In other words: only three of the seven classes remain, while the four other classes A, B, C and D are banned from the EU market.

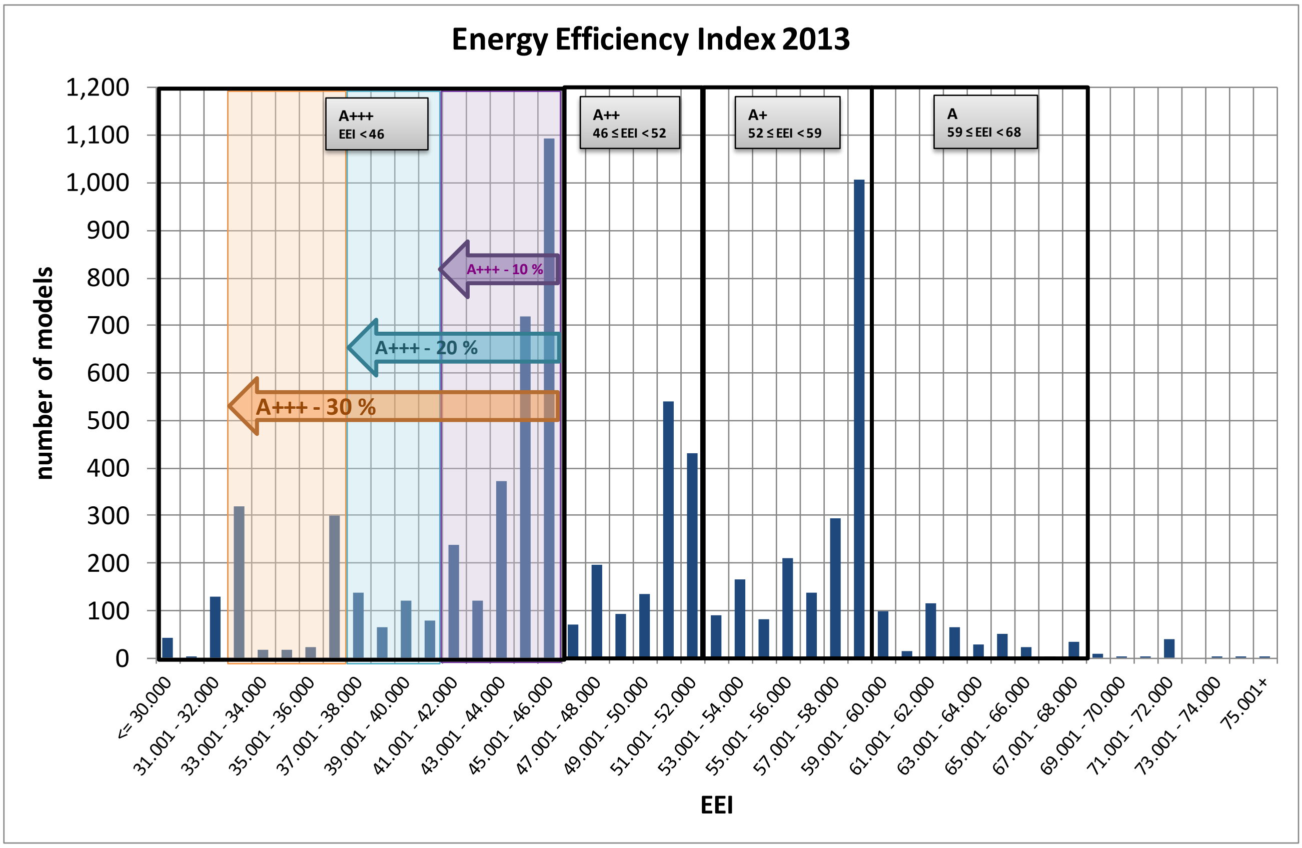


Figure 2.28: **Distribution of washing machine models in terms of energy efficiency index 2013 (CECED 2014)**

Washing performance classes of washing machine models available on the market

Savings in energy and water consumption have been realised without negative implications on the cleaning and drying performance of washing machines. They even could be increased. According to Figure 2.29, the washing performance has improved considerably from year 1997 till 2010. Subsequently the share of washing performance class A has increased whereas the share of other energy classes has declined. In 2010, almost all washing machine models registered in the database had washing performance class A.

From 2011 on, no further declaration of washing performance has been done, as it is mandatory according to the Ecodesign Regulation (EU) No 1015/2010 that all washing machines entering in the European market have to have washing performance class A. Accordingly, washing performance class has no longer been declared on the new Energy Label for washing machines, and database entries end in 2010.

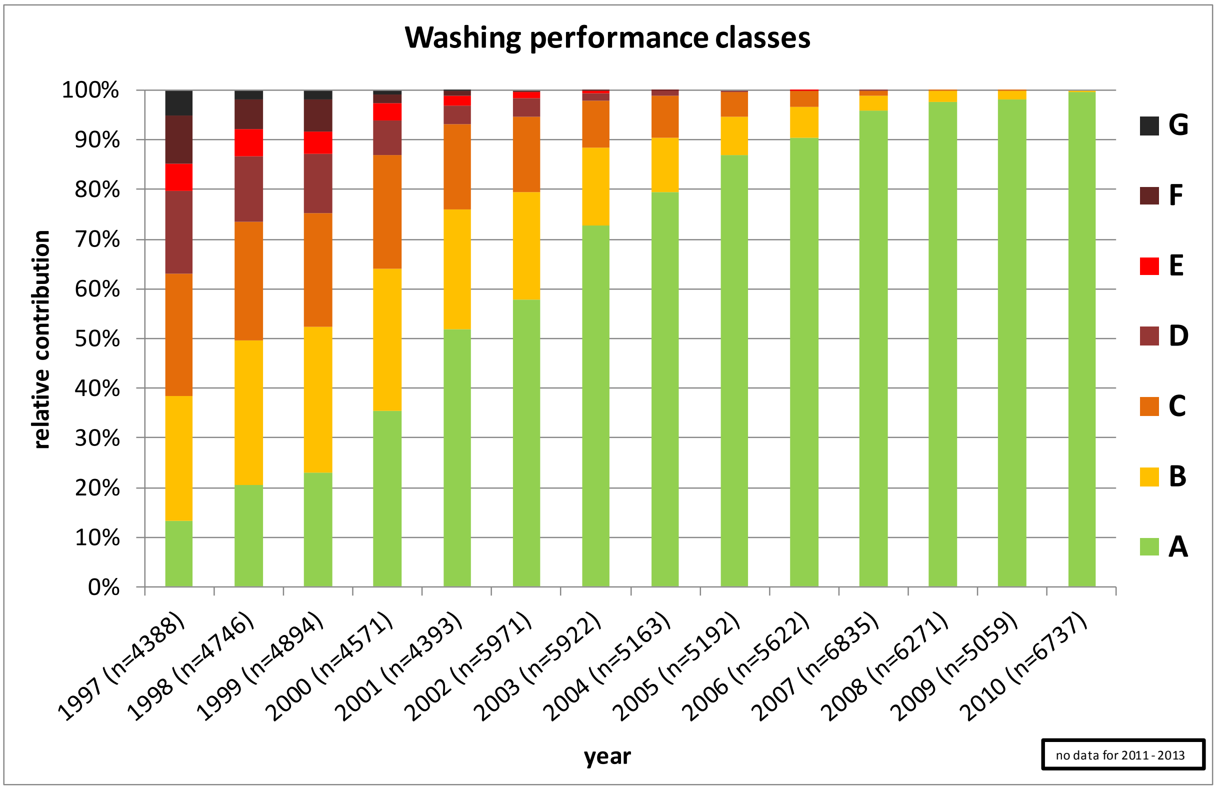


Figure 2.29: **Distribution of washing performance classes for washing machine models in 1997-2010 (CECED 2014)**

Spin drying performance of washing machine models available on the market

Spin drying performance ("efficiency" in the current wording) is part of the label information. The spinning performance is expressed in a class from A to G with A being the best performing class. There are no ecodesign requirements on spinning performance.

Spin drying is an energy consuming function. As spin drying is more efficient than tumble drying in terms of energy consumption, improving the performance of spinning can save energy if consumers use both washing machine and tumble dryer (cf. section 4.4.2.6). However, higher spinning speeds have higher wrinkling effects which may increase energy consumption when ironing is applied.

The development of the spin drying efficiency in comparison to washing performance is less obvious over the years (Figure 2.30). In 2013, around 56% of models registered in the CECED database were in class B, 18.5% in class A and 20% in class C. Other drying performance classes have a very low share (around 5 percent) according to the CECED database (CECED 2014).

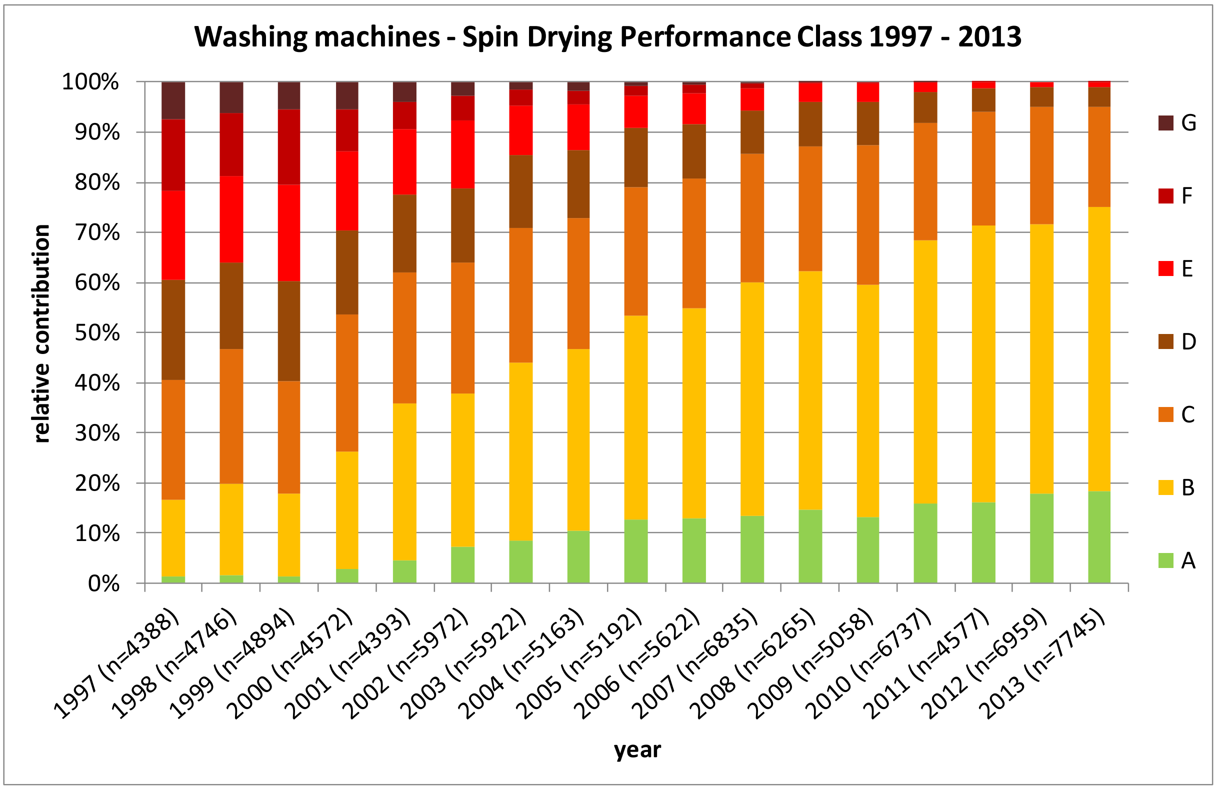


Figure 2.30: Distribution of spin drying performance classes for washing machines in 1997-2013 (CECED 2014)

Spin speed is a main driver for the drying efficiency value. The better the laundry is spun, the less energy is needed to dry it. Figure 2.31 shows a clear trend of substituting low spin speed machines (at 900 rpm or lower) by higher spinning machines. These results illustrate a steady increase of the average spinning speed from 828 rpm in 1997 to 1219 rpm in 2010.

According to one stakeholder, there is a trend for the maximum spin speed towards 1000-1600 rpm, whereas there is seen a minor trend that the spin speed < 1000 rpm decreases, and the market share is negligible for maximum spin speeds higher than 1600 rpm. There were machines with 1800-2000 rpm in the market at the end of nineties but they have disappeared because higher spin speeds can hardly achieve any further reduction in remaining moisture while product costs increase. Also, according to another stakeholder, there are some safety requirements that limit the maximum spin speed. The remaining moisture content is a more relevant performance parameter to consider for washing machines. According to one stakeholder, it is wrong that due to water use reduction in machines, there is less need of powerful spinning.

Figure 2.32 shows correlations between energy efficiency and spin drying performance class among the 7,745 registered washing machine models in the CECED database (CECED 2014).

About 70% of washing machines models with spin drying performance class A have energy efficiency class A+++. Another 15.2% have energy efficiency class A++ and 13.2% have energy efficiency class A+. This shows that there is some correlation between the energy efficiency of the washing process and the spin drying efficiency.

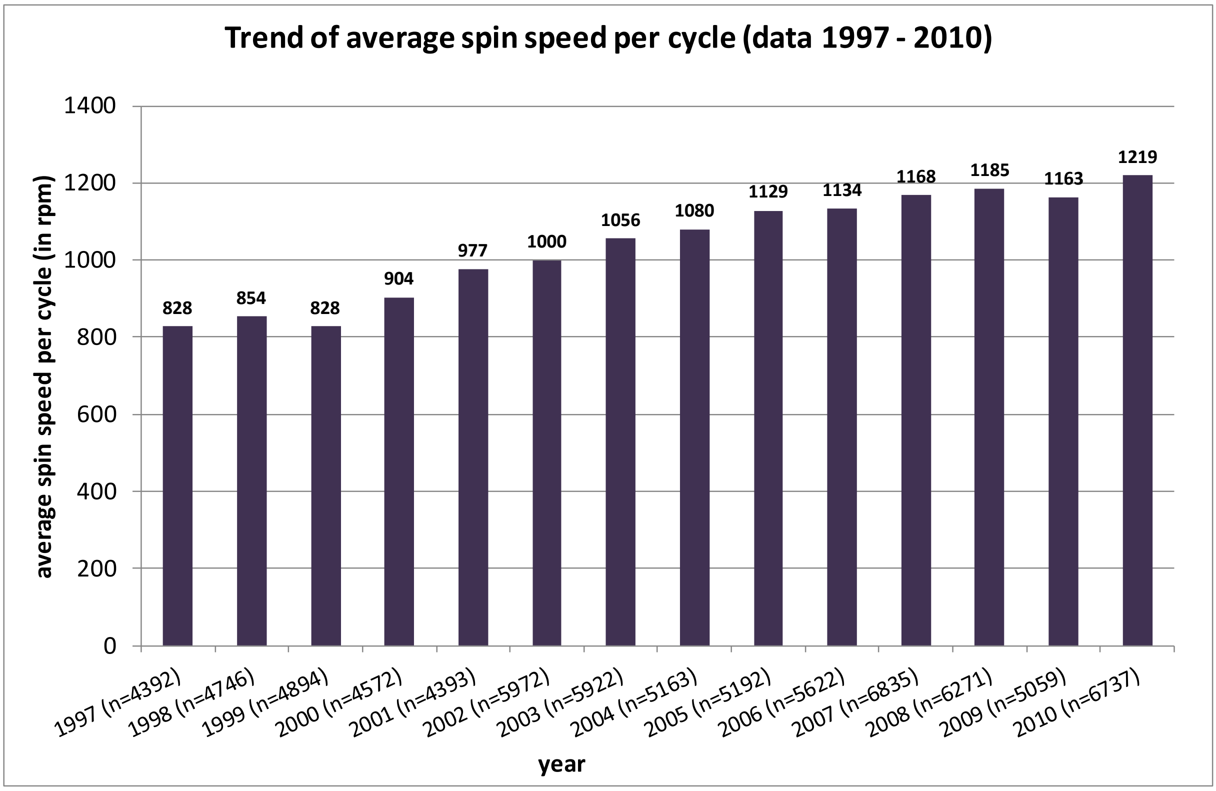


Figure 2.31: Development of average spin speed per cycle (CECED 2014)

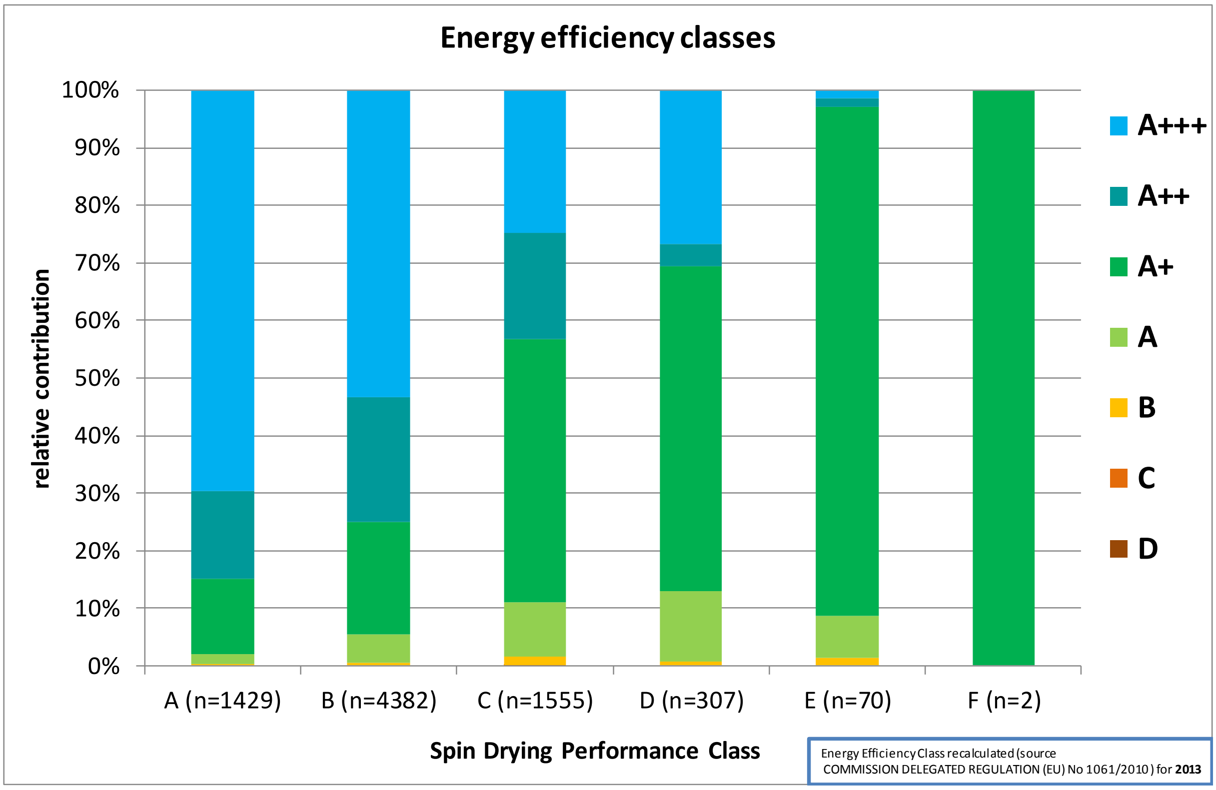


Figure 2.32: Spin drying performance class and energy efficiency 2013 (CECED 2014)

Water consumption of washing machine models available on the market

Figure 2.33 shows that the average water consumption of washing machine models per cycle significantly declined since 1997, but remained almost constant between 2011 and 2013. While in 1997 water consumption of the majority of machines was 66.8 litres per cycle, in 2013 this value was 45.1 litres per cycle.

When comparing the average specific water consumption (per kg) also ongoing improvement can be observed (Figure 2.33). Average water consumption per kg rated capacity for the years 1997 and 2013 was 13.9 l/kg and 6.5 l/kg respectively.

The difference in the results of the absolute versus specific consumption values is explained by the increase of the average capacity of the washing machines.

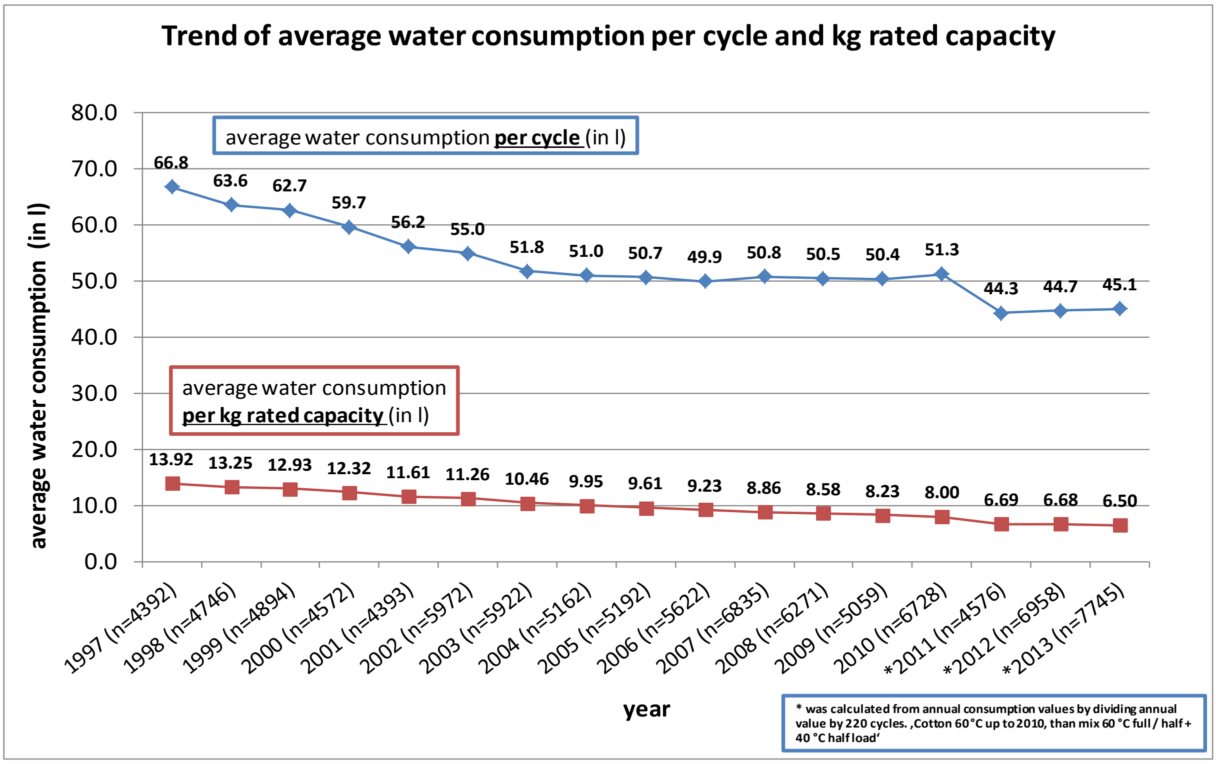


Figure 2.33: Development of the average water consumption per cycle and per kg (CECED 2014)

Figure 2.34 shows the average water consumption per cycle for washing machine models with 5 kg and 7 kg capacity. It can be seen that in both groups the average water consumption has declined by passing years. While the absolute water consumption of 7 kg machines is higher compared to a 5 kg machine, the average water consumption per kg capacity is less for the washing machine with 7 kg capacity compared to the washing machine with 5 kg capacity (Figure 2.35).

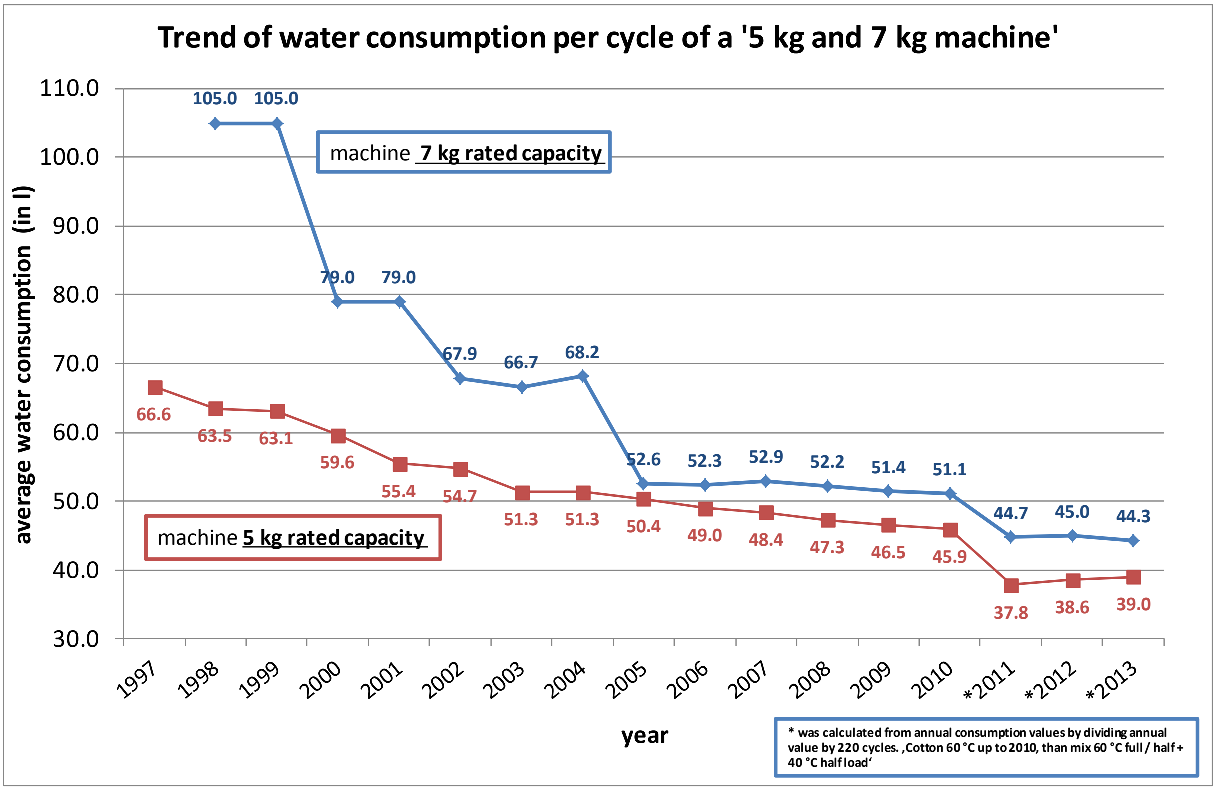


Figure 2.34: Trend of average water consumption per cycle of a machine with 5 kg and 7 kg rated capacity (CECED 2014). Please note the y-axis does not start with zero.

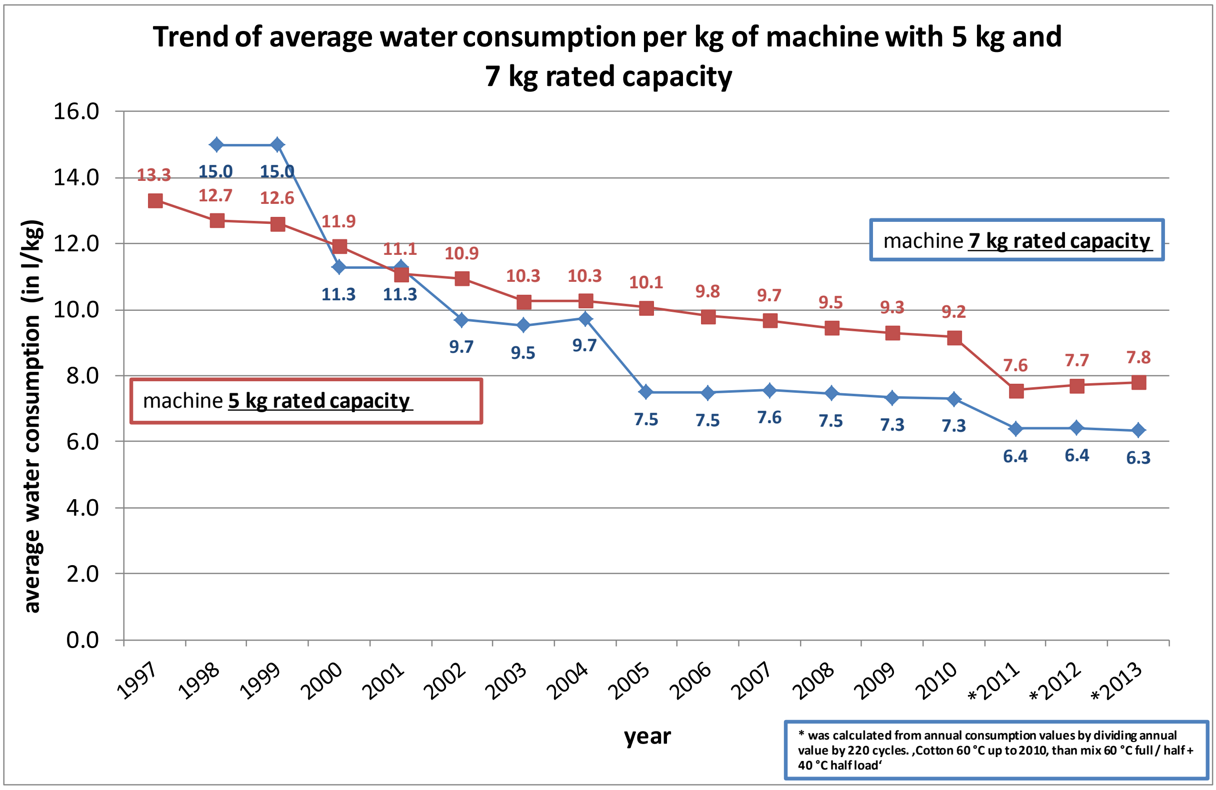


Figure 2.35: Trend of average water consumption per kg of machine with 5 kg and 7 kg rated capacity (CECED 2014)

Distribution of water consumption per cycle in 2013 is mainly between 39 and 51 litres. The average is 45 litres (Figure 2.36). The specific water consumption per kg of load is between 5.5 and 8 litres with an average of 6.5 l/kg (Figure 2.37).

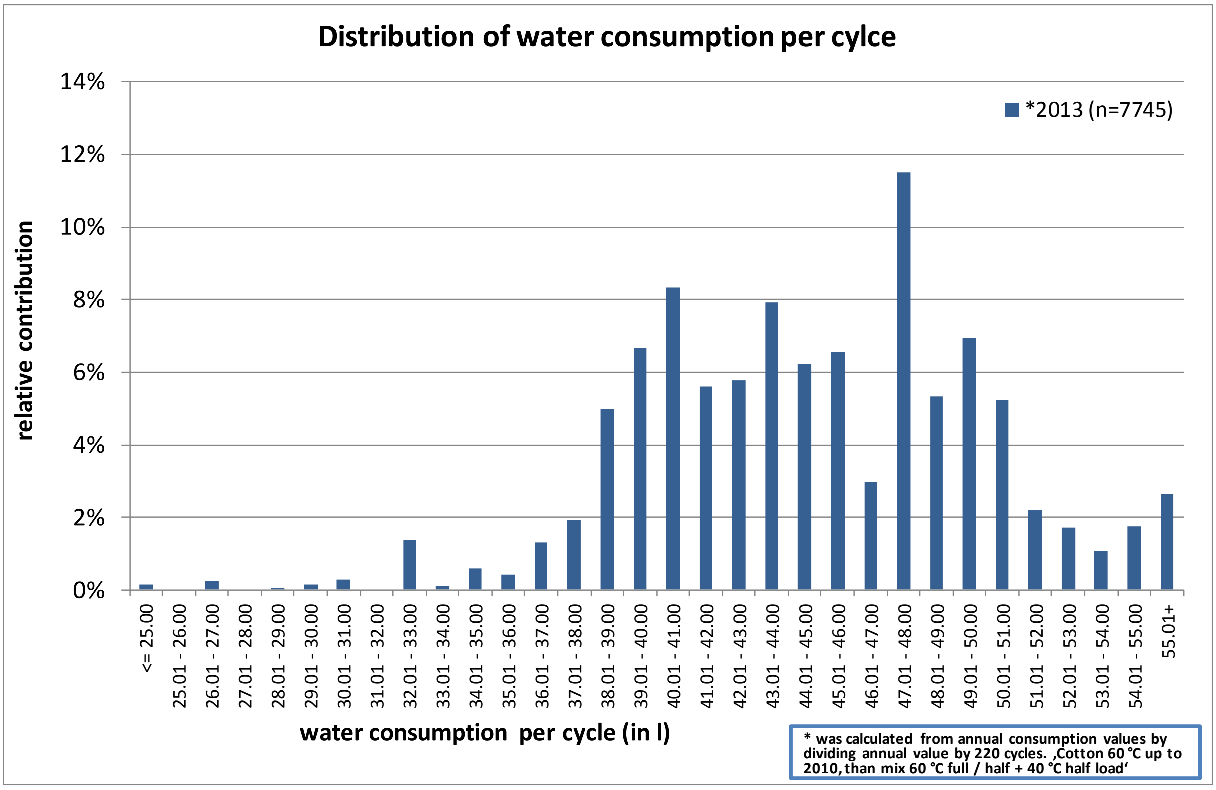


Figure 2.36: **Distribution of water consumption per cycle for washing machines 2013 (CECED 2014)**

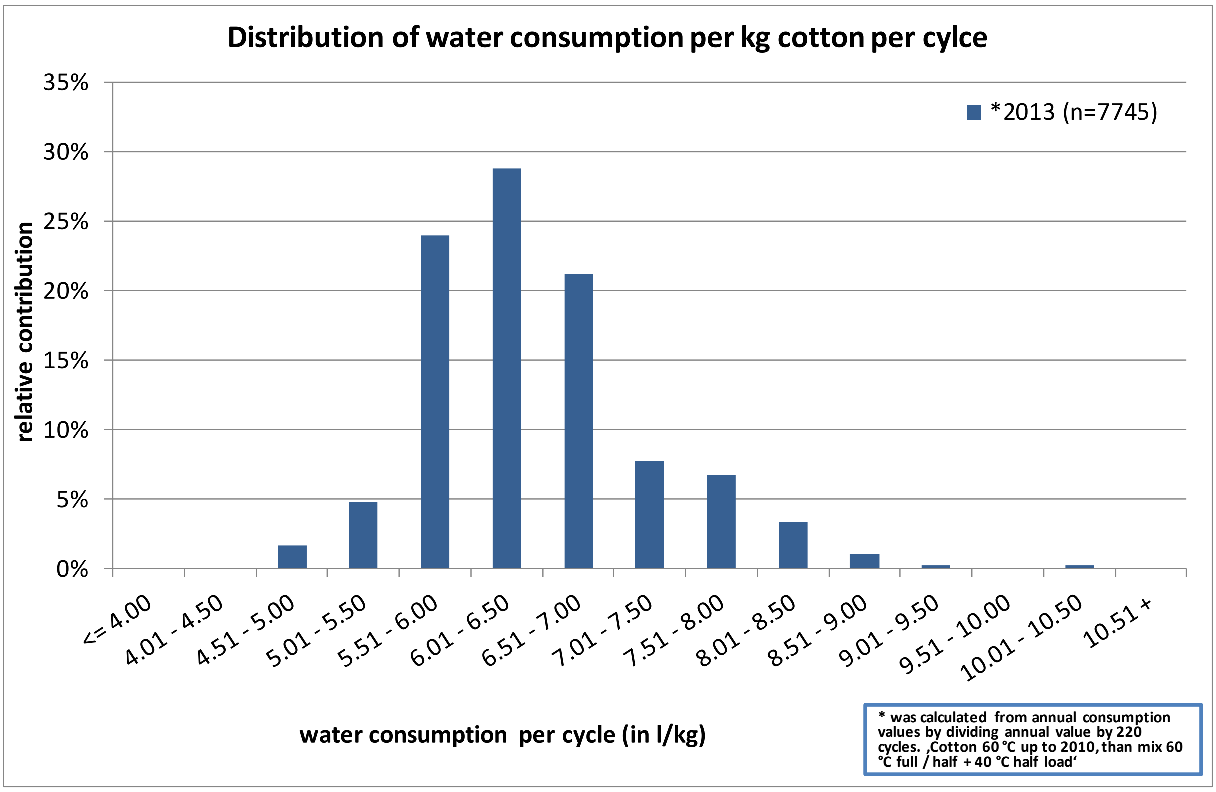


Figure 2.37: **Distribution of water consumption per kg cotton per cycle for washing machines 2013 (CECED 2014)**

Availability of automatic load detection of washing machine models available on the market

As not only the consumption at the rated capacity is of relevance, some information on the ability of the machines to adjust the energy and water consumption to lower loads (e.g. by 'fuzzy'-control) can be found by analysing the presence of the 'automatic load detection' feature, which is included in the reporting. This feature has gained importance and is available in about 98% of the models offered in 2013 (Figure 2.38).

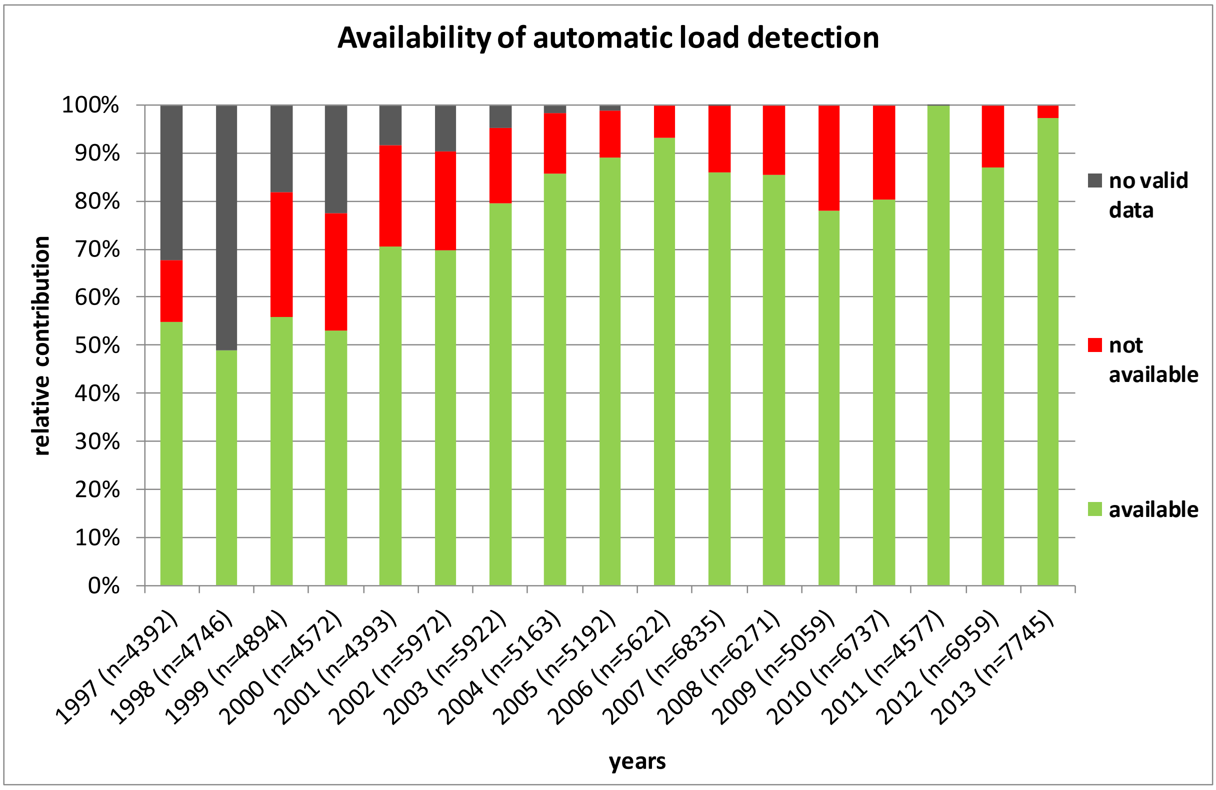


Figure 2.38: Development of the automatic load detection in washing machines (CECED 2014)

Noise emissions of washing machine models available on the market

In addition to the energy efficiency ranking and energy efficiency class, information about the machine's capacity, annual energy and water consumption (on the basis of 220 washing cycles), spin drying efficiency, noise in dB(A) in the washing and spinning phases of the washing cycle are included in the Energy Label layout.

Noise is addressed in terms of its declaration for both the washing and the spinning phases. This approach is considered the most appropriate since the loudest noise occurs during the spinning phase, especially at higher spinning speeds. The setting of any noise performance scale would negatively impact on the higher spinning speed machines, which are sold more in Nordic countries to be used in conjunction with dryers.

Figure 2.39 shows the distribution of the declared noise levels for the washing and spinning process for all models on the European market (CECED 2014).

Figure 2.40 shows the trend of average noise level of washing and spinning process in washing machine models for the period of 2009 till 2103. As it can be seen the changes on the average values are not significant.

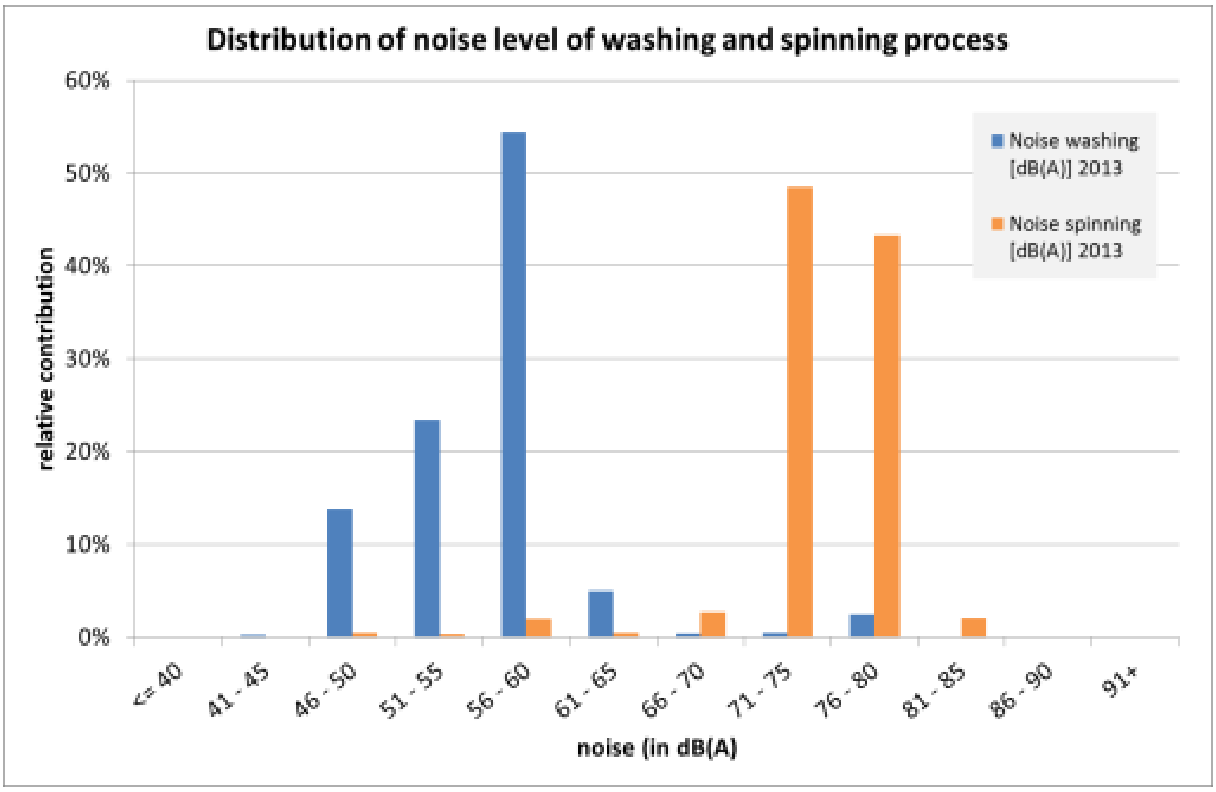


Figure 2.39: **Distribution of noise levels for washing and spinning process (Source: (CECED 2014))**

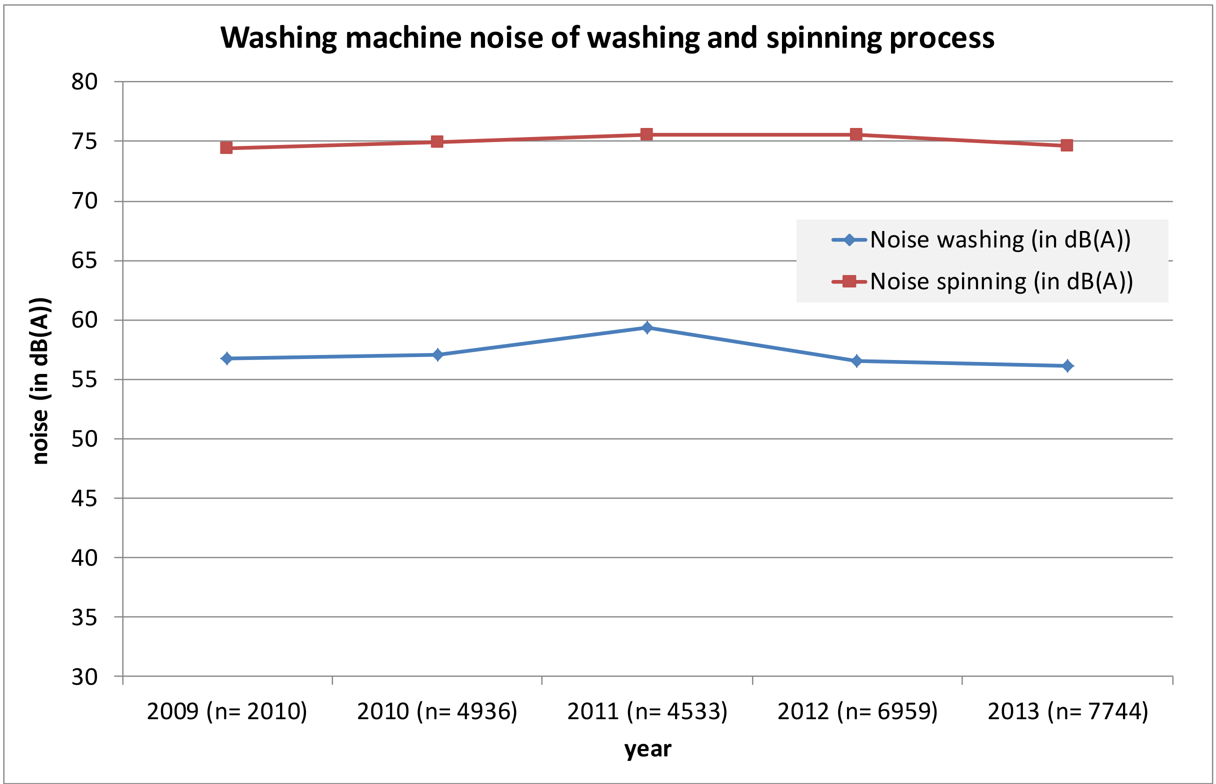


Figure 2.40: **Average levels of noise of washing and spinning process of washing machine (CECED 2014)**

2.2.4.2. Washer-dryer data up to 2013

The following trends are based on the analysis of available and valid CECED data of all models of washer-dryers placed on the European market between the years 1997 and 2013 (CECED 2014).

Total number of washer-dryer models available on the market

During this period the number of models shows a small increase (Figure 2.41) but in comparison with the number of washing machine models, washer-dryers show a very small amount of 5% in relation.

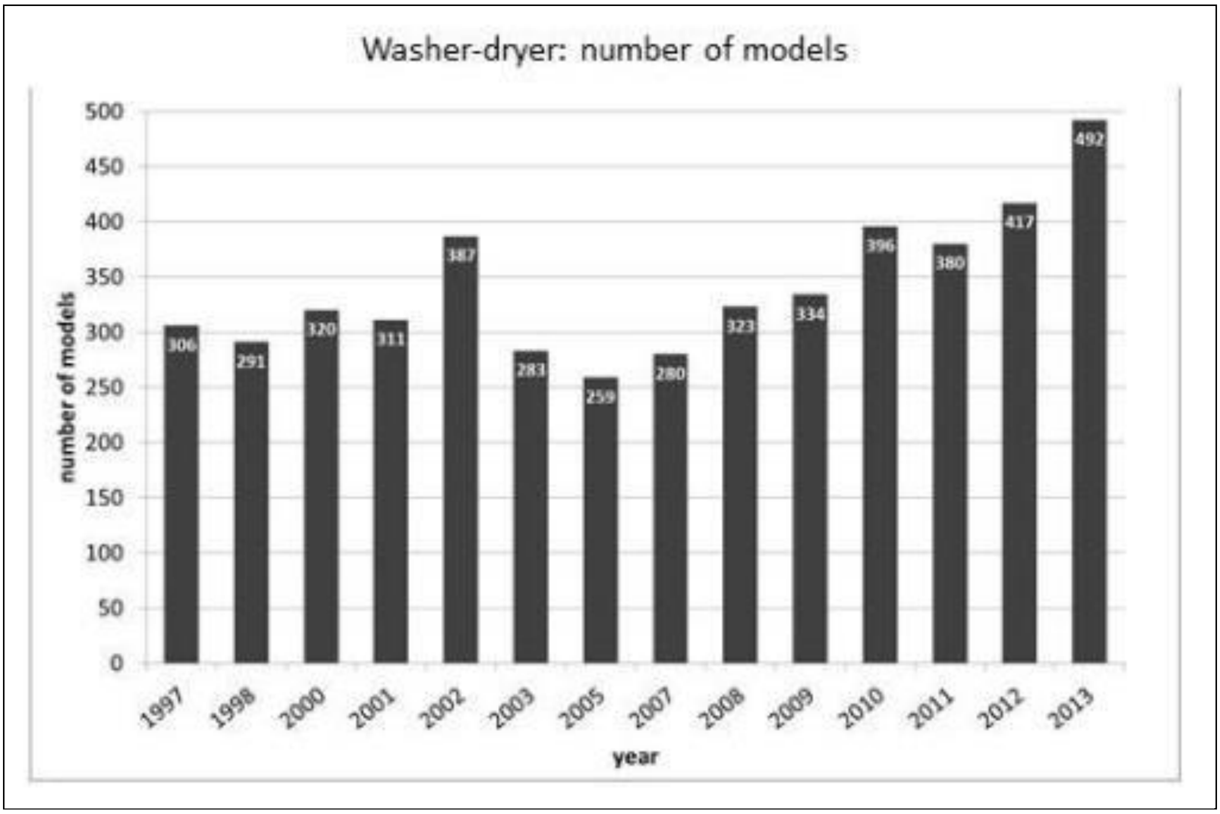


Figure 2.41: Development of total number of models of washer-dryers 1997-2013 (CECED 2014)

Capacities of washer-dryer models available on the market

The average washing and drying capacities show an increase of approximately 2.5 kg between 1997 and 2013 (Figure 2.42). A visible growth started in the year 2003. The average washing load capacity reached 7.4 kg (2013) and a maximum load capacity for washing of 11.0 kg (Figure 2.45) was reported.

In the year 1997 only about 50% of the load capacity of a washing cycle was able to dry in one drying cycle. Currently with almost 5 kg the average capacity of drying reaches about 66% of the washing capacity (Figure 2.43). The trend to larger washer-dryers with higher capacities for washing and drying is also visible in the analysis of the distribution of capacities classes over the years (Figure 2.43) and (Figure 2.44). Until 2003 over 60% of all models had a washing capacity up to 5 kg. In the following years larger machines show higher rates and actually over 50% have a washing capacity of 7 kg and higher.

Comparable is the increase of the drying capacity (Figure 2.46). Before 2003, the majority of all models was characterized by drying loading capacity up to 3.0 kg. Today, over 50% of all models offer a drying capacity between 4 and 7 kg (Figure 2.43).

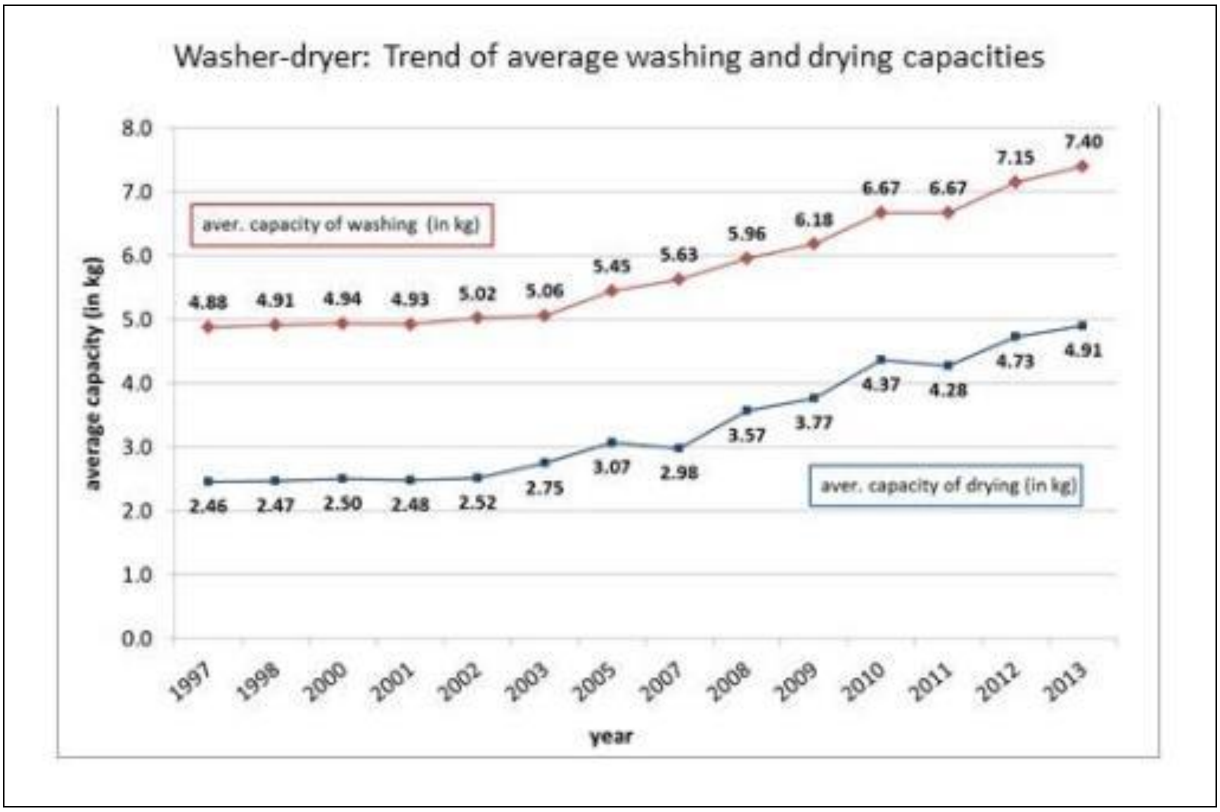


Figure 2.42: Trend of average washing and drying capacities of washer-dryer models (CECED 2014)

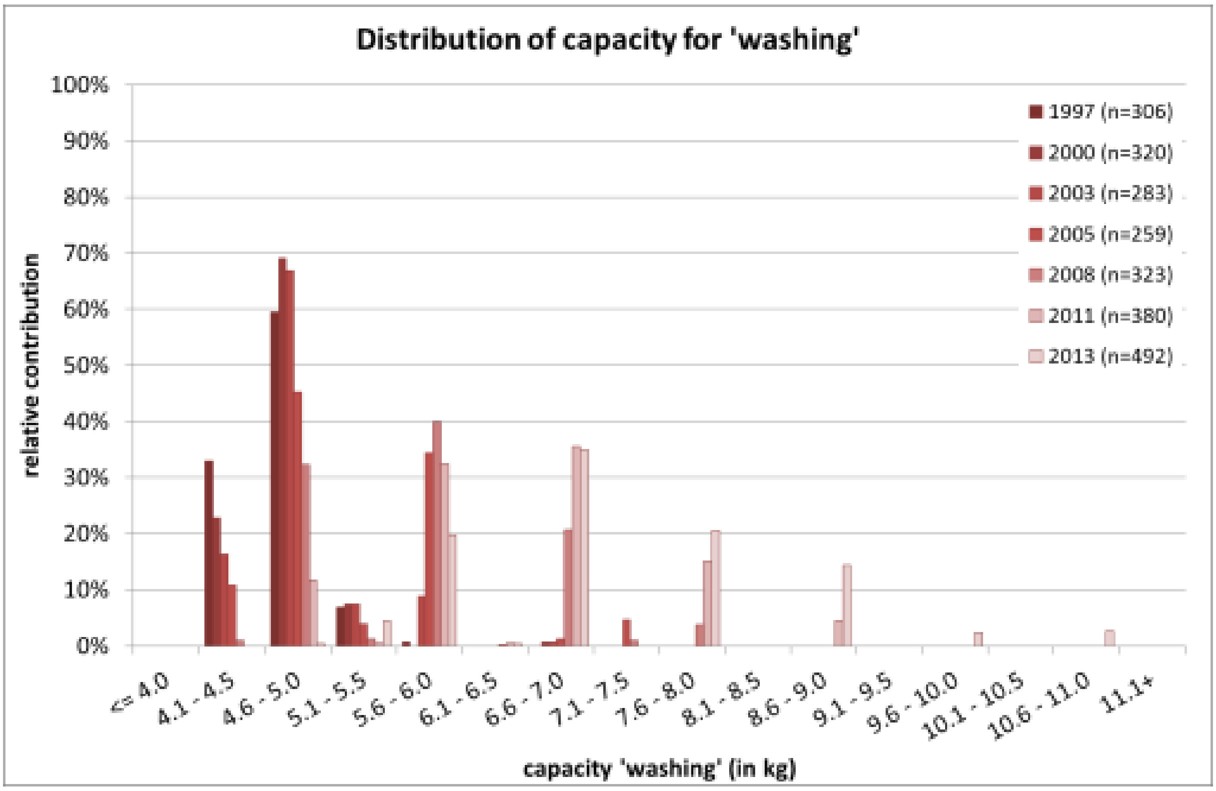


Figure 2.43: Distribution of rated capacity 'washing' of washer-dryer models (CECED 2014)

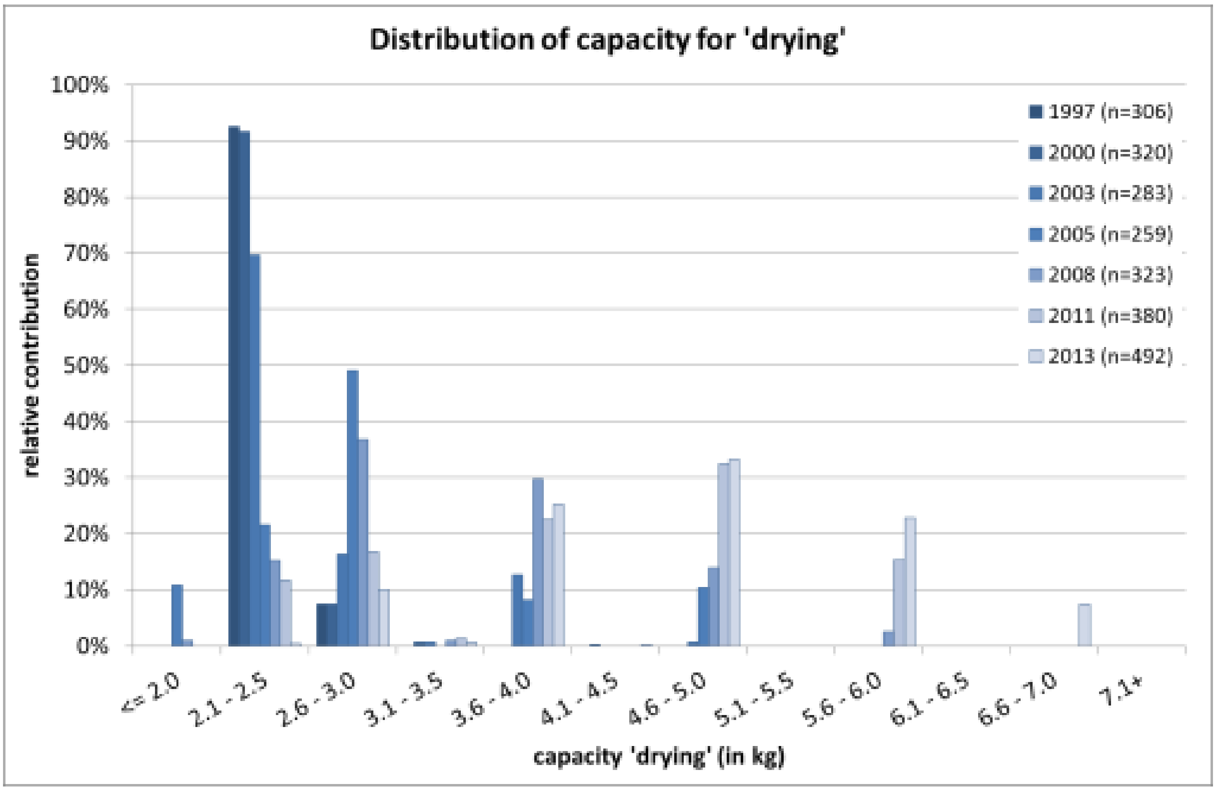


Figure 2.44: **Distribution of rated capacity 'drying' of washer-dryer models (CECED 2014)**

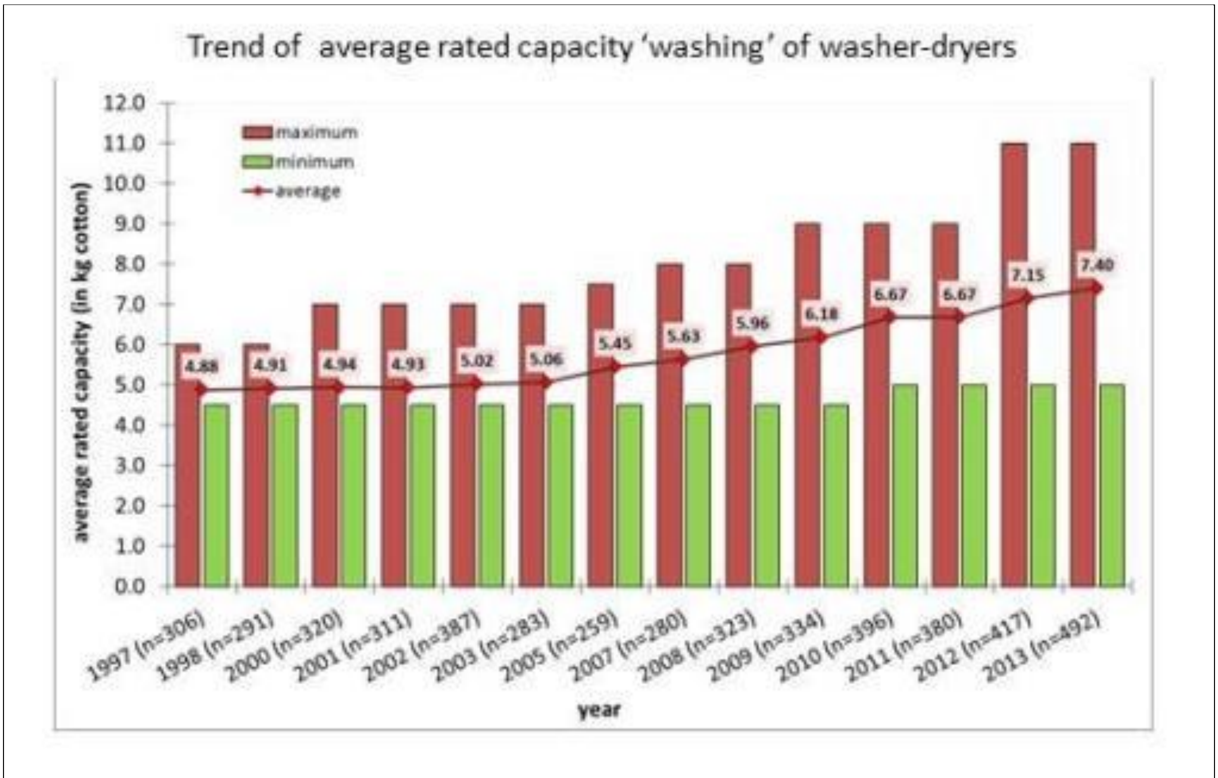


Figure 2.45: **Rated capacity 'washing' of washer-dryer models (statistical results based on (CECED 2014))**

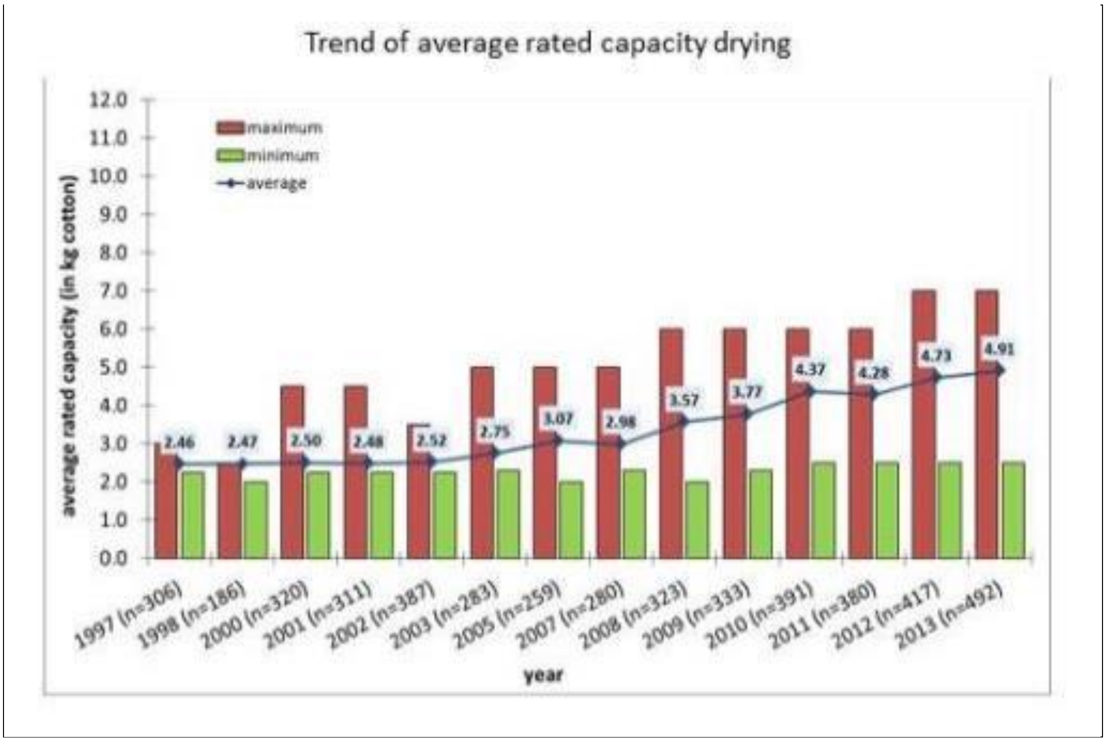


Figure 2.46: Rated capacity 'drying' of washer-dryer models (statistical results based on (CECED 2014))

Energy consumption of washer-dryer models available on the market

The development of the average energy consumption for the wash cycle only is comparable with the trend of washing machines. Up to the year 2010 the data of washer-dryers show slightly higher average energy consumption values than washing machines. Over this period the results are nearly constant with an energy consumption of approximately 1.1 kWh resulting in an average of 1.16 kWh per wash cycle in 2013 (Figure 2.47).

The distribution shows that in 2013 nearly 50% of all models have energy consumption up to 1.15 kWh (Figure 2.48).

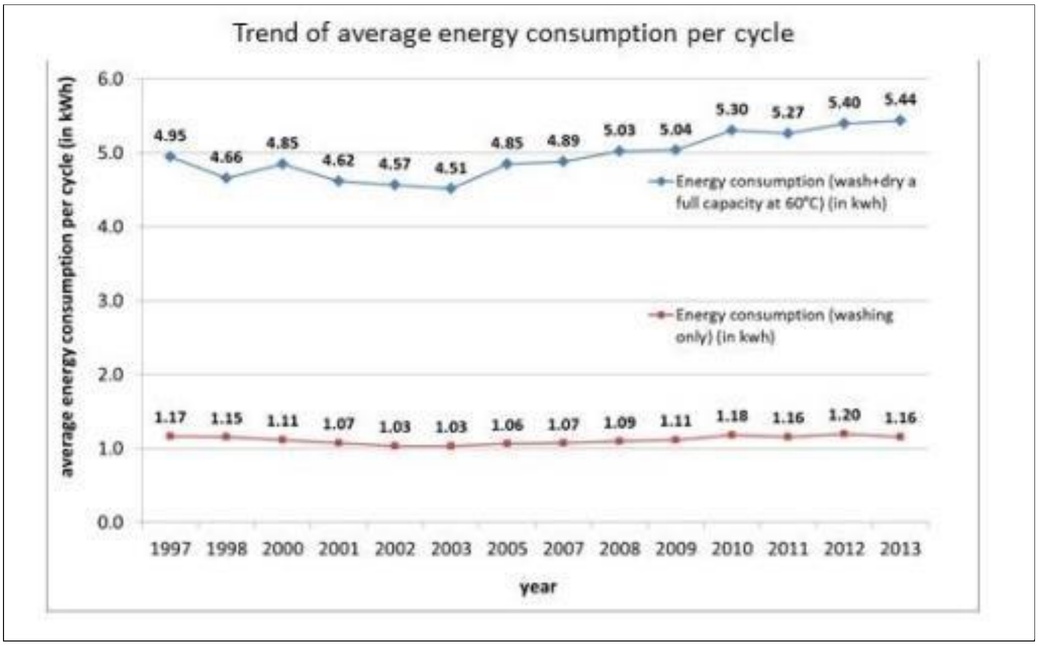


Figure 2.47: Trend of average energy consumption of washer-dryer models (CECED 2014)

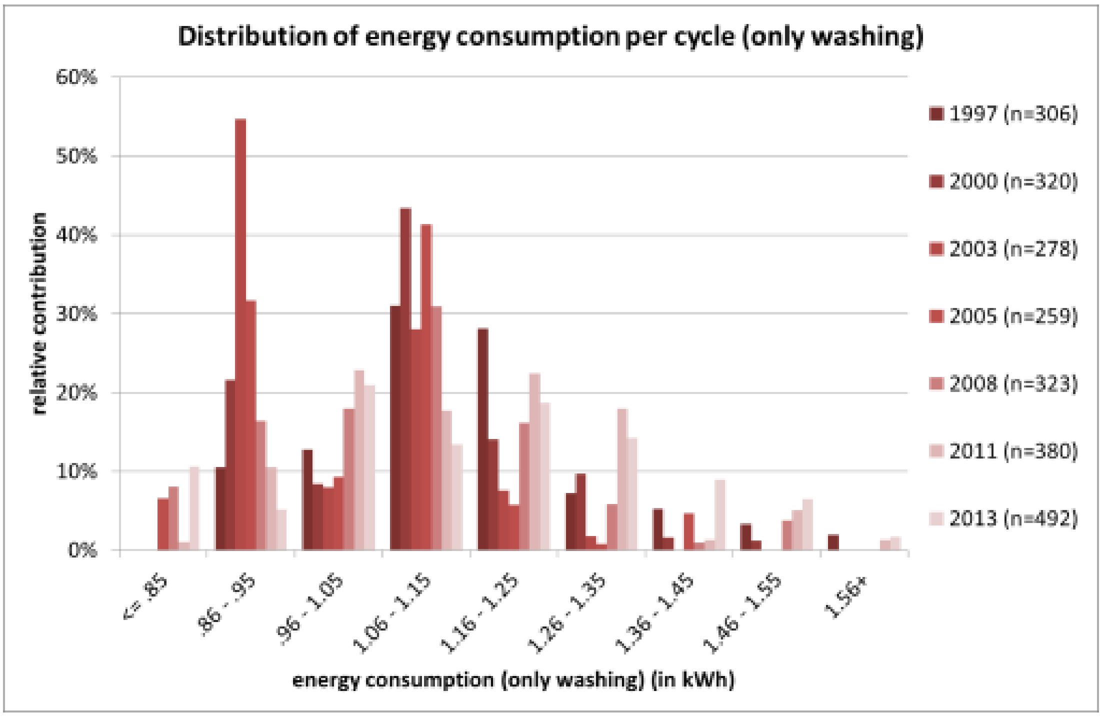


Figure 2.48: **Distribution of specific energy consumption for wash cycle of washer-dryer models (CECED 2014)**

Considering the <u>'wash and dry' cycle</u> (washing and drying of the full (wash) capacity, as shown in Figure 2.45, in one cycle) the absolute energy consumption has increased by 0.5 kWh per cycle between 1997 and 2013 (Figure 2.47). Until 2003 the energy consumption shows a slightly decrease. But then a stronger growth in consumption started and reached actually 5.44 kWh per cycle on average in 2013.

The distribution shows that in 2013 over 60% of all models reached an energy consumption of 5.50 kWh per ‚wash and dry' cycle (Figure 2.49).

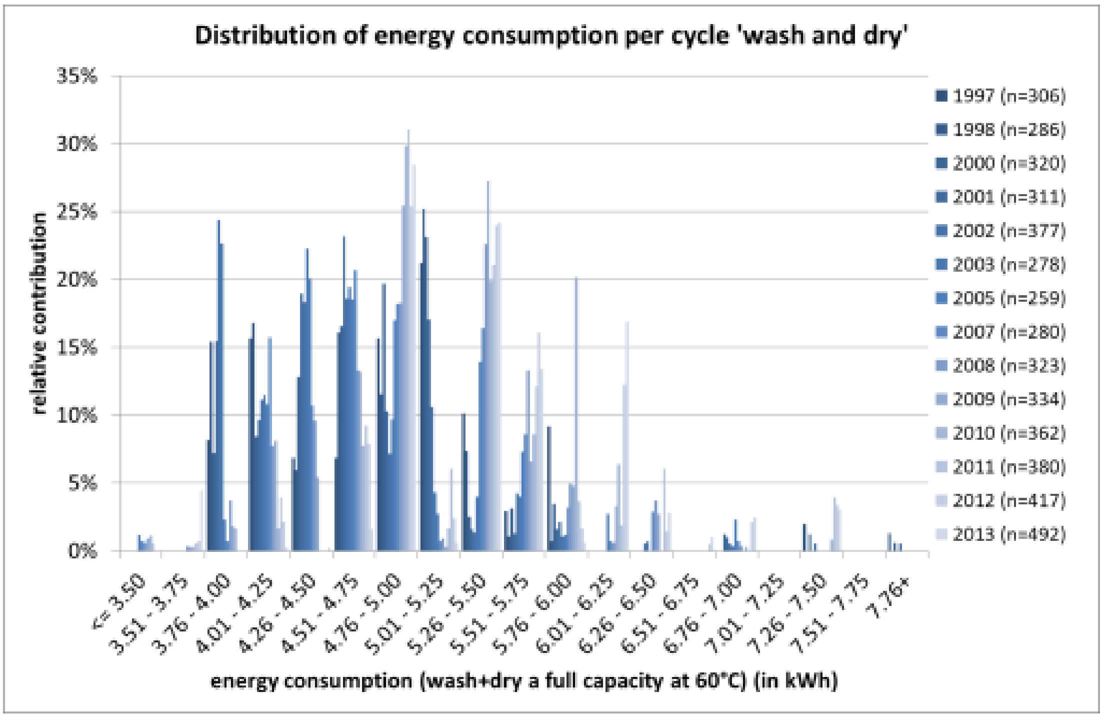


Figure 2.49: **Distribution of energy consumption for 'wash and dry' cycle of washer-dryer models (CECED 2014)**

The growth of the rated capacities of 'washing' and 'drying' over the years gives a possible reason for the observable increase of the energy consumption (Figure 2.50). However, in comparison with the trend in increasing total energy consumption, the specific energy consumption of 'wash and dry' (the division of total energy consumption by the capacity of 'washing') shows continuously declining values (Figure 2.51). From 1997 to 2013 the specific energy consumption 'wash and dry' decreased from 1.02 kWh/kg to 0.74 kWh/kg in 2013. Also the specific energy consumption of a 'wash cycle' only (calculated by dividing the energy consumption of a wash cycle by the capacity of 'washing') shows a constant declining trend (Figure 2.51) and lies on average at 0.20 kWh per kg load.

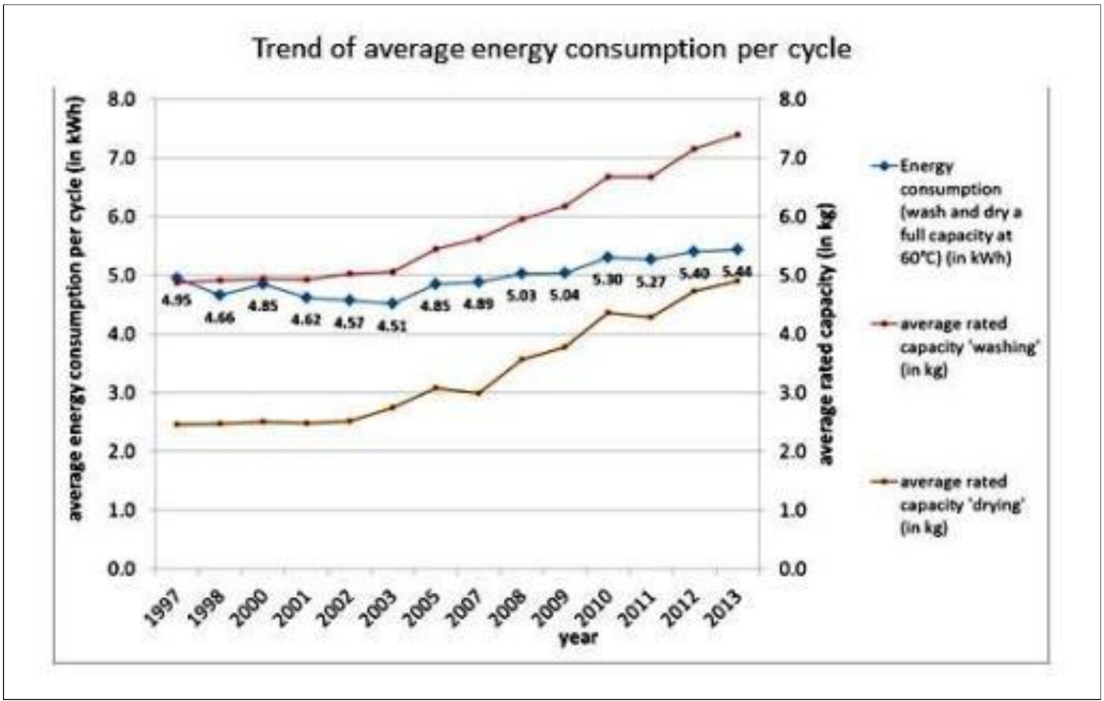


Figure 2.50: **Average energy consumption (wash and dry) and rated capacities of washer-dryer models (CECED 2014)**

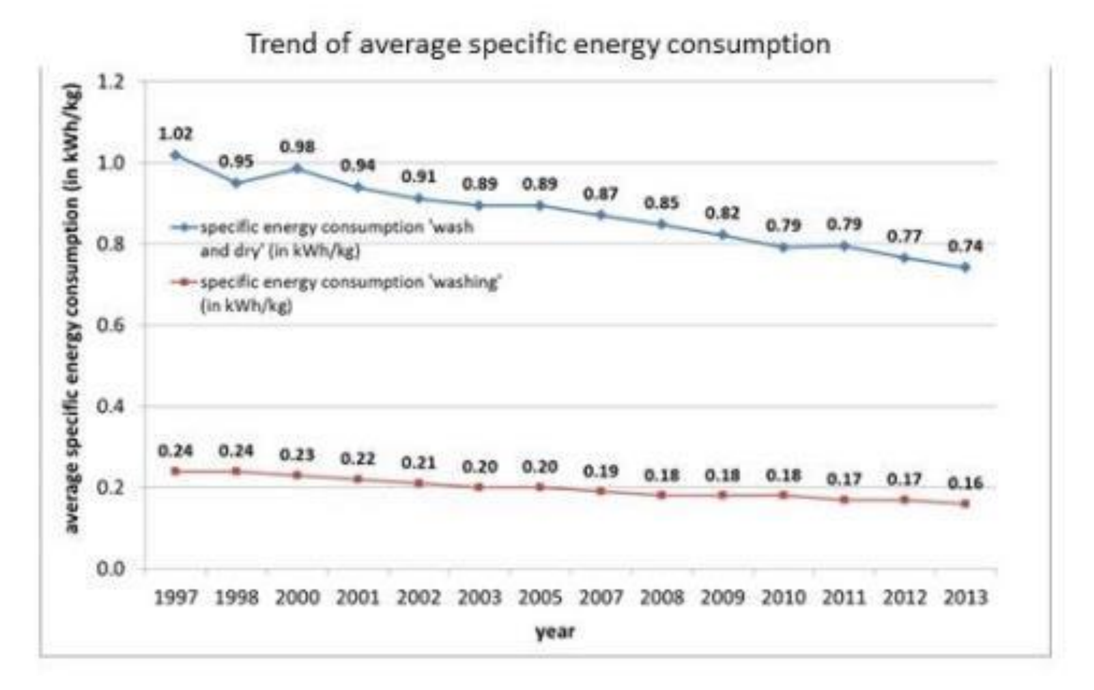


Figure 2.51: **Trend of average specific energy consumption of washer-dryer models (CECED 2014), per kg cotton capacity**

Energy efficiency classes of washer-dryer models available on the market

From 1997 to 2013 the distribution of Energy Efficiency classes has been shifted dramatically towards higher efficiency classes (Figure 2.52). In 2013 about 50% of washer-dryers were labelled with class A and the majority of the rest was labelled as B (Figure 2.53). A minimal share of models, approximately 4%, lies marginal below the limit of specific energy consumption per cycle of 0.68 kWh/kg.

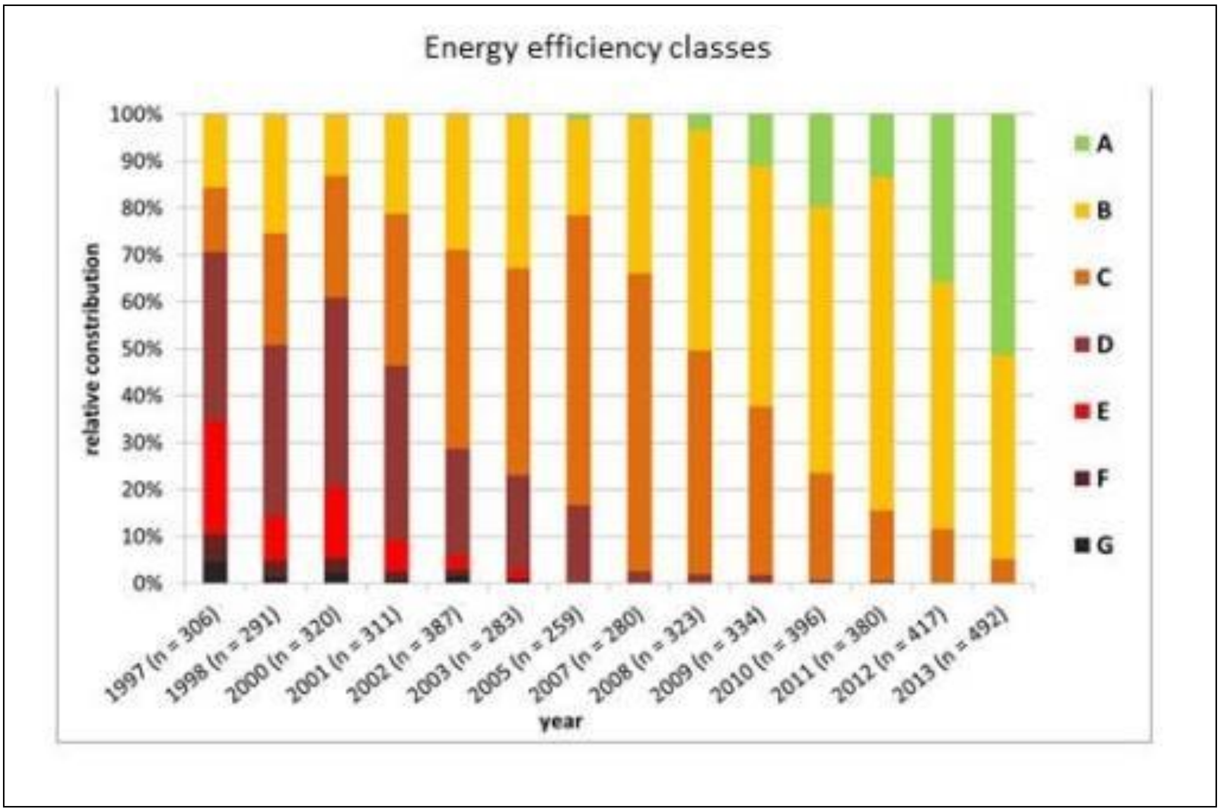


Figure 2.52: Distribution of Energy Efficiency classes of washer-dryer models (CECED 2014)

Figure 2.53 illustrates the distribution of washing-dryer models in terms of the limit values for the Energy Label classes.

As for washing machines, it can be seen that the majority of models had an energy consumption that complies with the lower limitation of the corresponding Energy Label class. For instance nearly 30% of washing-dryer models had an energy consumption of 0.81 kWh, which is the lower limit of energy efficiency class B 0.68 < C ≤ 0.81, whereas only very few models were in the upper limit of the Energy Label class B. Manufacturers seem to adjust the energy performance of the label programme to the minimum requirements of a desired Energy Label class.

Washing performance of washer-dryer models available on the market

Nearly 100% of all washer-dryer models reached a Washing Performance classes A between the years 2005 to 2011 (Figure 2.54). Later a small number of washer-dryer models are declared 'only' class B in Washing Performance again.

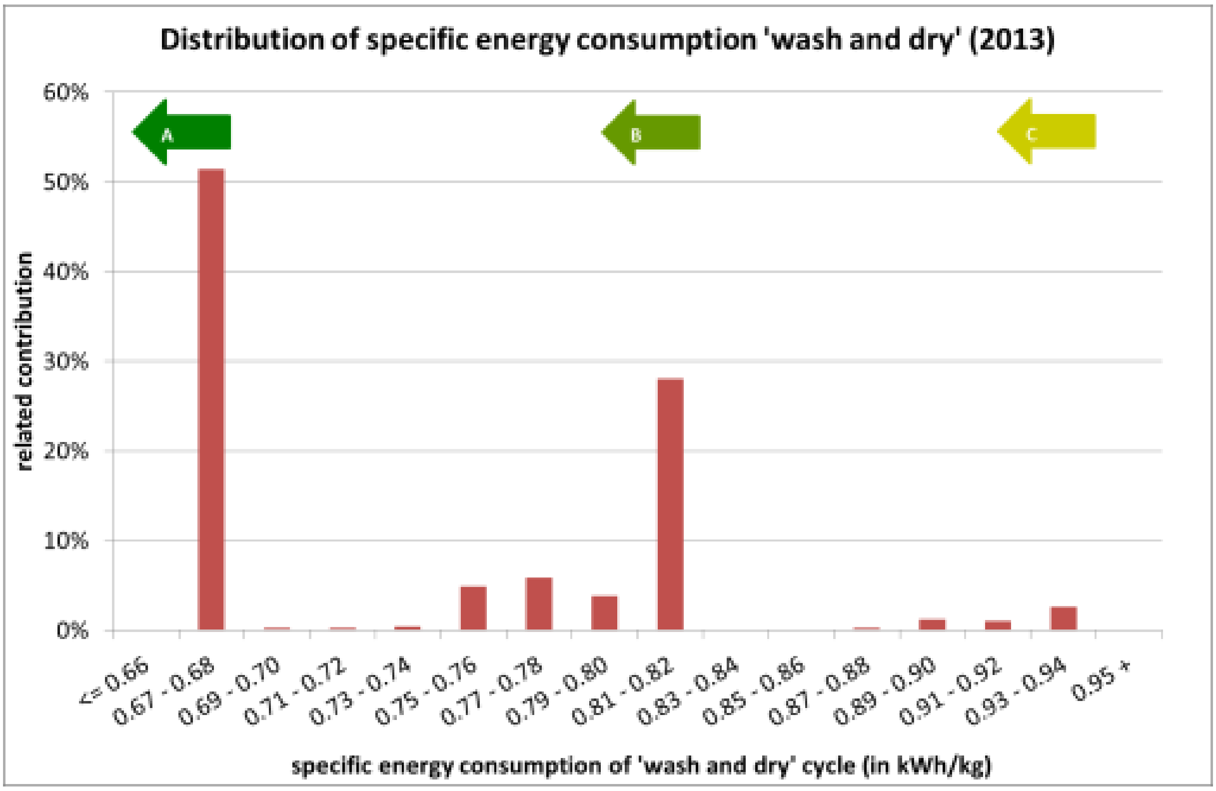


Figure 2.53: **Distribution of specific energy consumption of washer-dryer models 2013 (in-house elaboration based on (CECED 2014))**

Figure 2.54: **Distribution of Washing Performance classes of washer-dryer models (CECED 2014)**

Spin speed of washer-dryer models available on the market

A more or less continuous increase of the average maximum spin speed can be seen from 1,102 rpm (1997) per wash cycle to 1,396 rpm (2013) (Figure 2.55). While in 1997 most washer-dryers could be found in spin speed class between 901 and 1,000 rpm, in2013 most machines are in spin speed classes between 1,301 – 1,400 rpm (Figure 2.56). In 2013 17% were even declared to be between 1,501 and 1,600 rpm (Figure 2.57).

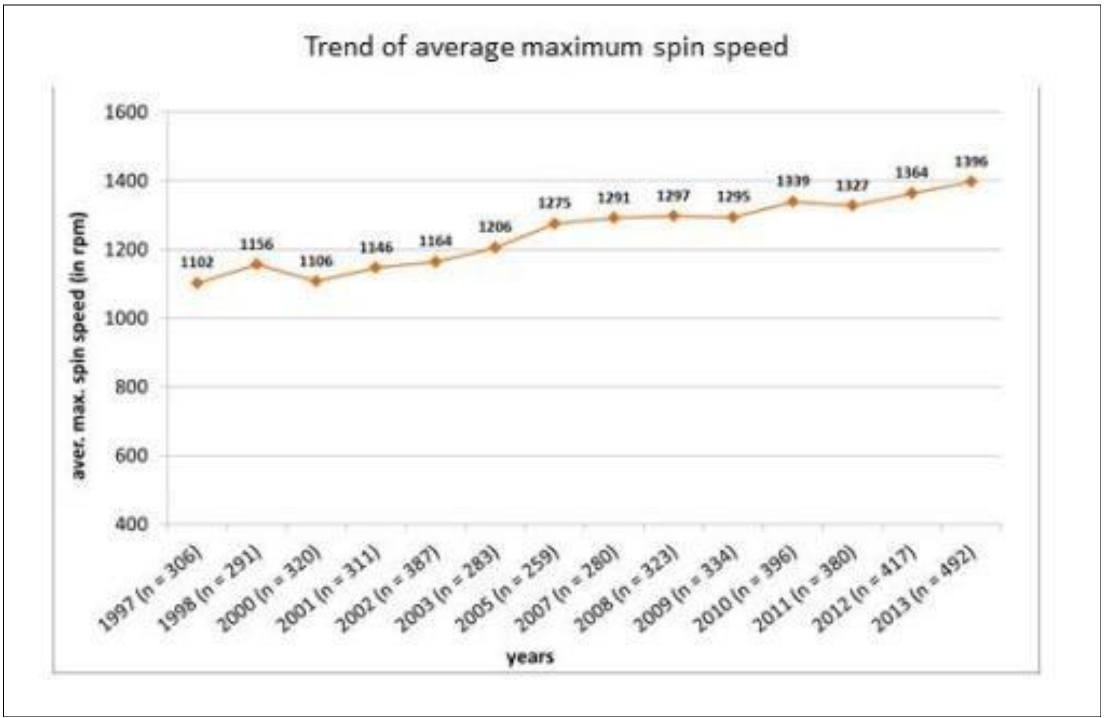


Figure 2.55: **Trend of average maximum spin speed of washer-dryer models (CECED 2014)**

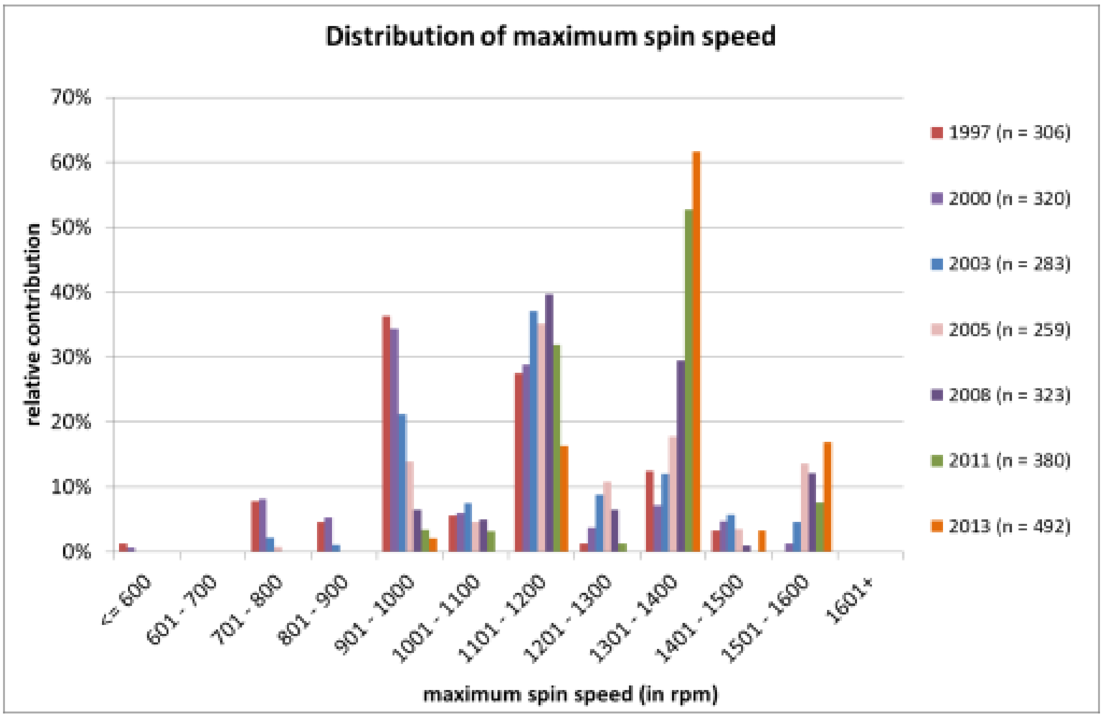


Figure 2.56: **Distribution of average maximum spin speed of washer-dryer models (CECED 2014)**

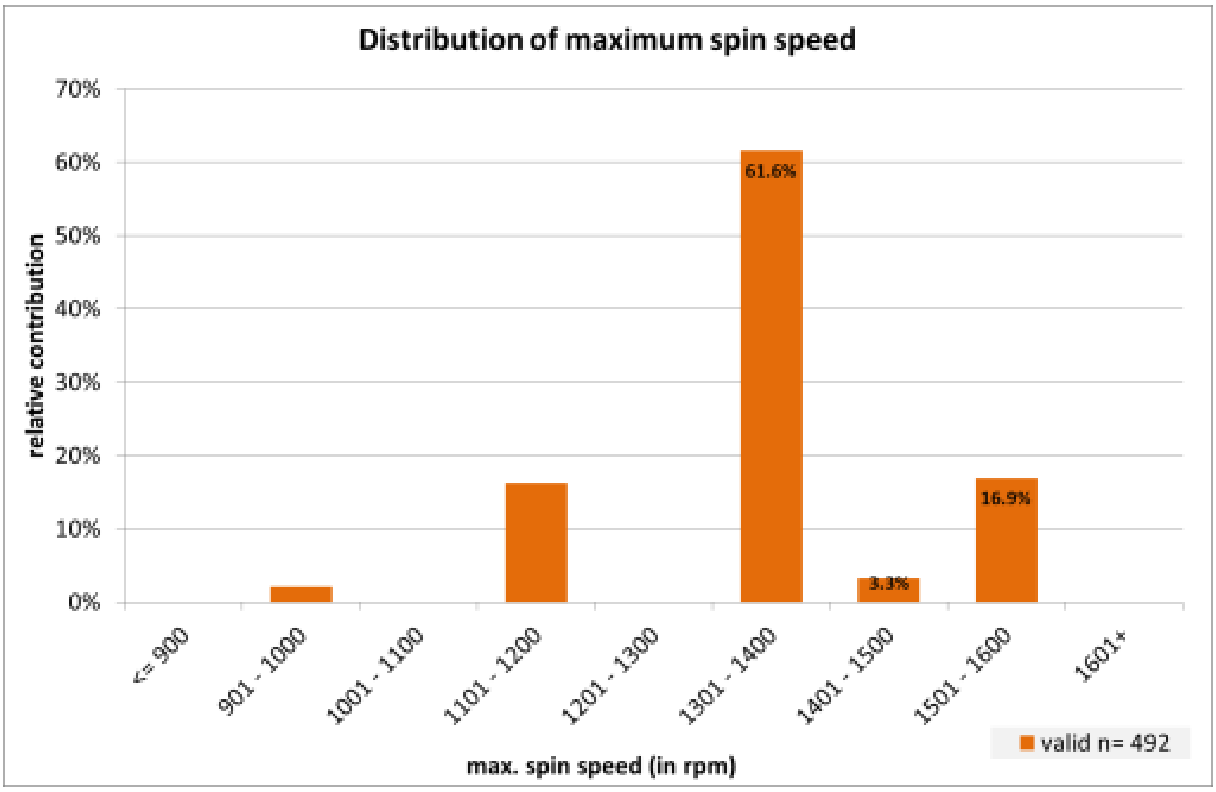


Figure 2.57: **Distribution of average maximum spin speed of washer-dryer models in 2013 (CECED 2014)**

Water consumption of washer-dryer models available on the market

The average total water consumption for washing and drying of washer-dryer models has declined from 129.7 litres down to 98.1 litres (Figure 2.58). This is an improvement of 24% between 1997 and 2013. Nevertheless, most of washer-dryers on the market still consume around twice as much water as a washing machine of the same capacity due to additional water being used in the drying process because of the water-based condensing system (cf. section 4.3.2).

The average specific water consumption rated to the capacity of the models has actually halved from 26.8 l/kg down to 13.4 l/kg over this period (Figure 2.59). This again is fostered by the combination of lower absolute values and increasing capacities.

The distribution shows that in 2013 half of all models have consumption values below 100 l per cycle (Figure 2.60).

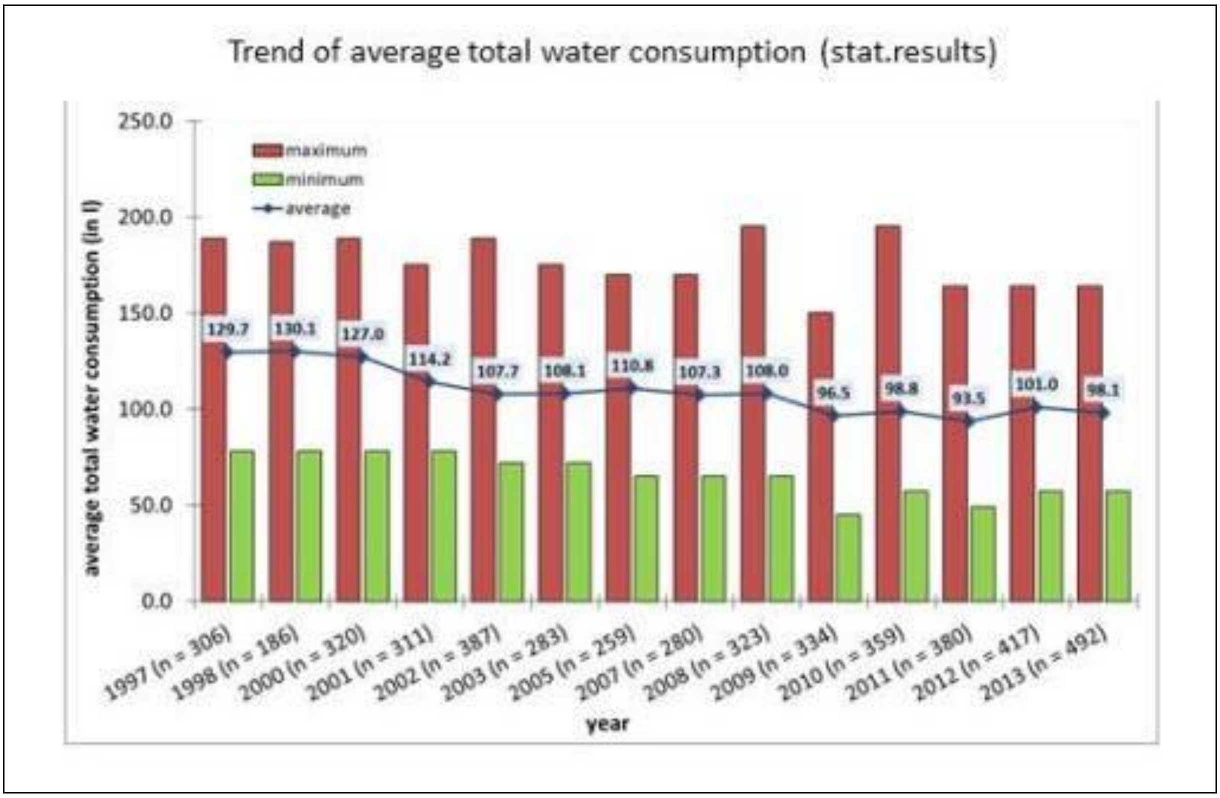


Figure 2.58: Average total water consumption of washer-dryer models (statistical results based on (CECED 2014))

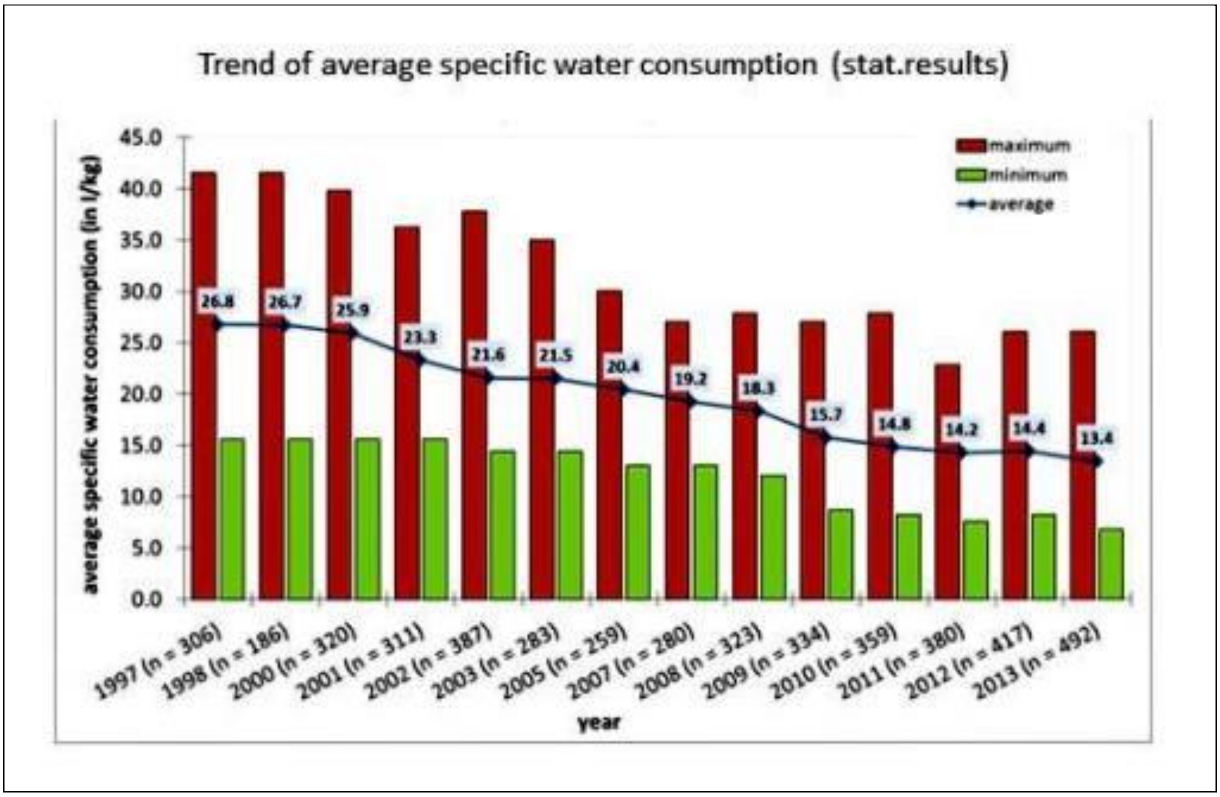


Figure 2.59: Average specific water consumption of washer-dryer models (statistical results based on (CECED 2014))

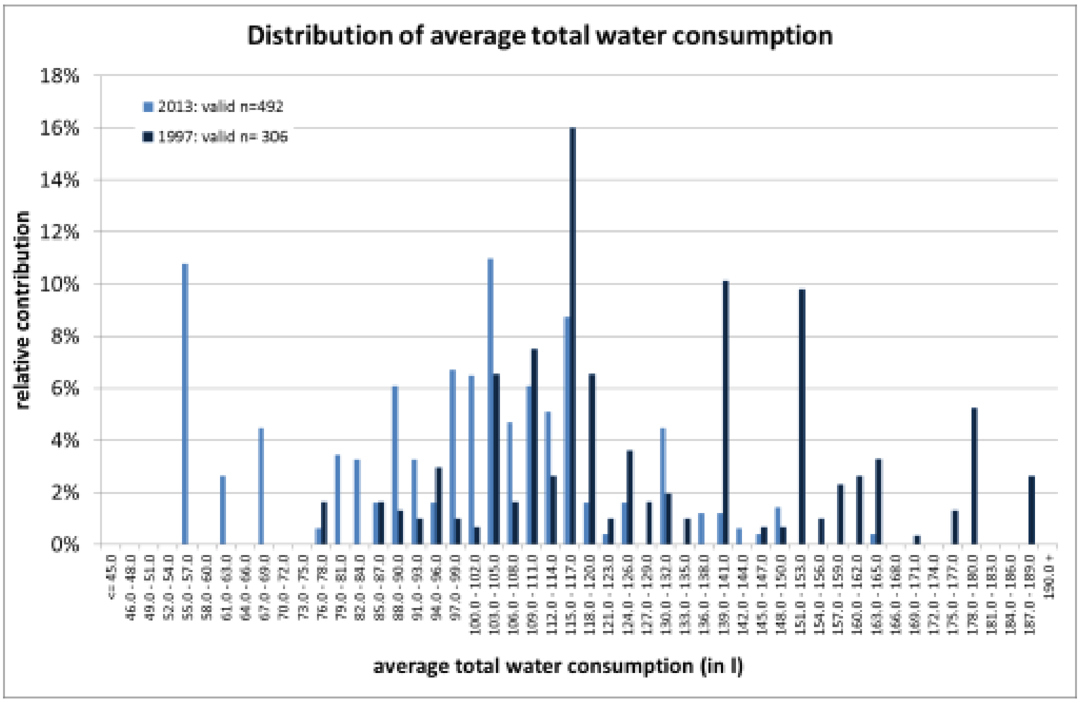


Figure 2.60: **Distribution of average total water consumption of washer-dryer models (CECED 2014)**

Noise emissions of washer-dryer models available on the market

For the analysis of the noise emissions only data between 2009 and 2013 are available. In comparison to the 'washing' or 'drying' cycle, the noise emission of the spinning cycle of washer-dryers is highest (Figure 2.61). Constantly over this period the noise level of spinning lies by approximately 75 dB(A). The noise emission of 'drying' is on average at 62 dB(A) over the years and also shows no significantly changes during this period. Accordingly the distributions of ‚'drying' and ‚'spinning' indicate no significant changes over the years (Figure 2.62, Figure 2.63). By comparison, the noise emission of 'washing' decreased by 4 dB(A) to 55 dB(A) in 2013 (Figure 2.61).

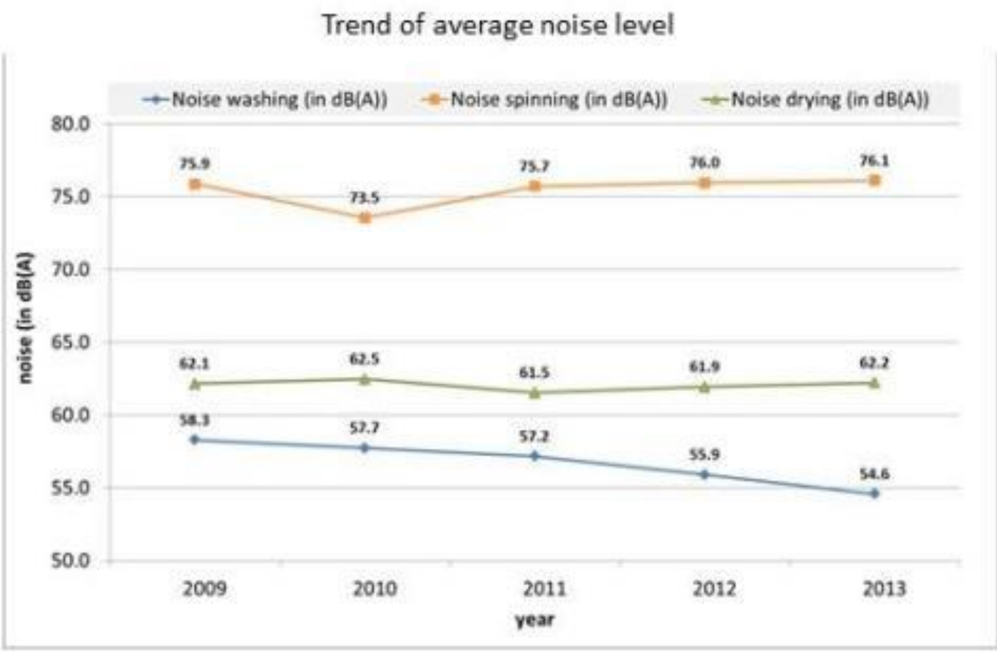


Figure 2.61: **Trend of average noise levels of washer-dryers (CECED 2014)**

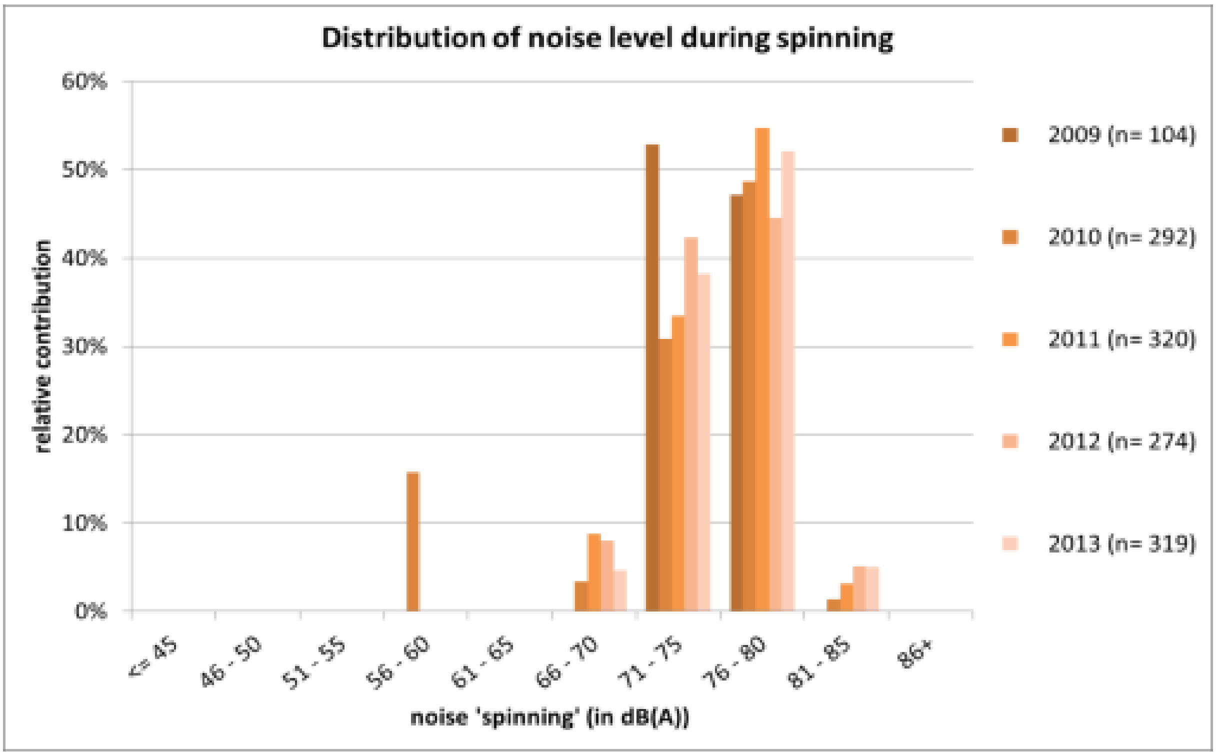


Figure 2.62: Distribution of average noise level during 'spinning' of washer-dryers (CECED 2014)

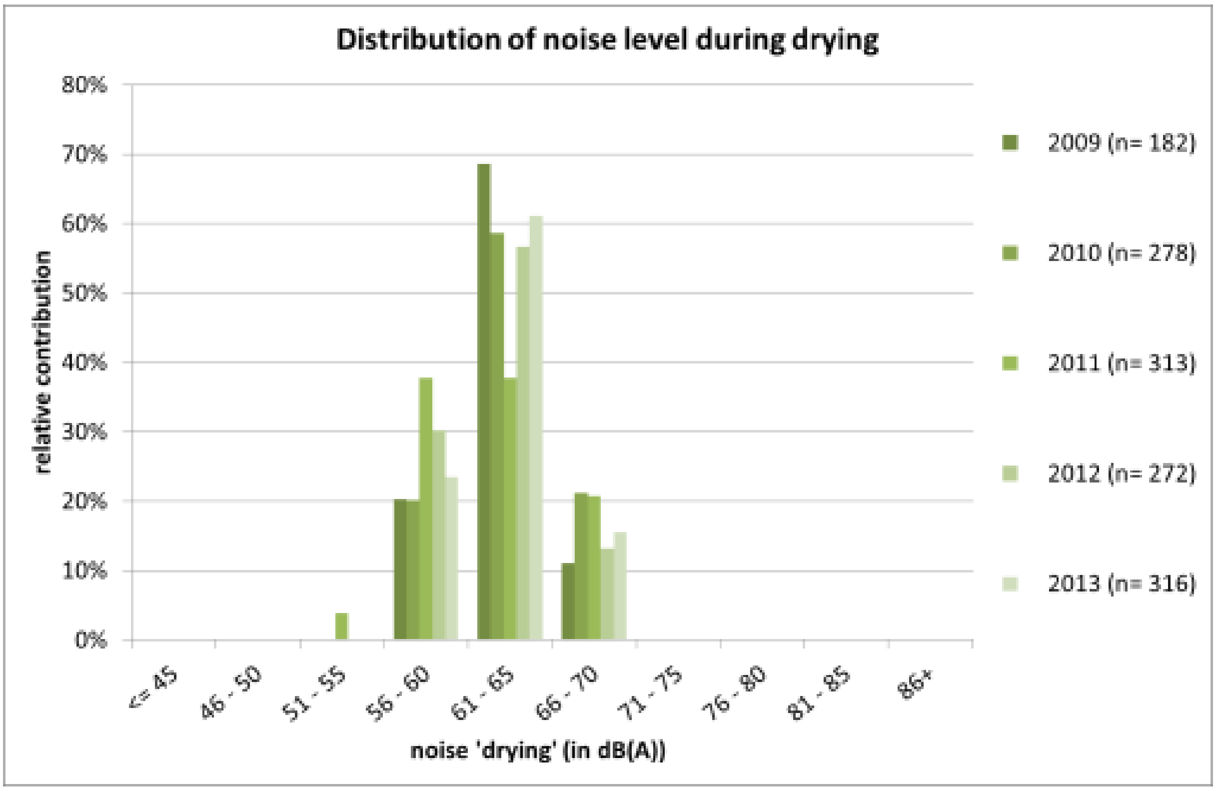


Figure 2.63 Distribution of average noise level during ''drying' of washer-dryers (CECED 2014)

Over 50% of all models reach a noise level of 55 dB(A) or lower during 'washing' (Figure 2.64). Especially in the noise range between 46 dB(A) and 50 dB(A) show a noticeable growth up to 18% of all models in 2013.

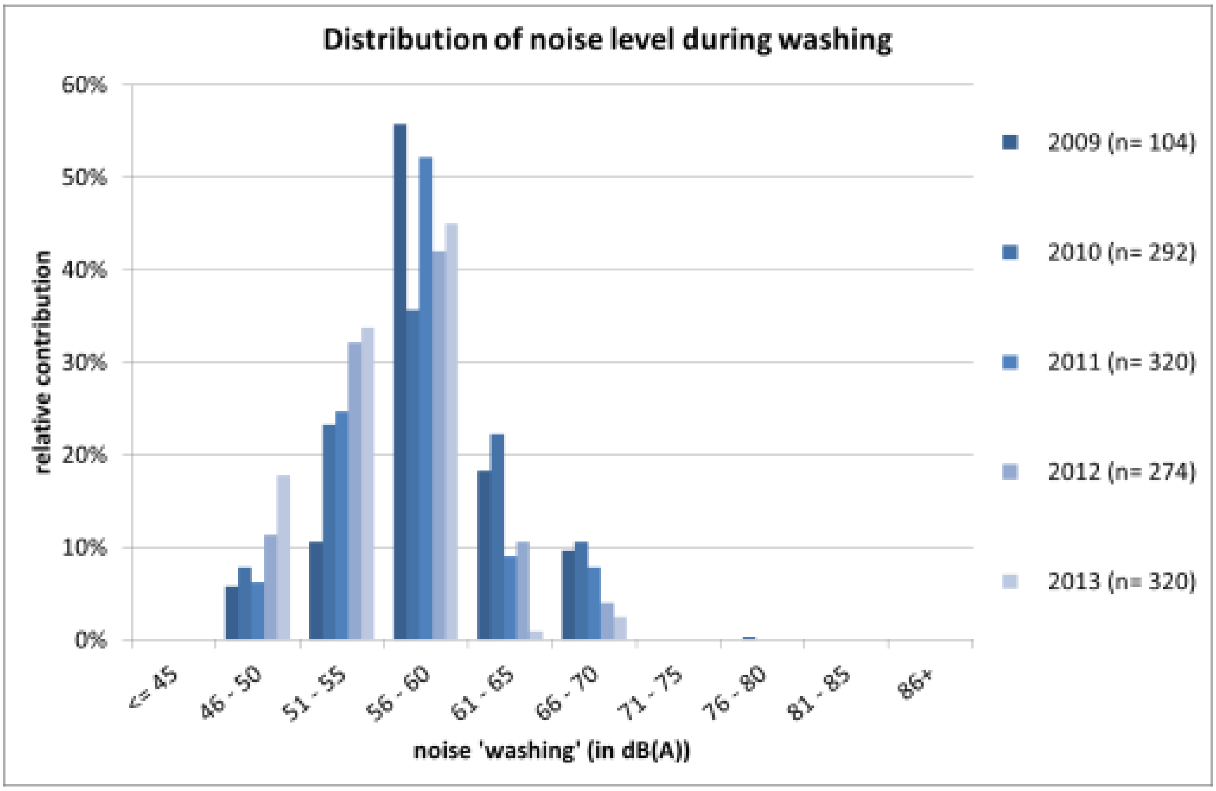


Figure 2.64: **Distribution of average noise level during ''washing' of washer-dryers (CECED 2014)**

2.2.4.3. Washing machine and washer-dryer data: Summary and update of CECED database 2014

After the release of the draft Task 1-4 report, additional data on washing machines and washer-dryers from the CECED database became available which will be summarized in the following.

CECED database of washing machine models 2014

Continuation of the trends observed earlier can be observed by comparing data of the 2014 database (CECED 2014) with the 2013 database.

The rated capacity of the washing machine did increase by almost 2.5% between 2013 and 2014: the average washing machine in 2014 had a capacity of 7.2 kg. At the same time the average weighted annual energy consumption of the cotton standard programmes decreased by 2.2%, while the specific consumption per kg to be washed decreased by 4.8%. Instead, the water consumption increased by 0.8%, as absolute value per cycle, and by 1.6% for the specific values per kilogram of laundry washed.

Table 2.15: **Average values of CECED databases for washing machines for 2013 and 2014 and trend of change**

CECED database	2013		2014		2014 vs 2013
	average	valid data	average	valid data	
Capacity (in kg) (cotton)	7.04	7,745	7.22	6,311	2.49%
Weighted annual energy consumption (in kWh/year)	182.6	7,745	178.6	6,311	-2.21%
Weighted annual water consumption (in L/year)	9.911	7,745	9.992	6,311	0.81%
Noise washing (in dB(A))	56.1	7,744	55.4	6,311	-1.34%
Noise spinning (in dB(A))	74.6	7,741	75.4	6,307	0.98%

CECED database	2013		2014		2014 vs 2013
	average	valid data	average	valid data	
Dimension width (in cm)	57.7	6,599	58.4	5,664	1.10%
Weight (in kg)	70.2	6,532	71.1	5,374	1.31%
Energy consumption per cycle (in kWh) (calculated from annual consumption values by dividing annual value by 220 cycles)	0.830	7,745	0.812	6,311	-2.21%
Specific energy consumption (in kWh/kg)	0.120	7,745	0.115	6,311	-4.78%
Water consumption per cycle (in L) (calculated from annual consumption values by dividing annual value by 220 cycles)	45.1	7,745	45.4	6,311	0.81%
Specific water consumption (in L/kg)	6.50	7,745	6.40	6,311	-1.60%

CECED database of washer-dryer models 2014

For the washing function, the rated capacity of washer-dryers continued to increase by 1.0% from 2013 to 2014. While it decreased slightly (by 0.3%) for the drying function (Table 2.16). Energy consumption for washing and drying the full load was reduced in average by only 0.5%. However, for the washing only function it decreased by 4.4%. Also the average total water consumption decreased by 3.4%.

Table 2.16: Average values of CECED databases for washer-dryers for 2013 and 2014 and trend of change

CECED database	2013		2014		2014 vs 2013
	aver.	valid data	aver.	valid data	
Capacity (washing) (in kg)	7.40	492	7.48	409	1.04%
Capacity (drying) (in kg)	4.91	492	4.89	409	-0.26%
Energy consumption (wash and dry a full capacity at 60 °C) (in kwh)	5.438	492	5.410	409	-0.51%
Energy consumption (washing only) (in kwh)	1.156	492	1.106	409	-4.36%
Max.spin speed (in rpm)	1396	492	1414	409	1.24%
Water consumption (total) (in l)	98.1	492	94.8	409	-3.37%
Noise washing (in dB(A))	54.6	320	53.7	300	-1.51%
Noise spinning (in dB(A))	76.1	319	76.0	300	-0.18%
Noise drying (in dB(A))	62.2	316	61.6	288	-0.97%
Dimension width (in cm)	59.9	360	59.9	400	0.00%
Weight (in kg)	78.6	344	82.3	231	4.67%
Specific energy consumption 'washing' (in kWh/kg)	0.158	492	0.151	409	-4.86%
Specific energy consumption 'drying' (in kWh/kg)	1.142	492	1.157	409	1.27%
Specific water consumption (in l/kg)	13.37	492	12.85	409	-3.93%

2.2.5. Study "ATLETE II – Appliance Testing for Washing Machines Energy Label and Ecodesign Evaluation"

2.2.5.1. General compliance check of household washing machines

Atlete II was an EU-funded project (see www.atlete.eu) with the main objective to check the compliance of washing machines to the provisions of EU Energy Labelling and Ecodesign legislation. Combined washer-dryers were not in the scope of this study.

Selection of products

Specific models were chosen for testing, involving all known manufacturers and conducted by a notary. Appliances were selected on the basis of the companies' market share and the product's availability in specific markets. 50 washing machine models were selected.

Selection of test laboratories

All available laboratories in Europe that were able to test (at least in theory) washing machines were identified. There were 20 in total. All of them were contacted and invited to participate. Thirteen replied positively, and the eight best were shortlisted based on proven capabilities. Based on a visit by two laboratory experts (one nominated by the representation of manufacturers – CECED, and the other by the representation of consumers – ICRT), the six best available laboratories to test washing machines in Europe at that moment were selected.

Selected test parameters

The following parameters were tested: energy consumption, water consumption, washing performance, spinning performance, spin speed, load capacity, power consumption and duration of off mode and left-on mode, ecodesign minimum requirements, product specific requirements and information requirements.

The laboratory tests were conducted on the parameters shown in Table 2.17:

Table 2.17: Parameters tested

Parameter measured	Relevant for		Unit	Tolerance
	Ecodesign	Labelling		
Annual energy consumption	✓	✓	kWh	+10%
Energy consumption	✓	✓	kWh	Step 1: +10% / Step 2: +6%
Programme time	✓	✓	min	+10%
Water consumption	✓	✓	litre	+10%
Remaining moisture content		✓	%	+10%
Spin speed		✓	rpm	-10%
Power consumption in off mode P_0 and left-on mode P_l	✓	✓	W	if > 1W: +10% if ≤ 1W: +0.10 W
Duration of the left-on mode	✓	✓	min	+10%
Airborne acoustic noise		✓	dB(A) re 1 pW	measured and ratedvalue shall meet
Washing efficiency index	✓			-4%

The harmonized standard EN 60456: 2011 has been applied by the laboratories selected.

Additionally, the following generic, respectively documentation requirements were checked:

- Energy Labelling (EU 1061/2010)
    - Presence of Energy Label in the WM unit(s) to be tested

  - Presence of the product fiche in the unit(s) to be tested or delivered by the supplier upon request, the mandatory declarations and in the order requested
- Ecodesign generic requirements according to EU 1015/2010 (different deadlines)
  - Generic requirements about the washing machine
  - Presence and identification of the 20 °C cycle
  - Identification of “standard programmes” on the front of the machine
  - Information in the instruction booklet:
  - Indication of the standard programmes and of their performance
  - Power consumption of the off mode and left-on mode
  - Recommendations on detergent use
  - Indicative information for the main washing programmes (duration, moisture content, energy and water consumption)

The results were communicated to the individual company responsible for each washing machine model, and to market surveillance authorities (MSAs) of countries where the appliances were available, and are finally becoming fully publicly available (http://www.atlete.eu/2/).

Verification of declaration

In the course of the project, the degree of compliance to energy labels affixed to washing machines were tested, checking if these provided accurate information about the technical specificities of the appliance, including their energy efficiency and functional performance. The results of the testing campaign are:

- 100% compliance rate with the energy efficiency class and energy consumption declarations for the Energy Label;
- 100% compliance rate with energy and water consumption ecodesign minimum requirements;
- 92% overall compliance rate for functional performance class and parameters;
- 84% overall compliance of the product fiche, and information availability and proper format requested by ecodesign;
- 64% compliance with the requirement to indicate the standard programme on the machine;
- 38% compliance rate for the information requested by ecodesign to be provided in the instruction booklet; and
- 30% overall compliance rate when including all individual parameters.

Non-compliance cases

Non-compliance cases were essentially due to formal requirements, and not wrong declaration of energy labels. Some specific examples are

- standard cotton programmes not clearly identifiable on the programme selection device or on the display
- missing one or several pieces of information in the instruction booklet, such as indication of the standard cotton programmes, energy consumption of the standard 60 °C cotton programme at full and partial load and of the standard 40 °C programme at partial load, weighted power consumption of the off mode and of the left-on mode, programme time, remaining moisture content, energy and water consumption for the main washing programmes at full or partial load.

A number of manufacturers have subsequently signed the ATLETE II "Voluntary protocol for manufacturer's pro-active participation" limiting the number of non-compliant models to only 8 cases out of 50 models tested (and out of 35 initially assessed as non-compliant).

However, the ATLETE II consortium had neither the responsibility nor the capability to verify that the new and correct documentation has actually been enclosed in all models on the market, or that the model claimed to be discontinued was not sold under a different name/commercial code number in the EU internal market.

The examples of non-compliance described above highlight the complexity brought up by the way generic Ecodesign and Energy Label documentation requirements are formulated, introducing an area for interpretation due to ambiguities for proper implementation by manufacturers and compliance verification by individual MSAs.

2.2.5.2. Machine technical data overview

The machines tested within ATLETE II also provide a snapshot of the market in the years 2012 and 2013. Due to the semi-random approach of selecting machines from the market, representativeness is not fully ensured, but the selection of 50 models may be seen as a good representation of the models available on the market in 2012 and 2013. Some of the key characteristics of the machines tested are presented below, providing an illustration of the distribution of models in the European market.

Energy consumption values

The energy consumption of a washing machine is measured combining three stages (60 °C full load, 60 °C half load, and 40 °C half load) and three different low power modes (unstable left-on mode, stable left-on mode, and off-mode).

The average of the total energy consumption from the 62 machines measured within ATLETE II was 0.78 kWh, with the distribution presented below: Figure 2.65.

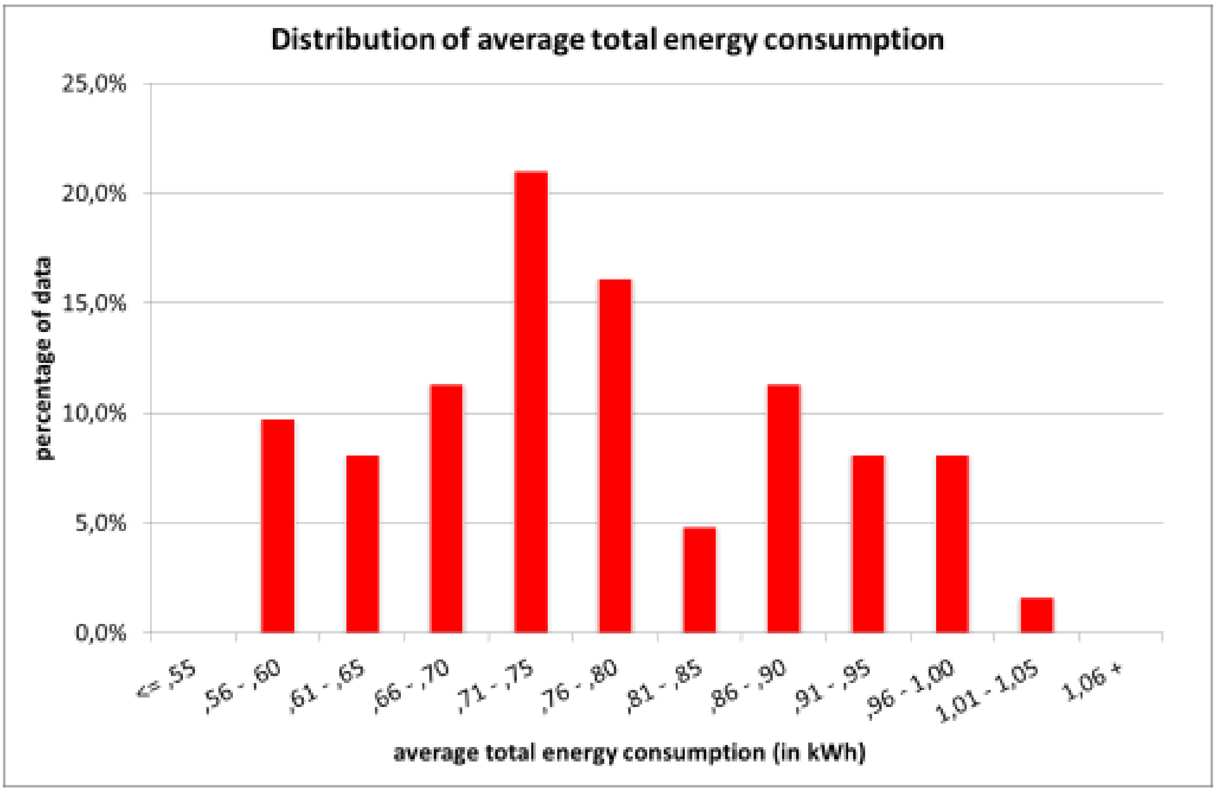


Figure 2.65: Distribution of the (weighted) average total energy consumption per cycle

Summary of technical parameters measured in ATLETE II

A number of additional parameters were also measured, including capacity, low-power energy consumption share, water use, etc. all of which can be checked on the project's website, project authors, and related publications. Key summary figures are presented in Table 2.18 below.

Table 2.18: Summary of measured data from 62 washing machines measured in ATLETE II (www.atlete.eu). Values per washing cycle, 2012/2013.

	Average	Minimum	Maximum	valid data
Energy efficiency index (in %)	**49,91**	29,90	62,00	62
Standard annual energy consumption (in kWh)/year)	**351,14**	239,70	427,70	62
Weighted annual energy consumption (in kWh)	**173,87**	128,05	233,41	62
Average total energy consumption (in kWh)	**0,78**	0,56	1,04	62
Average power during post programme phase LU (in W)	**0,89**	0,18	2,93	62
Average power during post programme phase LO (in W)	**0,60**	0,02	1,66	62
Average power in off mode (in W)	**0,20**	0,02	0,52	62
Average programme time (in min)	**171,48**	108,00	235,00	62
Average total water consumption (in l)	**41,90**	26,00	63,00	62
Annual water consumption (in l)	**9.218,71**	5.720,00	13.860,00	62
Average value for the total water consumption for the treatment 60 with full load (in l)	**47,52**	33,00	68,00	62
Average value for the max. spin speed (in rpm)	**1.141,27**	909,00	1.595,00	62
Lowest value for the max. spin speed (in rpm)	**1.133,74**	816,00	1.594,00	62
Average remaining moisture content (in %)	**57,40**	45,00	74,00	62
Maximum remaining moisture (in %)	**58,06**	45,00	75,00	62
Nominal total load mass (in kg)	**6,37**	4,00	8,00	62
Washing Efficiency Index for the combined test series	**1,043**	0,994	1,11	62
Specific average total energy consumption (in kWh/kg):	**0,123**	0,073	0,153	62
Specific average programme time (in min / kg):	**27,225**	17,750	35,600	62
Specific average water consumption (in l / kg	**6,651**	4,875	9,800	62
Specific average value for the total water consumption for the treatment 60 with full load (in l / kg):	**7,530**	5,250	10,200	62

2.2.6. Market trends

According to stakeholders, the following general trends can be expected for the next years:

- A clear trend towards washing machines with a capacity over 8 and up to 13 kg can be observed (5-7 kg machines are becoming less and less). Greater capacity is not in terms of larger drums but larger rated capacity. However, the problem of filling washing machines often only partially is a well-known fact. Even if larger machines would wash more efficiently per kg, the relative savings per kg nominal load are lost in case more and more inefficient part load washing occurs. In other words: large washing machines are only fine as long as they have a low energy and water consumption when they are only little filled. However, rinsing can improve when the machine is partly filled.The average washing machine sold has lower capacity than the average of models available, this reflects a general trend which sees higher volumes sold at the medium-lower prices.
- Less water consumption. This can result in worse rinsing efficiency, or that people do an extra rinse or load less, which gives less water and/or energy efficiency.
- Shorter durability.
- Greater attention on exterior design.

Besides these general trends and the technical innovation of washing machines and washer-dryers (cf. section 4.4), specific trends can be identified also with respect to the features of the programmes offered in the machines to save resources in a washing cycle, as:

1. design of specific 'standard programmes'
2. lower maximum washing temperatures than indicated on the programmes

3. longer cycle duration

2.2.6.1. Trends to the design of specific 'standard programmes'

Further, reducing water temperatures in the wash phase of a washing programme and increasing the overall cycle durations are the latest trends in realising energy savings of washing programmes, and in particular for the so called 'standard programmes'. The Ecodesign Regulation 1015/2010 requires a 'standard programme' to wash cotton at 40 and 60 degrees. Since the implementation of the regulation, all washing machine models provide a 'standard' 60 °C and a 'standard' 40 °C washing programme that are used for the performance testing according to EN 60456:2011 and are also basis for the data declared on the Energy Label.

The Energy Label gives valuable information at the point of sale. Before purchasing white goods, many consumers inform themselves about latest state of the art in technologies, consumptions and relevant product factors that have to be considered. To do so, they read for example users advice online and or recommendations of independent consumer organisations, e.g. German "Stiftung Warentest" (STIWA), British "Choice" or French "Que Choisir". Those consumer associations periodically perform washing machine tests and publish the results in their magazines and on their webpages, together with useful information about best practices, new technologies and features.

For instance, referring to differences between 'standard programmes' and 'normal programmes' with regard to energy consumption, water consumption, approximate duration and remaining moisture as well as cost of electricity and water some studies have been carried out by "Which?" and "Stiftung Warentest". In the following some results of these surveys are described.

Most modern washing machines have more than one programme for washing cotton at each 40 °C and 60 °C. The more efficient one is often declared as eco programme or energy saving programme. In the regulation this programme is referred to as the 'standard programme'. This programme usually uses less electricity and less water than other cotton washing programmes at 60 and 40 degrees. For example, Figure 2.66 compares the electricity and water cost in one wash cycle for both the energy saving 'standard programme' and the 'normal programme' at 60 degree. The analysis shows that the consumption of energy and water (expressed as costs) in the normal 60 °C programme is considerably higher compared to the 'standard 60 °C programme'.

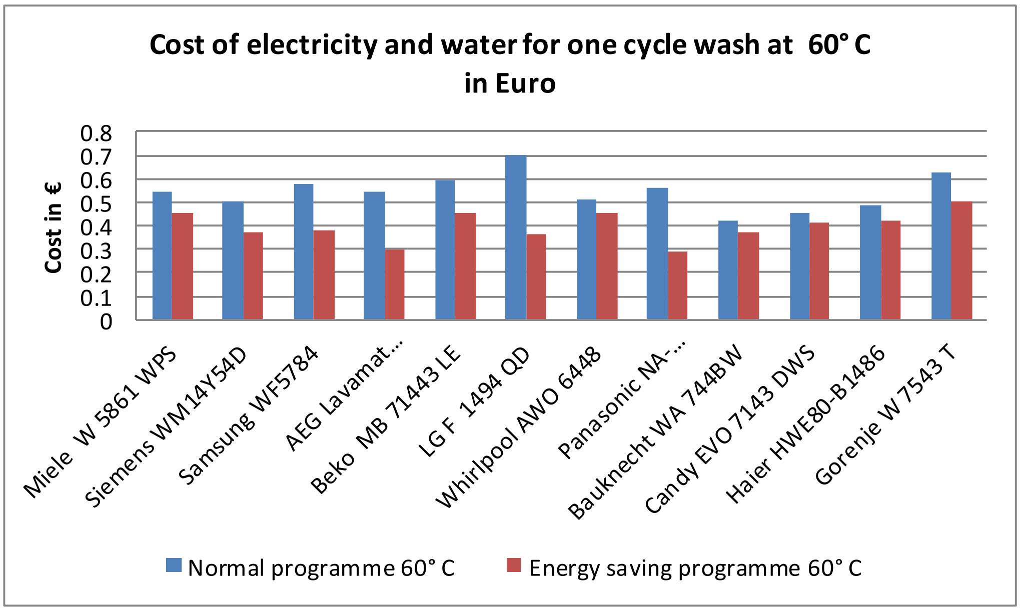


Figure 2.66: Cost of electricity and water for one washing load at 60 °C in Euro (according to Stiftung Warentest (2013))

The 'standard' programmes are often designed to use as little energy at the minimum requested washing performance as possible, in order to maintain high energy efficiency classes on the Energy Label. Especially since the implementation of the new energy efficiency classes in 2010, manufacturers seem to apply a washing strategy with lower temperatures combined with longer programme durations to realise energy savings needed to meet the requirements of the highest energy efficiency class possible.

A comparison of the 25 most sold washing machine models in Europe 2014 (models data provided by (GfK, personal communication 2014) shows that the normal programme for a cotton 60 °C load uses in average 38% more energy and 34% more water than the 'standard cotton programme' for the same load. Depending on the machine this may go up 80% or more. This is done at a programme duration which is reduced by just 17%.

Table 2.19: Ratio of normal cotton wash 60 °C to 'standard cotton 60 °C programme' at full load regarding for 25 most selling washing machines (based on (GfK, personal communication 2014))

	average	max	min
Energy	138%	185%	92%
Water	134%	176%	105%
Time	83%	103%	58%

2.2.6.2. Trends to lower maximum washing temperatures than indicated on the programmes

This is a trend observed by different organisations. For example, "Which?" tested 12 washing machines and found out that 8 of them did not reach 60 °C on the 60 °C cotton programme. The washing machines that reached 60 °C only maintained that temperature for either a few minutes or a few seconds. Of the nine machines that reached 55 °C or more, the water spent less than 10% of its time at or above this temperature, on average.

Almost all of the washing machines tested follow a similar pattern: the water is heated until it reaches the hottest temperature (sometimes for just seconds) and then the temperature falls quickly before setting into a long cooling process, as Figure 2.67 shows.

Even though the test results demonstrate machines often do not hit 60 °C, manufacturers are not actually cheating the EU Energy Label because there's no minimum requirement for the washing machine to reach the temperatures stated on the control panel. However, the programmes used to calculate the rating stated on the Energy Label – the 40 ˚C and 60 ˚C cottons programmes – must reach a certain level of washing performance (the weighted average of the washing performance of the standard programmes at 40 and 60 °C has to be >1.03 which represents class A in washing performance according to EU regulation 95/12/EC). Instruction manuals must also contain wording stating that the temperature specified might not be reached, which many manufacturers have quoted as the reason for not needing to reach 60 ˚C.

For example, the "Whirlpool WWDC6400/1" reached just 54 °C in tests carried out by "Which?" (Which? 2013a). A "Whirlpool" spokesperson said: 'On this machine the 60 °C cottons programme is operating within the Energy Labelling criteria, which is optimised for energy consumption and cleaning efficiency.' This also means that the "Hoover" washing machine that only reaches 43 °C and gets an A+++ energy rating is acceptable under the current requirements of the EU label.

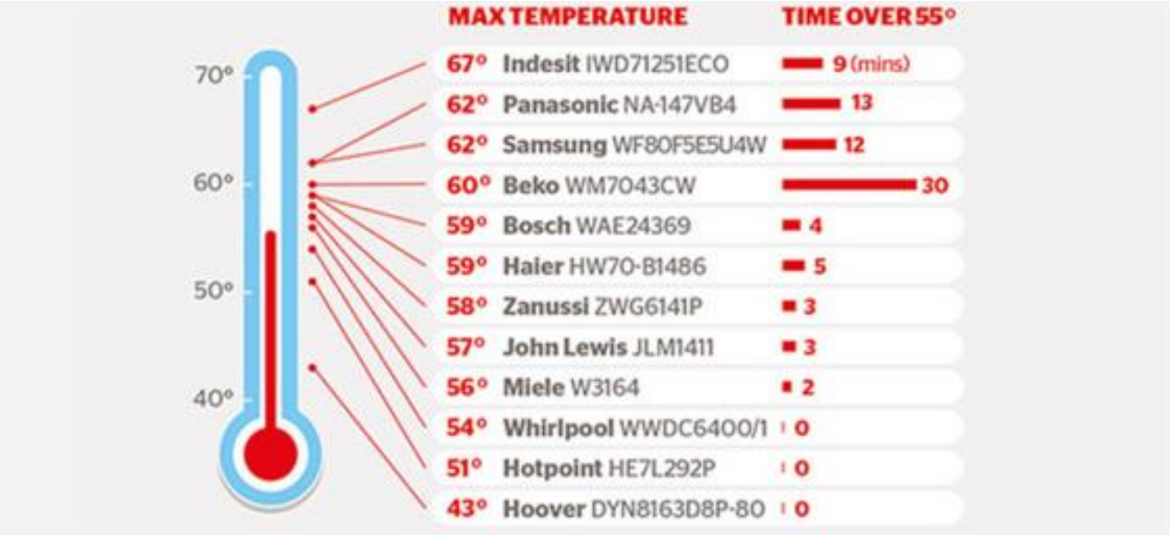


Figure 2.67: **The highest temperatures reached and duration each machine spent above 55 °C in the 60 °C cotton programme (Which? 2013a)**

2.2.6.3. Trends to longer cycle duration

Table 2.19 shows that energy saving programmes takes longer washing times as comparable normal programmes (see 4.1.1.1 Sinner circle). This approach saves considerable energy. The reduced temperatures are compensated through longer cycle durations.

Where the 'normal 60 °C cotton programme' needs between 2 and 3 hours the 'standard cotton 60 °C programme' runs for 3 to 5 hours. For instance, Siemens introduced washing machine to the market which consumes 50 percent less energy than the washing machine in the energy efficiency class A+++. In this regard, the washing duration has increased to 6 hours 30 minutes to compensate reducing the temperature and having a good washing result.

Longer cycle time opens the possibility to wash with lower temperatures with the same washing result and can therefore increase the energy efficiency. Figure 2.68 shows the amount of energy consumption, water consumption, approximate duration and remaining moisture in 'Cottons 60 °C', 'Cottons 40 °C' versus 'Standard 60 °C cotton' and 'Standard 40 °C cotton' in the "AEG L89495FL" washing machine (AEG 2014b).

As it can be seen in Figure 2.68, the amount of energy consumption for the 'Cottons 60 °C' is 1.55 kWh and for 'Standard 60 °C cotton' is 0.64 kWh. At the same time, the approximate duration in 'Cottons 60 °C' and 'Standard 60 °C cotton' is 170 and 226 minutes respectively, i.e. the duration of the 'standard cotton programme' is considerably longer than the duration of normal cotton programme.

Programmes	Load (Kg)	Energy consumption (kWh)	Water consumption (litre)	Approximate programme duration (minutes)	Remaining moisture (%)[1]
Cottons 60 °C	9	1.55	79	170	52
Cottons 40 °C	9	0.97	79	164	52
Synthetics 40 °C	4	0.55	54	120	35
Delicates 40 °C	4	0.60	59	89	35
Wool/Hand wash 30 °C	2	0.35	58	60	30
Standard cotton programmes					
Standard 60 °C cotton	9	0.64	57	226	52
Standard 60 °C cotton	4.5	0.34	41	185	52
Standard 40 °C cotton	4.5	0.34	40	199	52

1) At the end of spin phase.

Figure 2.68: Energy consumption, water consumption, approximate duration and remaining moisture in different programmes (AEG 2014b)

The increase of energy efficiency often goes along with longer programme times. However, high energy efficiency and relatively short programme times do not have to exclude each other. This is demonstrated by washing machines listed at Topten machines with short times of the 'standard programmes', as for instance:

- 2 h 20 min (60 °C full), 1 h 35 min (60 °C half) and 1 h 30 min (40 °C half) respectively (Schulthess 'Spirit eMotion 7040i' and Merker 'Bianca 735', both with a capacity of 7 kg and an EEI of 43, which equals A+++ -6.5%).
- New Miele-models presented at IFA 2014 reach A+++ - 40% by introducing a new washing system called Power Wash 2.0. They achieve the required performance with a washing programme just below 3 hours and are consuming just 130 kWh per year for a 9 kg rated capacity.

Further indications provided by Topten are provided in Table 2.18 below.

Table 2.20: Programme duration of best performing washing machines according to Topten.eu

Rated capacity (kg cotton)	Programme		
	60 °C full	40 °C full	40 °C partial
< 8 kg	140 – 240 min	95 – 210 min	90 – 210 min
8 kg	179 – 240 min	120 – 220 min	130 – 215 min
> 8 kg	179 – 240 min	120 – 210 min	130 – 180 min

2.2.6.4. Impacts on real-life energy and water consumption

The real energy and water consumption of a washing machine depends on how consumer uses the machine. This can rather differ from the rated annual consumption as shown on the product information. The rated energy and water consumption is based on test results of the 'standard programmes'. By providing different programmes (normal and standard) for the same washing 40 °C and 60 °C cotton, with considerably different energy and water consumptions as well as programme durations, it might be that

- Consumers do not detect the energy efficient standard programmes at all on the panels;
- Consumers do not understand the differences between standard and normal cotton programmes and thus accidentally chose the more consuming normal programmes;
- Consumers intentionally chose the more consuming normal programmes
  - Due to too long cycle times not being convenient for consumers (some stakeholders comment that to their knowledge, consumers' maximum acceptable duration is around 3hrs);
  - Due to the lower washing temperatures as indicated as consumers might be concerned about hygienic issues.
- Consumers may not even find the data about the difference of consumptions for the normal and standard programmes as this is not requested by the regulation.
- Energy (and water) consumption at the consumers' home may be significantly higher as what is declaration on the Energy Label and what was the basis for the purchasing decision.

These possible influences on consumer behaviour are further analysed in Chapter 3.

2.2.7. Market data and trends with regard to detergents

According to AISE, detergents available on the market can be classified as follows:

- Powder Detergents, aggregating standard and concentrated powder detergents.
- Detergent Tablets, including detergents sold in tablet format for machine washing. These could either be in compressed powder or liquid form.
- Liquid Detergents, aggregating standard and concentrated liquid detergents.
- Fabric Softeners, including all products that are added to the final rinse or tumble dryer to condition, freshen and soften fabrics, reduce static, wrinkling and drying time, and make ironing easier.
- Laundry Aids, aggregating spot & stain removers, other laundry boosters, colour-safe laundry bleach, curtain care, starch/ironing aids, water softeners, fabric fresheners and home dry cleaning products.

The market analysis done within the EU Ecolabel revision for laundry detergents revealed that laundry detergents are available in a range of formats. In general, market trends show that sustainability is of growing importance to consumers of laundry detergents, with an increase in concentrated/compacted products, use of plant-based ingredients and minimisation of packaging (JRC IPTS 2015a).

The market analysis of 2012 provided by JRC IPTS (2014a) for the laundry detergents indicates that powder detergents were the type of detergent most used (34% of the market by volume), followed by liquid detergents (19%). Detergent tablets made up a relatively small proportion of the market in comparison (4% by volume) with other detergents accounting for 4% of the total market for laundry care products. Other laundry care products include fabric conditioner (31% of the market by volume), stain removers and other additives (6%) and fabric fresheners (2%).

JRC IPTS (2014a) summarised the product trends in the laundry detergent market as follows:

- An overall increase in liquid detergents (+47% between 2007-2012, compound annual growth rate (CAGR): +6.61%).

- An overall decrease in the use of powder detergents (-17% between 2007-2012, CAGR: -8.46%).
- An increase in liquid tablet detergents (+193% between 2007-2012, CAGR: +20.09%) which is mirrored by a decrease in sales of compacted powder tablets.
- An increase in the use of concentrated products, most significantly concentrated liquid detergent (+228% for concentrated liquid detergents between 2007-2012, CAGR: +21.94%).

Thus, in Europe the trend in the laundry detergent market is towards concentrated liquid (including gel) detergents both in liquid and tablet form. However, according to JRC IPTS (2014a) this trend is highly sensitive to price – in 2011 there was an increase in powder detergent use in Europe as consumers went for lower priced options.

Many of the recent developments and innovations in the detergent market have centred on the production of laundry tablets (also marketed as 'pods') and unit dose products. The convenience factor is a significant driver for the sales of laundry tablets, which provide an easy way to dose detergents. Sales of liquid capsules in particular have seen significant growth since 2007 (with a compound annual growth rate CAGR of 20.09%) but still make up a very minor part of the market. This trend appears to be driven by a select few European countries – primarily Italy and the UK – where take-up of these laundry tablets has grown significantly since 2007 (JRC IPTS 2014a).

Many manufacturers are offering double concentrated formats instead of standard concentrated products. Besides at least 2times but often 3times concentrated products, further innovation in compaction technology has even led to the development of 8times concentrated laundry detergents. The increase in these 'super-concentrated' products with a dosage per wash below or equal to 35 ml can be seen across Europe. However, the move towards more concentrated products needs to be accompanied by a greater amount of information on packaging aimed at consumers. Without proper information, consumers continue to dose as with non-concentrated products and therefore overdose these concentrated detergents which are very resource efficient due their compaction. For example, a 2 litre bottle of concentrated detergent may provide the same number of 'washes' as a 3 litre bottle, but consumers are measuring out the same amount regardless of bottle size (JRC IPTS 2014a).

Those products have a growing market share and represent convenience benefits for consumers in terms of dosage, and

According to JRC IPTS (2014a), unit dose products (mono dose capsules) are a relatively new innovation in the laundry care market and act as a direct replacement for the more traditional liquid and powder laundry detergents. These products consist of 'pods' or packets which contain a pre-measured unit dose of laundry detergent. Liquid 'pod' detergents in particular are advertised as a sustainable innovation in the laundry market. These consist of a liquid detergent in a water-soluble and (typically) biodegradable film capsule. This prevents the user from over-dosing the laundry detergent, a common problem with liquid or powder detergents.

Finally, in recent years detergent manufacturers have invested significant efforts to improve washing performance at low temperatures. In addition to being compacted, at the same time the detergent formulations need to work rapidly at lower temperatures with a reduced quantity of water per wash cycle. Household laundry detergents are now available on the market which claim wash efficacy at temperatures as low as 15 °C. This has largely been achieved through the choice of surfactants and polymers and the use of sophisticated enzyme systems.

More recent data confirms a very firm trend for the liquid detergents to overtake powder detergents in most EU countries (see Table 2.21). Also the introduction of washing machines with automatic dosage system in the market (cf. section 4.4.2.7) which work with liquid detergents only might increase this trend further. This may be of practical interest at standardisation level in order to evaluate the appropriateness of the detergents used for the performance tests. According to A.I.S.E., a liquid detergent would be more appropriate for most wash cycles at low temperature, with the exception of those at 60 °C.

Table 2.21: Market sizes of different detergents in the European Union in M€ (source of table: (A.I.S.E, personal communication 2015))

Categories	2012	2013	2014
Automatic Laundry Powder Detergents	3274.5 (1133.6 kt)	3139.0 (1062.4 kt)	3078.5 (1024.1 kt)
Automatic Laundry Detergent Tablets	892.0	971.9	1032.7
Automatic Laundry Detergent Liquids	3914.0 (1080 ml)	4015.1 (1052.5 ml)	4044.6 (1033.8 ml)
Fabric Softeners	2265.4	2300.1	2335.8
Laundry Aids	1737.9	1698.2	1665.1

Research Sources: Home Care: Euromonitor from trade sources/national statistics © Euromonitor International

2.3. Consumer expenditure data

2.3.1. Average unit value of household washing machines produced in EU28

According to the Ecodesign Impact Accounting study by (VHK 2014 / Status 2013), the price of a household washing machine is assumed to be relative constant at about 450 € including VAT (in 2010 prices) for the assumed Business-as-Usual (BAU) scenario, while for the ECO scenario the cost increase estimated by the introduction of the Energy Labelling requirements according to EU 1061/2010 and Ecodesign requirement according to EU 1015/2010 is predicted to be 100 € in maximum but is reduced continuously after 2015 and will end up with the same price as in the BAU scenario (see Figure 2.69). For further details regarding the scenarios, please refer to section 2.2.3.

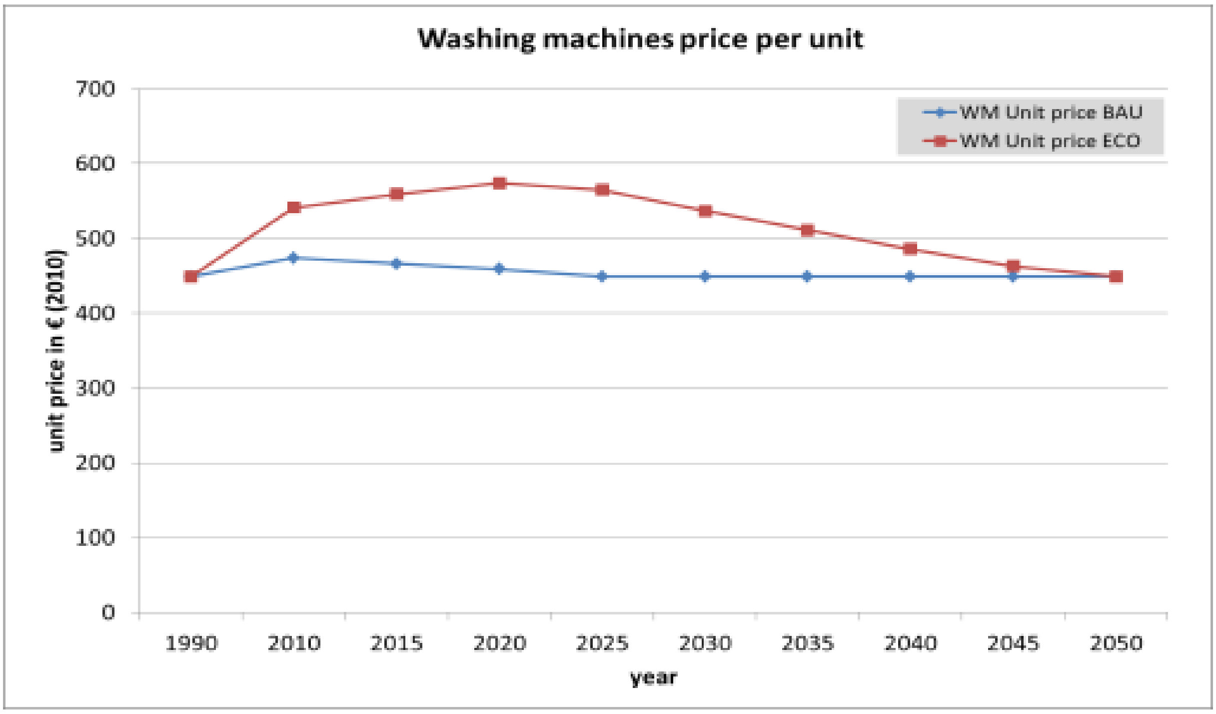


Figure 2.69: Average price in € (basis 2010) for a washing machine in the European market from 1990 to 2050 (data from (VHK 2014 / Status 2013)

Additional to these data, the following table shows the calculated average unit values of 'Clothes washing and drying machines, of the household type' produced in EU28 and certain Member States as reported by (Eurostat 2015a) for those Member States where information was available (cf. section 2.1.1). It can be seen that the unit value of clothes washing and drying machines produced in Germany achieve higher unit values compared to the other producing Member States as well as the EU28 average. In total, the values have been rather stable or partly increasing between 2007 and 2013. However, it has to be noted that Prodcom values data relate to the manufacturer selling price, not to the end consumer price, and data cover not only washing machines, but also clothes dryers and combined washer-dryers.

Table 2.22: Calculated average unit value (in Euro) of 'Clothes washing and drying machines, of the household type' produced in the EU28 between 2007 and 2013 (own calculation based on (Eurostat 2015a))

Declarant	2007	2008	2009	2010	2011	2012	2013
France	0	220	213	203	204	213	230
Germany	476	:	481	476	455	:	:
Italy	193	193	203	210	207	210	208
Poland	213	220	201	200	181	192	186
Spain	193	197	195	209	:	219	222
Sweden	341	:	:	:	:	:	:
United Kingdom	140	171	174	:	:	:	:
EU28TOTALS	230	230	234	232	226	228	221

":" means data not being available

Figure 2.70 illustrates the trend of changes in prices of the washing machines in 14 western European countries (AT,BE,DE,DK,ES,FI,FR,GB,GR,IE,IT,NL,PT,SE) from 2004 to 2012 based on the provided data by German Gesellschaft für Konsumforschung (GfK, personal communication 2013). As it can be observed the washing machines price per unit has declined gradually from 462 Euro in 2004 to 434 Euro in 2012.

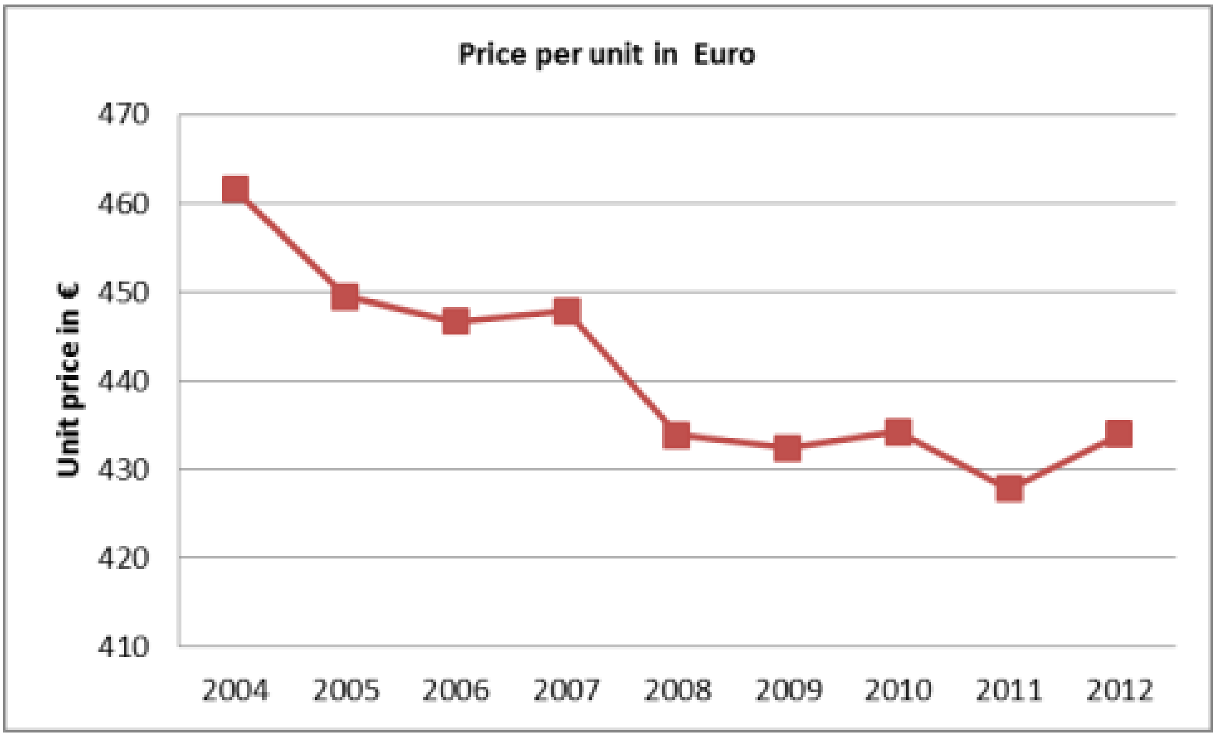


Figure 2.70: **Average price per unit of washing machine in Euro for 14 Western European countries from 2004-2010 (GfK, personal communication 2013)**

Across the EU-21, average nominal washing machine prices have declined by 8% from 2004 to 2014 – despite higher efficiency and larger capacities – and is at 399 € in average in 2014.

2.3.2. Repair costs

Regarding repairs, in September 2014, Portuguese consumer organization DECO Proteste published a study on washing machine repair services. In the context of the study, DECO contacted 29 different repair shops/services for a small repair of a specific washing machine. DECO also investigated the price of replacement parts for washing machines and more specifically for parts that could be replaced by the consumer himself. For these parts, the costs vary from under 2 € to 50 €.

Within the research project "Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence" (Prakash et al. 2016), manufacturers have been asked about the repair costs for different components of washing machines. The range of costs for spare parts is between around 10 Euros up to 262 Euros. However, it has to be noted that for nearly all repairs additional costs for the personnel apply depending on the time needed for the repair which adds another 100 to 200 Euro.

Table 2.23: Repair costs excl. VAT of washing machine components based on manufacturer information (source: (Prakash et al. 2016))

Washing machine component	Personnel costs (Euro)	Costs for spare parts (Euro)	Duration of the repair
Supply / drain hose	ca. 103,-	ca. 60,- / 23,-	ca. 30 Min.
Suds pump (pump motor)	ca. 125,-	ca. 53,-	ca. 45 Min.
Pump casing	ca. 125,-	ca. 16,-	ca. 45 Min.
Spring	ca. 103,-	ca. 9,-	ca. 30 Min.
Shock absorbers	ca. 146,-	ca. 30,-	ca. 60 Min.
Ball bearings	ca. 233,-	ca. 29,-	ca. 120 Min.
Seals	ca. 125,-	ca. 20,-	ca. 45 Min.
Suds container	ca. 233,-	ca. 40,- plus 170,-	ca. 120 Min.
Radio interference suppression	ca. 103,-	ca. 17,-	ca. 30 Min.
Pressure controller / sensor	ca. 103,-	ca. 33,-	ca. 30 Min.
Heating element	ca. 103,-	ca. 46,-	ca. 30 Min.
Thermostat	ca. 103,-	ca. 27,-	ca. 30 Min.
Control electronics (circuit board)	ca. 125,-	ca. 158,-	ca. 45 Min.
Input-/output electronics (keys, display)	ca. 125,-	ca. 147,-	ca. 45 Min.
Tachometer generator	ca. 125,-	ca. 23,-	ca. 45 Min.
Door lock (electronics)	ca. 125,-	ca. 45,-	ca. 45 Min.
Door handle (mechanics)	ca. 103,-	ca. 47,-	ca. 30 Min.
Temperature sensor	ca. 103,-	ca. 46,-	ca. 30 Min.
Motor (carbon)	ca. 125,-	ca. 262,-	ca. 45 Min.
Aqua Stopp System	ca. 125,-	ca. 11,-	ca. 45 Min.

2.3.3. Consumer prices of consumables

The German consumer journal Stiftung Warentest conducts performance tests with washing machine detergents on a regular basis. In 2012 extensive test has been performed to compare different kind of detergents. In this regard, 21 washing detergents (2 powder detergents and 19 liquid detergents) were investigated.

Results of survey shows that even though powder detergents have a higher price than several tested liquid detergents but they have better cleaning effects than liquid detergents. Another recently published article compared the best washing powder for white clothes; washing powder from the big package versus compact powder. The data indicates that in general the compact powder is better than powder from big packages, while there is no remarkable difference between prices of these detergents (Stiftung Warentest 2012a); (Stiftung Warentest 2014).

Table 2.24: Price of detergent per cycle in Germany 2012 and 2014 (according to (Stiftung Warentest (2012a) and Stiftung Warentest (2014)

		Powder		Liquid	
	Product tested	Min.	Max.	Min.	Max.
2012	21	0.21 €	0.25 €	0.13 €	
2014 (Compact)	13	0.11 €	0.32 €	-	
2014 (Big pack.)	8	0.10 €	0.32 €	-	

2.3.4. Further prices

The Methodology for the Ecodesign of Energy related Products (COWI and VHK 2011) suggests to use EU average values for all preparatory studies, partly adjusted with an overall escalation rate (e.g. for energy prices) which results in the monetary outcomes of all studies being comparable. The EU-27 average data provided in this study are the following for electricity, gas, water, interest, inflation and discount rates.

Table 2.25: Energy, water and financial rates as proposed by COWI and VHK (2011) for the year 2011

	Domestic (incl. VAT)	Long-term growth per year
Electricity	0.18 €/kWh	5%
Gas (net calorific value NCV)	14.54 €/GJ	3-5%
Water	3.70 €/m³	2.5%
Interest	7.7%	-
Inflation rate	2.1%	-
Discount rate (EU default)	4.0%	-
Energy escalation rate, i.e. real (inflation-corrected) increase per year*	4.0%	-
VAT	20.0%	-

* To be applied to the electricity rate in order to adjust the actual rate for 2015 for the case that the real inflation-corrected energy prices growth rates do not deviate more than 1%-point from the given 4%. If that happens, the differentiated LCC calculation with actual prices should be followed.

In COWI and VHK (2011) the electricity prices for households in EU-27 are indicated as a sum of production and distribution costs, indirect taxes and value added taxes. The total price per kWh lies between 0.09 €/kWh in Bulgaria and 0.28 €/ kWh in Denmark, while the average of all 27 EU countries is 0.18 €/ kWh. Tax rates are fluctuating and contribute a high percentage of the total electricity price in several countries, e.g. Denmark and the Netherlands.

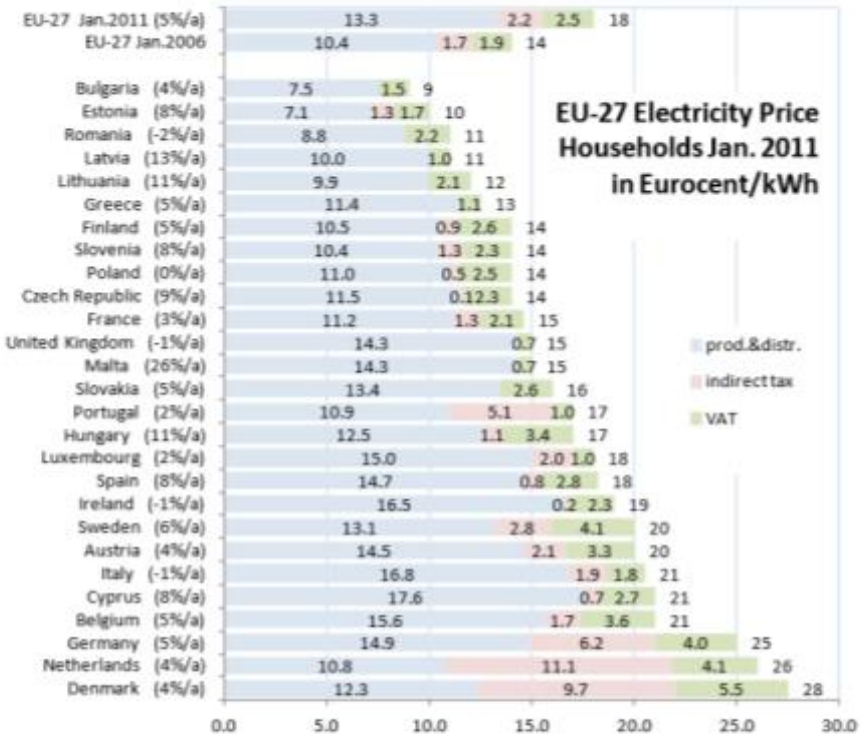


Figure 2.71: **Electricity prices households Jan. 2011 (recent annual growth rates in brackets, in %/a) (COWI and VHK 2011)**

Consumer information material published by (VZ RLP & Öko-Institut 2012) provide a comparison of total costs for energy and water, for washing machines with different energy efficiency classes (see Table 2.26).

Table 2.26: **Comparison of yearly costs for washing machines of different energy efficiency classes (VZ RLP & Öko-Institut 2012)**

Efficiency class	A+++	A +	old appliance*
Power consumption	150 kWh	220 kWh	250 kWh
Power cost**	36 €	53 €	60 €
Water consumption	9270 l	11660 l	13135 l
Water cost***	36 €	46 €	52 €
Total costs	72 €	99 €	112 €

* 6 kg capacity, 12 years old, ** 0.24 €/kWh, *** 3.9 €/m³

2.3.5. Overview of life cycle costs

On the basis of the analysis of the feedback received from stakeholders in response to the technical questionnaire that was released in March 2015, a preliminary table has been compiled to start compiling and summarising life cycle costs to use in the development of next tasks.

Table 2.27: Summary of information on life cycle costs for washing machines and washer-dryers on the basis of the feedback received from stakeholders

Cost category	Average costs	
	Washing machines	Washer-dryers
Consumer purchase prices of the machine (€/product)	220 - 380 EUR (but they can often cost also about 1000 EUR)	400 - 630 EUR (but they can often cost also about 1000 EUR)
Factory prices (production costs) (€/product)	Not available	Not available
Consumer purchase price for detergents (€/kg, please specify type of detergent)	About 0,50 EUR per cycle	
Installation costs (€/product)	From 0 EUR to about 50 EUR	
Type, average number of maintenance actions and related costs (e.g. deep cleaning) along the product life time (€/product – please specify the considered lifetime)	From 0 EUR to about 2 times per lifetime at a cost of 150 Euro/a time	
Type, average number of repairs and related costs along the product life time (€/product – please specify the considered lifetime)	About 2 times per lifetime at a cost of 150 Euro/time	
Disposal costs (€/product) It is assumed that under WEEE, the financing of the costs of collection, treatment, recovery and environmentally sound disposal of WEEE from private households is producer's responsibility. Normally, this cost is passed over to the consumer in the final purchase price.	In accordance to the WEEE directive provisions, producers fulfil their responsibility of financing the costs of collection, treatment, recovery and environmentally sound disposal of domestic WEEE deposited at collection facilities. To some extent these costs are passed over to the consumer in the final purchase price. WEEE financing is a part of selling price, with relevant differences across the EU. In UK the fee is not visible, in Italy the fee is visible to trade partners, but not to consumers, in France the fee is visible also to final consumer. Costs also vary from country to country, logistic costs are a main source of variability. Manufacturers can leverage on economies of scale to ensure that collection and treatment costs are optimised.	
Note: 1. it is assumed that VAT is included 2. It is assumed that all costs are given with reference to 2015		

Information on purchase price of high efficient washing machines and washer-dryers is provided on most of the 18 Topten-websites in Europe. The total costs of the average of the most energy efficient models listed at TopTen amount to 2,459 to 3,015 Euro (Table 2.28). The last two lines in the table show that there is a difference of 600 to 1000 Euro between the total costs for the least and the most expensive Topten model. Compared to that, the total costs of inefficient models amount to 1,919 to 2,532 Euro (Quack 2010)

Table 2.28: Overview of life cycle cost structure for washing machines. Assumed life time: 15 years (Quack 2010)

	CEE (Poland)		North (Norway)		West (Germany)		South (Spain)	
	Topten models	inefficient models	Topten models	inefficient models	Topten models	inefficient models	Topten models	inefficient models
Average purchase price	911 €	261 €	1.198 €	554 €	771 €	399 €	1.392 €	582 €
Average total energy costs	398 €	410 €	548 €	581 €	666 €	752 €	451 €	646 €
Average total water costs	490 €	588 €	609 €	577 €	506 €	544 €	496 €	644 €
Average total detergent costs	660 €	660 €	660 €	660 €	660 €	660 €	660 €	660 €
Average total costs	**2.459 €**	**1.919 €**	**3.015 €**	**2.372 €**	**2.604 €**	**2.355 €**	**2.998 €**	**2.532 €**
Min total costs Topten models	1.945 €		2.723 €		2.335 €		2.554 €	
Max total costs, Topten models	3.699 €		3.677 €		3.054 €		3.223 €	

The results of the life cycle cost analyses of washing machines show that the average total costs of the Topten models are always higher than the total cost for the inefficient model, (Table 2.28). The total energy costs are always lower for the Topten models' average then for the inefficient model. Norway is an exception due to the rated capacity of the models in Norway being 7-8 kg instead of 5-6 kg as for the other countries. (Quack 2010).

Besides the purchase costs that contribute with 30 to 46% (average of most efficient Topten models) respectively 14 to 23% (inefficient models) to the total life cycle costs of washing machines the share of the costs during the use phase is also significant (Figure 2.72): the electricity costs, the water costs and the detergents costs. Their share is between 15 and 32% each. Together they amount to 54 to 86% of the total life cycle costs, being highest for the inefficient models (77 to 86 percent).

In most of the cases the detergent costs have the highest absolute value and share of total costs. As for all countries the same costs were assumed for the detergents (0.22 Euro/washing cycle, (ISIS 2007a)), there will be some variance in reality. Concerning the water costs, for some countries they are higher than the electricity costs (Poland; Germany; Norway, Topten models), only for Spain and Norway (inefficient model) they are lower resp. equal. For the water costs it must be stated that the same water price was assumed throughout Europe (3.70 Euro/m^3, (ISIS 2007a)). As the water price mostly is organised on the level of the municipalities it may vary and therefore the results for one specific city may deviate significantly from the above calculations (Quack 2010).

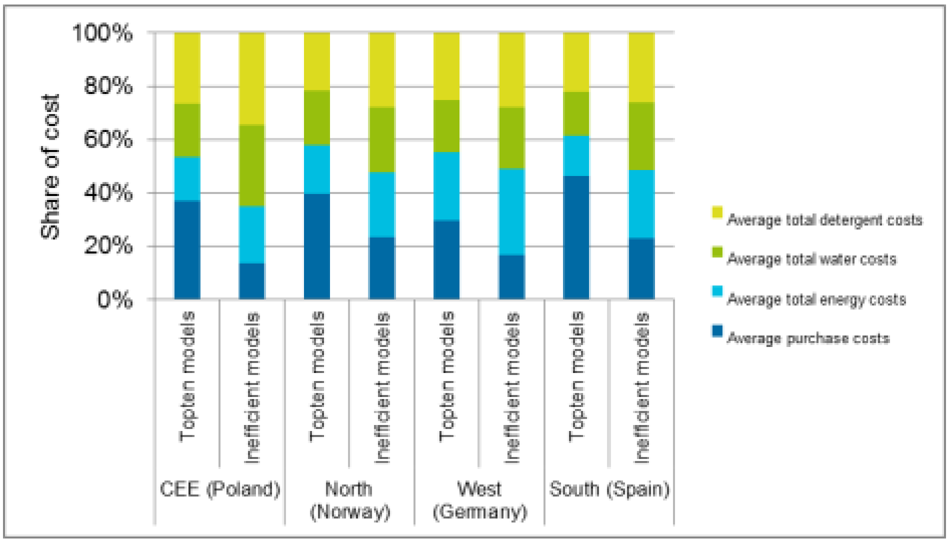


Figure 2.72: Share of the different cost elements of the Topten washing machines and the inefficient models in the different countries (according to Quack (2010).

2.4. Summary: Markets

The following preliminary findings have resulted from the market data collection exercise undertaken:

- At European level, the penetration of washing machines in households is constant to slightly growing, and lies at about 90% on average. The market penetration of washer-dryers is around 4%.
- The volume of produced household washing machines in the EU28 has declined from 27.7 million units in 2007 to 20.5 million units in 2013. The total value of produced household washing machines in the EU28 has declined from 6.4 billion Euros in 2007 to 4.5 billion Euros in 2013. Thus, the production value has decreased slightly more than the production volume.
- Germany, UK and France are the largest importing countries of household clothes washing and drying machines, followed by Italy, Netherlands, Sweden, Spain and Belgium. Slovakia, Poland and France have the largest number of exports from their country to other EU Member States. The trade data suggest that for nearly all Member States, the Intra-EU trade is greater than the Extra-EU trade. Sales of top-loading washing machines ≤ 6 kg is rather small compared to the front-loading machines. Exports to extra-EU countries are small.
- The average specific energy consumption the standard programmes of washing machine has been halved from 0.245 kWh per kg and cycle in 1997 to 0.120 kWh per kg and cycle in 2013. The average energy consumption per cycle (standard cotton cycles at 40 and 60 °C with full and half loads) of washing machine is 0.83 kWh per cycle (2013). Most of the washing machine models have energy consumption comprised between 0.86 to 0.90 kWh per cycle.
- Washer-dryers show slightly higher average energy consumption values than washing machines resulting in an average of 1.16 kWh per wash cycle in 2013 (based on a 60 °C cotton cycle full load).Considering the 'wash and dry' cycle (washing and drying of the whole load) the absolute energy consumption has increased by 0.5 kWh per cycle from 1997 (4.95 kWh/cycle) to 2013 (5.44 kWh/cycle) due to an increase of the capacity of the machines offered. However, the specific energy consumption of 'wash and dry' (the division of total energy consumption by the capacity of 'washing') shows continuously declining values. From 1997 to 2013 the specific energy consumption 'wash and dry' decreased from 1.02 kWh per kg and cycle to 0.74 kWh per kg and cycle in 2013. Also the specific energy consumption of a 'wash cycle' only shows a constant declining trend and lies on average at 0.20 kWh per kg load.
- The most common capacity class of the 7745 registered washing machine models in the CECED database in 2013 was 7 kg (31%). Within these 7 kg washing machine models, the distribution of energy efficiency classes is 48.7% A+++, 24.7% energy efficiency A++, 23.4% energy efficiency class A+, and 3.2% with energy efficiency B. Various stakeholders are concerned about the trend of larger capacity machines that are more efficient only at nominal full load conditions. Even if these larger machines wash more efficiently per kg, they fear that more partially load washing cycles will occur and no saving would be actually achieved under these conditions.
- The average washing and drying capacities of washer-dryer show an increase of approximately 2.5 kg between 1997 and 2013. A visible growth started in the year 2003. The average washing load capacity reached 7.4 kg in 2013 (similar to the corresponding value for washing machines) and the average of drying load capacity reached 4.91 kg. The energy efficiency classes of washer-dryer models available on the market from 1997 to 2013 shows the distribution of Energy Efficiency Classes has been shifted dramatically towards higher efficiency classes. In 2013 about 50% of washer-dryers were labelled with class A and the majority of the rest was labelled as B, according to the Commission Directive 96/60/EC (and not the Commission Delegated Regulation (EU) No 1061/2010). Nearly 100% of all washer-dryer models reach a washing performance classes A.

- The trend over the years is less clear for the spin drying efficiency of washing machines than for the energy performance. In 2013, around 56% of models registered in the CECED database were in class B, 18.5% in class A and 20% in class C. Other drying performance classes have a very low share (around 5 percent). These results illustrate a steady increase of the average spinning speed from 828 rpm in 1997 to 1219 rpm in 2010. For washer-dryers, a more or less continuous increase of the average maximum spin speed can be seen from 1102 rpm (1997) per wash cycle to 1396 rpm (2013)
- The average water consumption of washing machine models per cycle significantly declined since 1997, but remained almost constant between 2011 and 2013. While in 1997 water consumption of the majority of machines was 66.8 litres per cycle, in 2013 this value was 45.1 litres per cycle. The average water consumption per kg rated capacity for the years 1997 and 2013 was 13.9 l/kg and 6.5 l/kg respectively.
- The distribution of water consumption per cycle for washer-dryers in 2013 is mainly between 39 and 51 litres. The average is 45 litres. The specific water consumption per kg of load is between 5.5 and 8 litres with an average of 6.5 l/kg. The average total water consumption for washing and drying of washer-dryer models has declined from 129.7 litres down to 98.1 litres. This is an improvement of 24% between 1997 and 2013. The average specific water consumption rated to the capacity of the models has actually halved from 26.8 l/kg down to 13.4 l/kg over this period. This is fostered by the combination of lower absolute values and increasing capacities.
- Reducing water temperatures in the wash phase of a washing programme and increasing the overall cycle durations are the dominant trends for achieving energy savings of washing programmes, and in particular for the so called ‘standard programmes’. The ‘standard’ programmes are often designed to use as little energy at the minimum requested washing performance as possible, in order to be able to declare a high energy efficiency class on the Energy Label. The real-life energy and water consumption of a washing machine depends on how much consumers use the ‘standard cotton programmes’ of their machines. If they don’t use them, then the water and energy consumption can be higher.
- Powder detergents are the most used (34% of the market by volume), followed by liquid detergents (19%). Detergent tablets make up a relatively small proportion of the market in comparison (4% by volume) with other detergents accounting for 4% of the total market for laundry care products. Other laundry care products include fabric conditioner (31% of the market by volume), stain removers and other additives (6%) and fabric fresheners (2%). The trend in the laundry detergent market in Europe is a shift towards concentrated liquid (including gel) detergents both in liquid and tablet form. However, this trend is highly sensitive to price.
- The purchase price of a household washing machine in the EU is relatively constant, and lies at about 450 Euro (in 2010 prices, including VAT). Based on the provided data by German Gesellschaft für Konsumforschung (GFK), the washing machines price per unit has declined gradually but only slightly from 462 Euro in 2004 to 434 Euro in 2012 (including VAT). The cost increase estimated by the introduction of the Energy labelling requirements in 2010 was estimated to be 100 € at most, but it was also assumed that this would be reduced gradually and level out after 4-5 years.

3. Task 3: Users

Products must indeed be seen as part of a system. The consideration of system aspects is important for determining "indirect" burdens associated to the use of products. In the context of washing machines and washer-dryers, the overall product system concerning the laundry process is considered to include:

- Textiles and their production and usage
- Detergent and its usage
- Laundry sorting, washing, drying and ironing.

This section 3 in particular focuses on user behaviour while specific product technologies, system aspects and local infrastructure are described more deeply in Chapter 4.

The Ecodesign and Energy Label Regulations as well as their underlying test and measurement standards are based on certain assumptions on user behaviour. This includes among others elements related to the choice of programmes and temperatures, appliance capacity, annual number of cycles, or detergents.

There are some indications suggesting that the finally achieved savings based on real-life user behaviour deviate from an estimation of savings based on the assumed used of energy-saving programmes.

The objective of this chapter is to report and analyse information on the consumption of resources and on any other relevant environmental impacts during the use phase. In particular, to gain more reliable and up-to-date information, two current (2015) online user surveys have been designed in the context of this study, one for washing machines and another one for washer-dryers, by the University of Bonn. Their results are presented in sections 3.1.1.1 and 3.1.2.1. To provide a complete picture of current and past consumer behaviour, further results of prior consumer surveys are listed as well.

3.1. Consumer behaviour with regard to purchase and use phase

This section aims to address user behaviour aspects such as:

- Frequency of operations and loading practices
- Selection of washing and drying programmes, in particular with respect to the choice of energy saving programmes and washing temperatures and the duration of the washing and/or drying cycle,
- Selection of detergents and hygiene issues
- Availability and understanding of information reported on appliances and user manuals.

In this respect, results of consumer behaviour studies which have been carried out by Bonn University, the International Association for Soaps, Detergents and Maintenance Products (AISE) and other sources are presented in the following sections. The aim of section is to understand user behaviour as well as guide standardisation and revision of Ecodesign and Energy Label requirements for household washing machines and washer-dryers.

NOTE: Washing habits in Europe have been studied extensively by different organisations through the use of questionnaires asking thousands of consumers about their washing behaviour and attitude. Nevertheless, all these surveys are based on the information the interviewee was willing and able to provide and on the seriousness the answers were given. Also the formulation of questions and answers can influence the results. Therefore interpretation of the results of any analysis on consumer behaviour should be handled with care. Further, the study design of each of the consumer survey studies is specific (number of participants, characteristics of the panel, questions to the participants etc.), and the results are often not directly comparable. This is the reason for the results of all surveys being presented separately.

3.1.1. Washing machines

3.1.1.1. Consumer behaviour survey on washing machines 2015 by University of Bonn

A semi-representative EU online survey was conducted by Bonn University in April and May 2015 (Alborzi et al. 2015). The aim of the survey was to assess the washing behaviour of over 5,000 households in 11 European countries (Czech Republic, Finland, France, Germany, Hungary, Italy, Poland, Romania, Spain, Sweden and the United Kingdom) and obtain information on the wishes, experiences and level of consumers' awareness regarding the Energy label. This information is used to guide the standardisation and revision of Ecodesign and Energy label requirements for household washing machines. Toluna, a professional market research company located in Frankfurt am Main, Germany, was asked to translate the questionnaires into different languages, recruit respondents from the panel of registered consumers and fulfil the quotas for each country. Translations were checked by native speakers of the European Commision's Institute for Prospective Technological Studies (JRC-IPTS).

Qualified households were chosen following predefined quota:

- Selected age groups:
    - 20–39 years
    - 40–59 years
    - 60–74 years
- Household size: 1, 2, 3, 4 and more than 4 people
- Involvement in laundry washing: substantial
- Distribution of gender: more than 50% female

Furthermore, Eurostat data for each country were used to calculate the population distribution in the respective age class and household size as quotas for the consumer survey distribution in each country. In spite of all the efforts made, the survey is not fully representative for European households. The reason relates to the method of online data collection which automatically excluded several individuals who did not have any internet access.

The participants were asked about their laundry washing and drying behaviour, their opinion regarding energy-saving issues and their awareness of information reported on the Energy label of washing machines and usage of user manuals. Demographic data were additionally recorded. No economical or cultural indicators were considered in order to avoid complexity and ethical problems with the questionnaire.

Before starting the analyses, the validity of each dataset was controlled through two criteria. The first criterion was the comparison between the answers provided for 'the number of laundry loads washed per week' and 'the frequency of using different washing programmes per week'. The latter information was coded into numbers (following Table 3.3) and, when summed up, revealed a number of wash cycles per week. Higher figures were calculated from individual wash programmes. Therefore, the difference between both numbers was used as an indicator of inconsistent answering of the questionnaire. The second exclusion criterion was based on the question, 'Please indicate all types of the information you are able to identify on the label presented.' Among all the features given, three of them are not listed on the energy label; this criterion was considered fulfilled when two or all of them were chosen by participants. Datasets were excluded from the following evaluation in the case of giving an inconsistent answer to both criteria. After excluding the outlier data, the number of the panel diminished from 5,100 to 4,843 participants.

Furthermore, weighting according to the number of households of each country compared to the sum of all countries investigated was applied for calculating average EU results. Table 3.1 illustrates the contribution of European countries in the survey. These EU averages represent 82% of all households in EU-28.

Table 3.1: Contribution of European countries in the survey (source for number of households: UNECE Statistical Database, compiled from national official sources); (Alborzi et al. 2015)

Country	Panel	Valid data *	Households**	Contribution to total results %
Czech Republic	300	283	4,502,431	3%
Finland	300	288	2,579,781	1%
France	600	580	27,106,517	16%
Germany	600	580	40,656,000	23%
Hungary	300	279	4,105,708	2%
Italy	600	555	25,007,000	14%
Poland	600	563	13,567,999	8%
Romania	300	275	7,470,429	4%
Spain	600	567	18,083,690	10%
Sweden	300	294	4,725,279	3%
United Kingdom	600	579	26,414,000	15%
All households in the sample	5,100	4,843	174,218,834	100%
Total number of households in EU-28	…	…	213,656,847	…

* The selection criteria were modified after the first stakeholders meeting held in Seville on 23 June 2015. Therefore, small differences to the market data are explained.
** Source: UNECE Statistical Database, compiled from national official sources.

Coding values

This section provides information regarding the editing of the values assigned to answer choices.

Temperature coding

In order to calculate the average washing temperature, the options in the question about the 'frequency of using different washing programmes' were coded with the following temperatures.

Table 3.2: Temperature coding; source: (Alborzi et al. 2015)

Washing programmes	Coded temperature
Cotton 20 °C/Cold wash	20
Cotton 30 °C	30
Cotton 40 °C	40
Cotton 60 °C	60
Cotton 90 °C	90
Synthetic/Easy care 30/40 °C	35
Standard cotton 40 °C (Eco) or Energy-saving programme	40
Standard cotton 60 °C (Eco) or Energy-saving programme	60
Quick wash/Short	30
Mix (all fabrics)	40

Frequency of washing programme coding

In addition, the following coding was described for the question about the ‘frequency of using different washing programmes’.

Table 3.3: Frequency of washing programme per week coding; source: (Alborzi et al. 2015)

Frequency of using different washing programmes	Coded values
Not at all	0
Once every 4 weeks	0.25
Once every 2 weeks	0.5
1 to 2 times per week	1.5
3 to 4 times per week	3.5
5 to 6 times per week	5.5
More than 6 times per week	7

Load coding

Respondents were asked, ‘What is the maximum load of laundry in kg which can be washed in your washing machine (information given, for example, in the user manual)?’ The answers are coded as given in Table 3.4 when averages are calculated and referred to as ‘rated capacity’, as this is the technical term defined in standardisation and regulations.

Table 3.4: Loading coding in kg; source: (Alborzi et al. 2015)

Maximum load	Coded load
Up to 5 kg	5
6 kg	6
7 kg	7
8 kg	8
9 kg	9
More than 9 kg	10
I don’t know	Excluded

Household size coding

In order to calculate the average household size, the options in the question ‘How many people are living in your household, including yourself’ were coded with the numbers given in Table 3.5.

Table 3.5: Household size coding; source: (Alborzi et al. 2015)

Household size	Coded size
1	1
2	2
3	3
4	4
More than 4 people	5

Spin speed coding

Regarding the question, 'What is the maximum spin speed of your washing machine?', the coding was used as given in Table 3.6.

Table 3.6: Spin speed coding in rpm; source: (Alborzi et al. 2015)

Maximum spin speed	Coded Value
400 rpm	400
600 rpm	600
800 rpm	800
1000 rpm	1000
1200 rpm	1200
1400 rpm	1400
1600 rpm	1600
I don't know	Excluded

Results of EU online survey

A selection of the results of the EU online survey is presented in the following.

Purchase criteria

When the respondents were asked about the 'six main features that they would take into consideration when buying a new washing machine' and requested to sort them based on priority, 'low water and energy consumption and associated bills' was the most important aspect for the consumers when planning to buy a new appliance (Figure 3.1). 'Purchase price' and 'simple and easy to use' were the second and third priorities, respectively, among the other options, followed by 'expected rinsing results', 'washing performance', 'low noise emission' and 'short programme duration'. The attributes with the least importance were 'exterior design of washing machine' and 'network connectivity and communication between household appliances'.

Outcomes are aligned with those obtained from a parallel survey conducted for dishwashers. Durability aspects have not been included in the set of possible answers for washing machines. However, it should be observed that this was a relevant parameter in the answers for dishwashers, probably indicating that this fact can be extended also to washing machines due to similarities existing between the two products.

Some of these purchase criteria are easily accessible (e.g. energy consumption, water consumption and cost), whereas the concept of some others is not obvious and respondents might have a different understanding of their meaning (e.g. washing performance). Therefore, quality of answers might be affected by these differences.

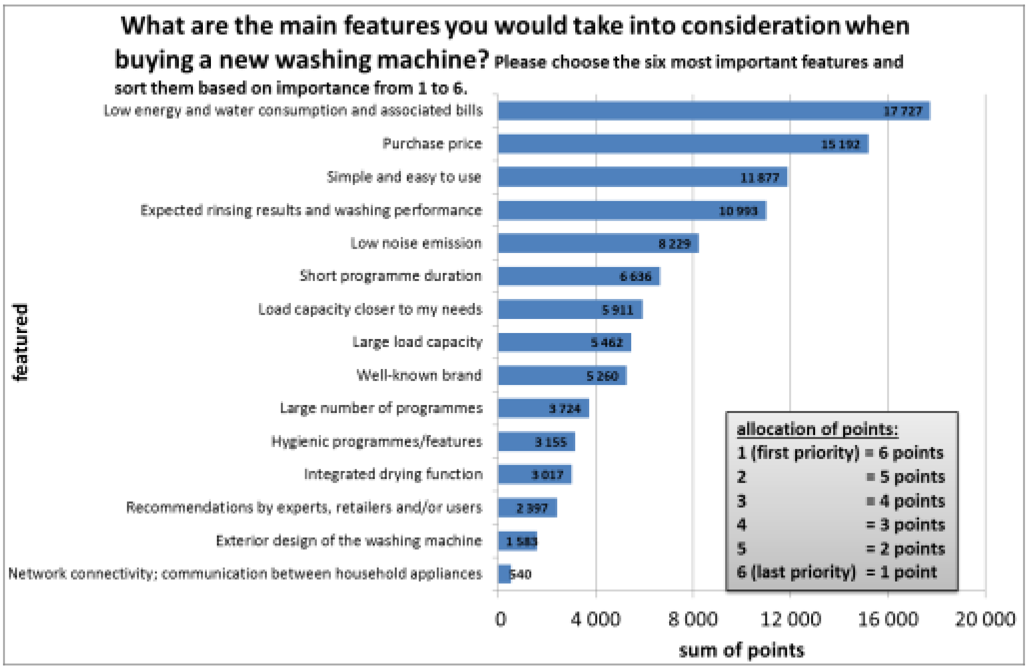


Figure 3.1: **Attributes with high importance for the consumer when buying a new washing machine (weighted n= 4,843); source: (Alborzi et al. 2015)**

Type and sources of information supporting purchase decisions

When the consumers were asked about the sources of information they would look at before purchasing a new washing machine (multiple answers allowed), the main source of information they mentioned was 'Online product rating' (51%) (Figure 3.2). The second source of information was 'Websites of manufacturers' (40%). 'Advice of the sales person in the shop' and 'Recommendation from friends, relatives, family and neighbours' have about similar importance as the website of the manufacturers. 'Label on the machine' was important as a source of information for 23% of the participants in the survey supporting purchase decision, whereas product fiche was selected by 30% of respondents.

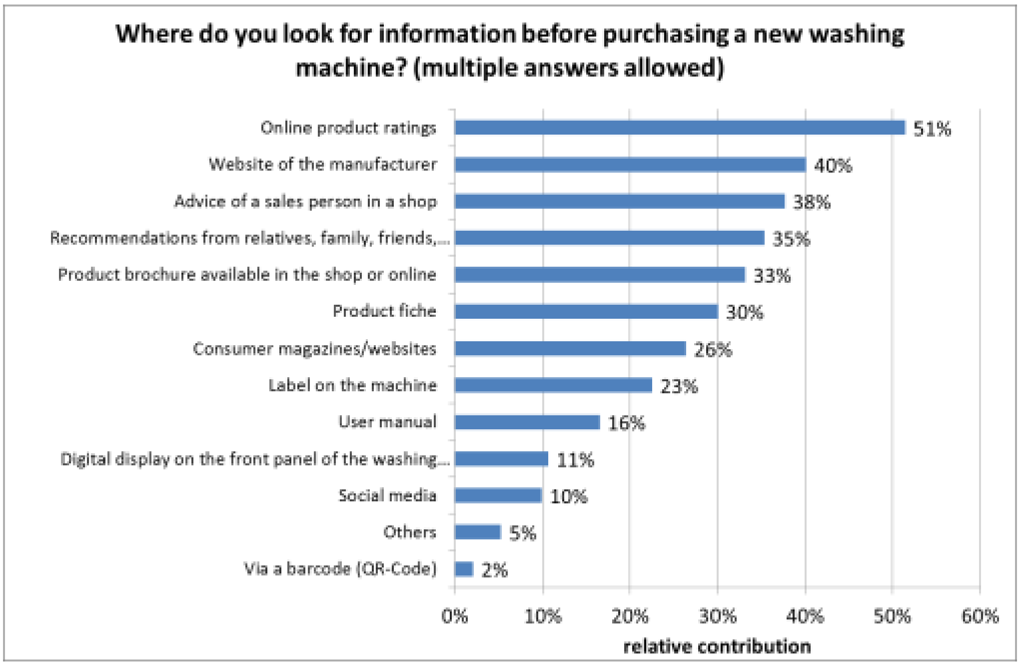


Figure 3.2: **Source of information consulted to support a purchase decision for a new washing machine (weighted n = 4,843); source: (Alborzi et al. 2015)**

Moreover, the participants were asked to indicate 'which information they would expect to see on the future Energy label' (multiple answers were allowed). 'Capacity in kg' (63%) and 'Energy efficiency class' (57%) are the two most demanded information (Figure 3.3).

Referring to water and energy consumption, participants seem to prefer getting this information per wash cycle (53% and 51%, respectively) rather than as annual consumption levels (42% and 45%, respectively).

'Noise emission' and 'Spin drying efficiency' were mentioned as important factors to be mentioned on the Energy label, selected by 50% and 43% of the participants, respectively.

Participants also indicate appreciation for additional information which is not listed on the current Energy label: 'Washing performance' (48%), 'Expected lifetime of machine' (42%) and 'Duration of energy-saving programme per cycle' (35%).

Other pieces of information including 'Programme used for assessment' and 'CO_2 footprint' resulted in being less important for a future Energy label (each selected by 14% of respondents).

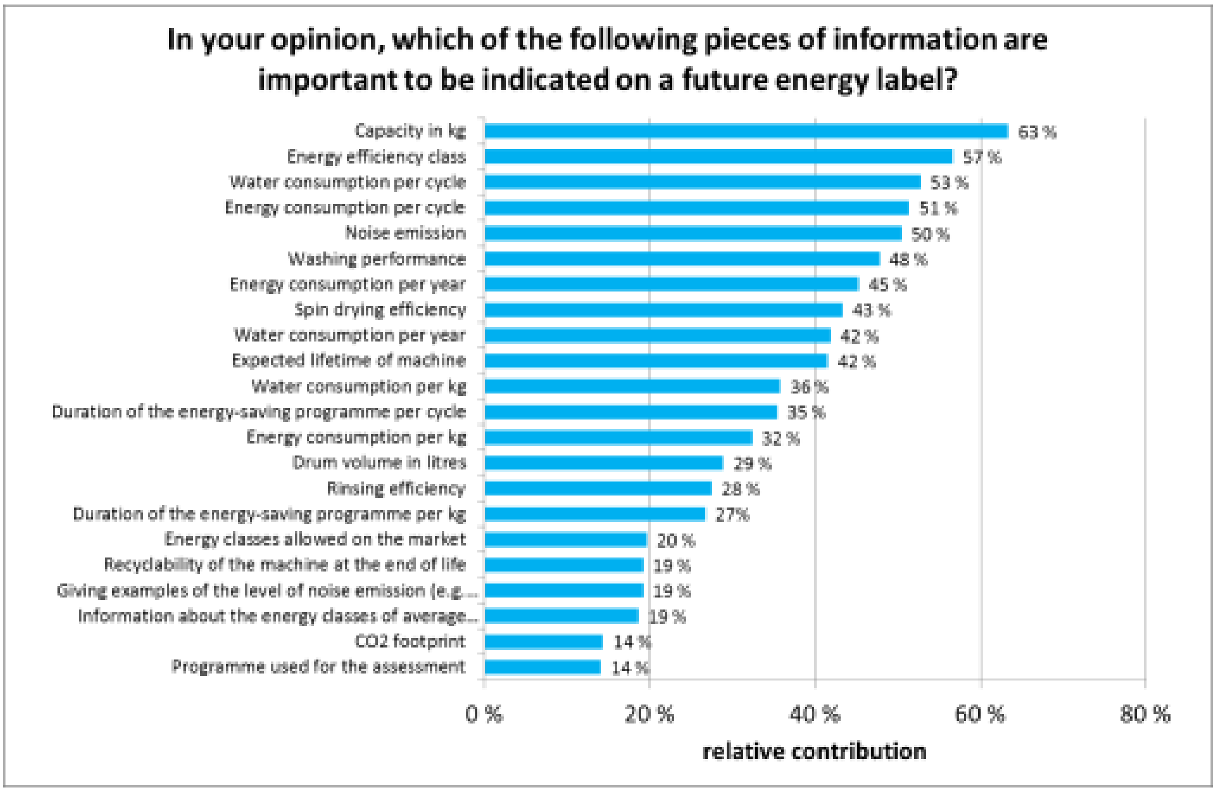


Figure 3.3: Information expected on the energy label (weighted n = 4,843); source: (Alborzi et al. 2015)

Usage of user manual and age of washing machine

Respondents were also asked 'Have you ever used the user manual of your washing machine?' Figure 3.4 shows the correlation of the usage of the user manual and the age of washing machine. The results show that the usage of the user manual is more common for younger than for older machines. Around 95% of the owners of the washing machines with the age class less than 1 year admitted that they use the manual of the washing machine especially in order to install the machine and get familiar with its use. These results confirm that the user manual is still an important source of information for consumers.

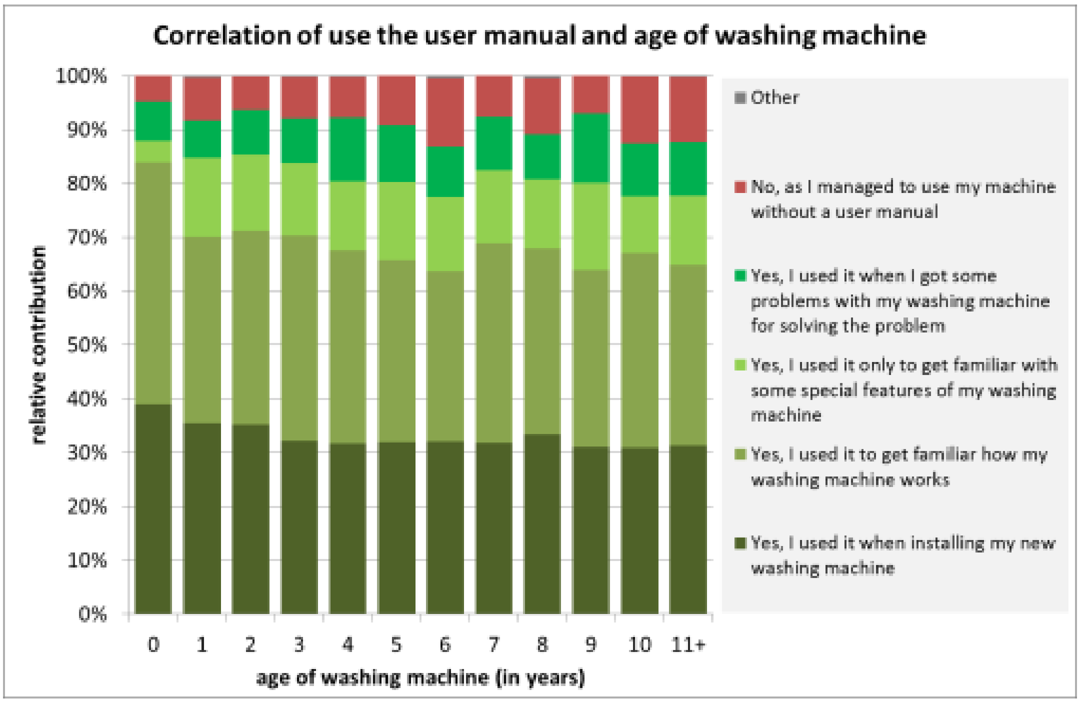


Figure 3.4: **Correlation of the usage of the user manual and the age of the washing machine; source: (Alborzi et al. 2015)**

Average rated capacity

When respondents were asked about 'the maximum load of laundry in kg which can be washed in their washing machine', the majority of respondents had knowledge about the rated capacity of their washing machine as only about 6% of them claimed that they don't know it.

The average rated capacity of a washing machine in this survey is 6.5 kg (Figure 3.5). The UK has the highest (7.2 kg) and Hungary has the lowest average rated capacity (5.7 kg) among the European countries participating in the survey. The average rated capacities of other countries lie between these ranges.

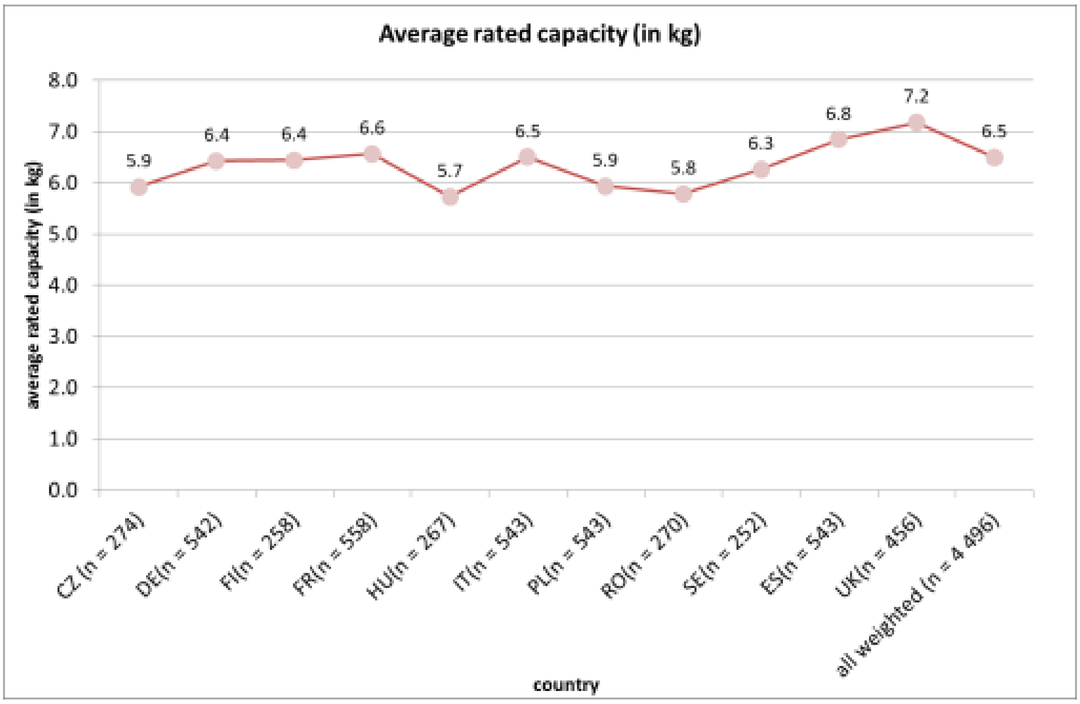


Figure 3.5: Average rated capacity of the washing machine; source: (Alborzi et al. 2015)

Age of the washing machine versus the rated capacity

According to the results obtained by Figure 3.6, there is a significant correlation between the age of a washing machine and its rated capacity (Spearman Rho correlation test leads to: rs= -0, 307, p < 0.001). The results show clearly how larger capacity washing machines have entered the households in the past decade. While washing machines which are 10 and more years old mainly have a load capacity of up to 5 kg, the majority of machines in 2015 have a load capacity of 7 or 8 kg. The capacity of 9 kg and more is still small (about 10%) for young machines.

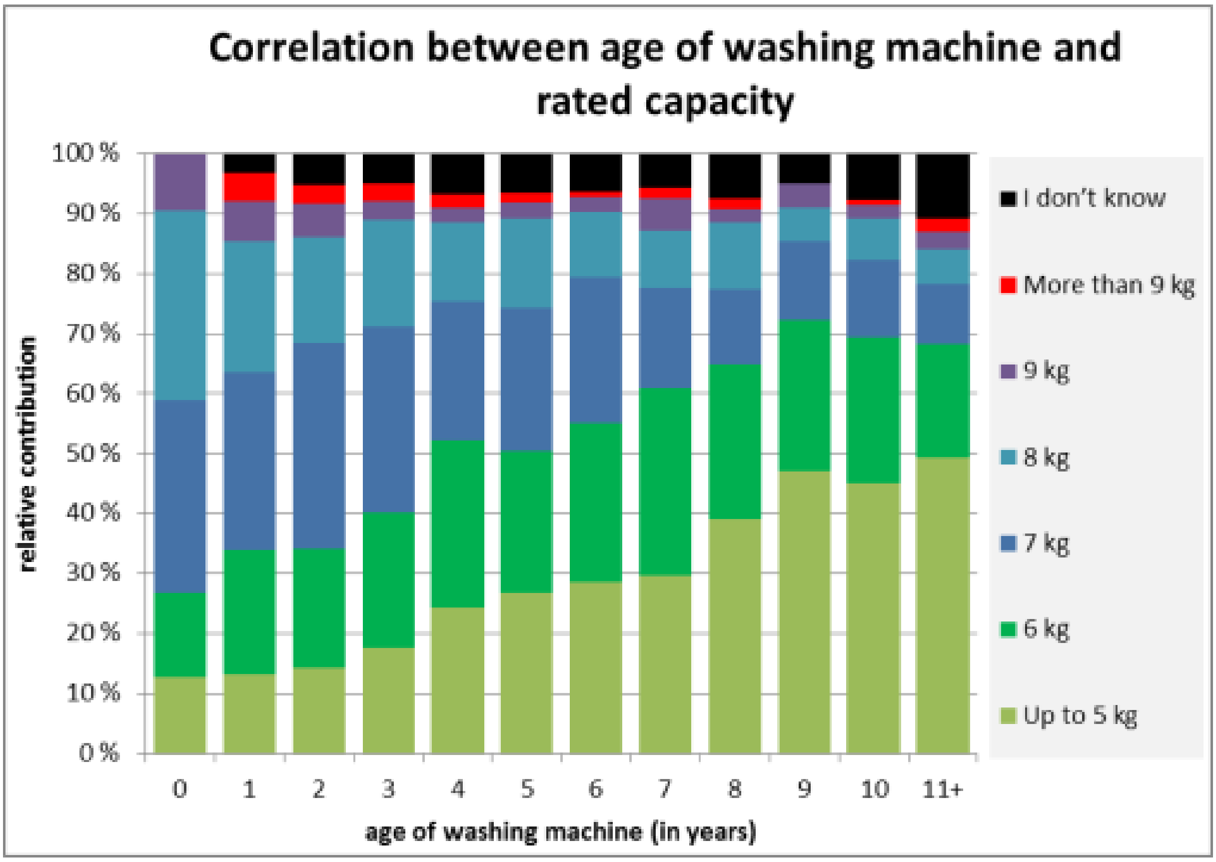


Figure 3.6: Correlation between the age of the washing machine and the maximum load capacity; source: (Alborzi et al. 2015)

Loading

Results of the survey illustrate that about 66% of the respondents claim to use the full capacity of their washing machine without overloading it and 7% admit to load 'the washing machine in such a way that it is almost overloaded' (Figure 3.7). However, in the survey carried out by Bonn University in 2011 (cf. section 3.1.1.2), almost 60% of respondents claimed to use the full capacity of their washing machine and approximately 10% of respondents mentioned that they overloaded the machine. Results illustrate that approximately the same percentage of people think they fill their washing machines completely in 2011 and 2015. However, between these years, there has been an increase in the average loading capacity of the washing machines. The average number of cycle per week has remained more or less the same, suggesting that consumers misjudge the "loading potential" of their appliances or their own loading behaviour.

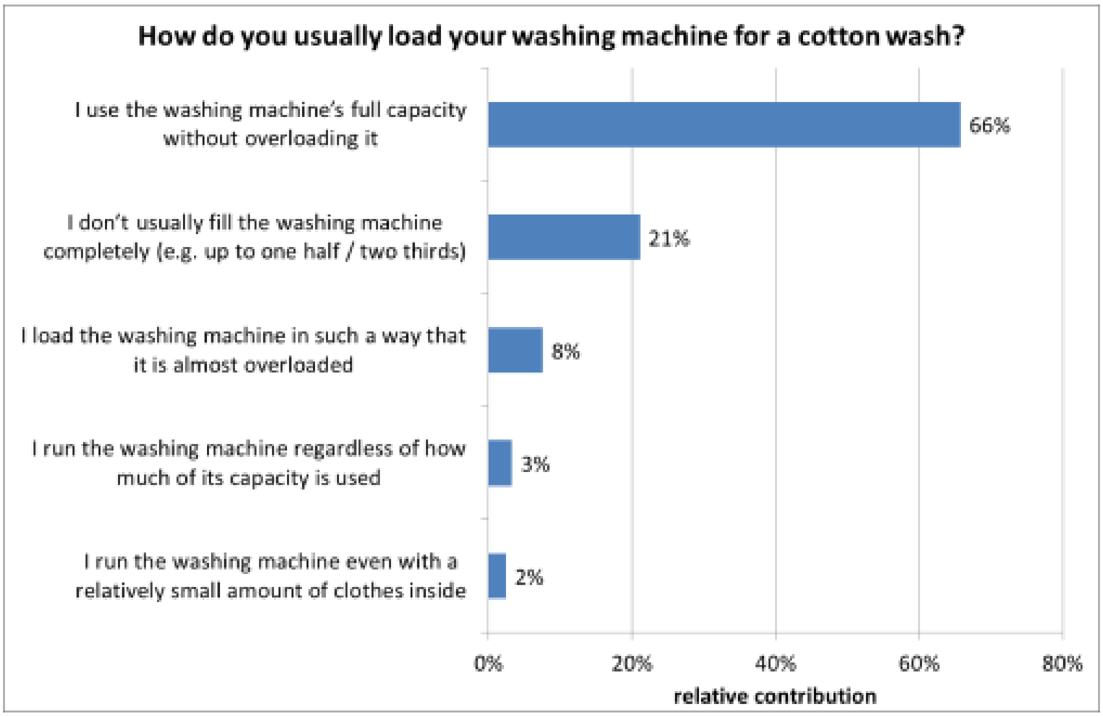


Figure 3.7: Consumer loading behaviour (weighted n = 4,843); source: (Alborzi et al. 2015)

Moreover, respondents who claimed that they do not fully load their washing machine or load with a relatively small amount of clothes inside were asked about 'the reasons for not filling up the space in the drum' (Figure 3.8). A total of 41% of respondents admitted that the reason for not filling up the space in the drum is their concern about the cleaning results, followed by not having much laundry to wash (34%) and filling up the space when necessary (34%).

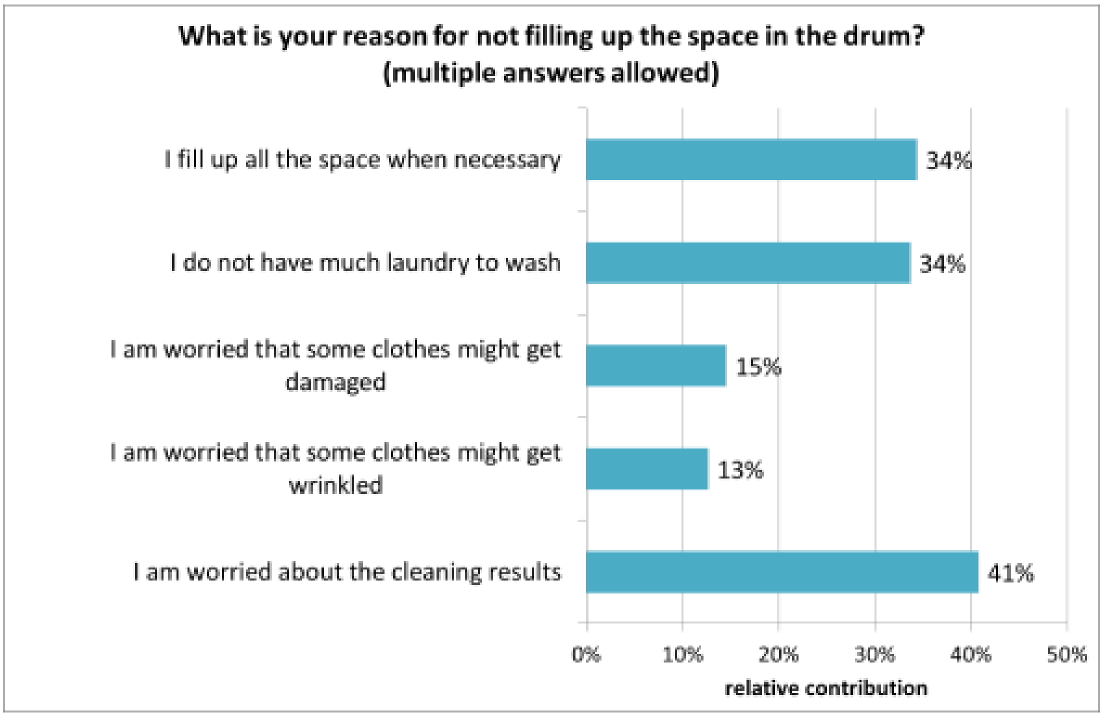


Figure 3.8: Reasons for not filling up the space in the drum (weighted n = 4,843); source: (Alborzi et al. 2015)

Average number of wash cycles per week per household size

Analysing the results of the 2015 consumer survey shows that the average number of wash cycles per week per household is 4.4 (i.e. 228.8 cycles per year).

As the household size in the current survey varied from one person to more than four people, it may be more relevant to analyse the number of wash cycles per week per household size (Figure 3.9). The results illustrate that the frequency of wash cycles is clearly related to the household size (Spearman Rho: rs= 0, 533, p < 0.001). This number lies between 2.1 cycles per week for a household size of one person to 6.8 cycles for more than four people.

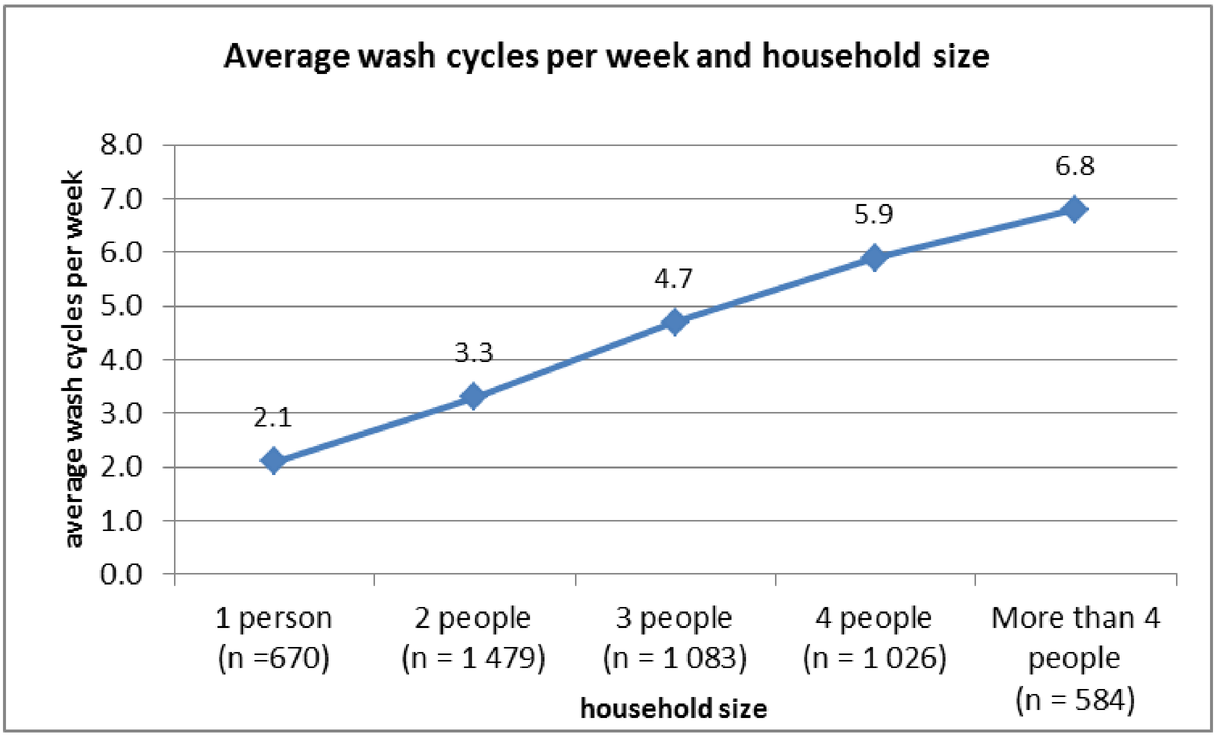


Figure 3.9: Average number of wash cycles per week per household size (weighted n = 4,843); source: (Alborzi et al. 2015)

Average rated capacity versus household size

Table 3.7 illustrates that the rated capacity of washing machine is also related to the household size (Spearman Rho: rs = 0.201, p < 0.001).

Table 3.7: Average rated capacity versus household size; source: (Alborzi et al. 2015)

		How many people are living in your household, including yourself?				
		1 person	2 people	3 people	4 people	More than 4 people
		% of households	% of households	% of households	% of households	% of households
What is the maximum load of laundry in kg which can be washed in your washing machine (information given, for example, in the user manual)?	Up to 5 kg	39 %	30 %	23 %	19 %	18 %
	6 kg	23 %	24 %	26 %	21 %	19 %
	7 kg	18 %	22 %	25 %	28 %	26 %
	8 kg	6 %	12 %	13 %	19 %	20 %
	9 kg	2 %	2 %	4 %	5 %	7 %
	More than 9 kg	1 %	2 %	3 %	2 %	5 %
	I don’t know	10 %	8 %	7 %	5 %	5 %

Prewash clothes inside the machine

When respondents were asked the question 'Do you prewash clothes inside the machine?', only 11% admitted that they 'Always' or 'Often' prewash their clothes in the machine, and about 70% mentioned that they 'Rarely' or 'Never' prewash their clothes inside the machine (Figure 3.10). Figure 3.10 shows that less prewash is done inside the machine in countries such as Germany, France and the UK in comparison to Finland, Italy, Spain or Poland.

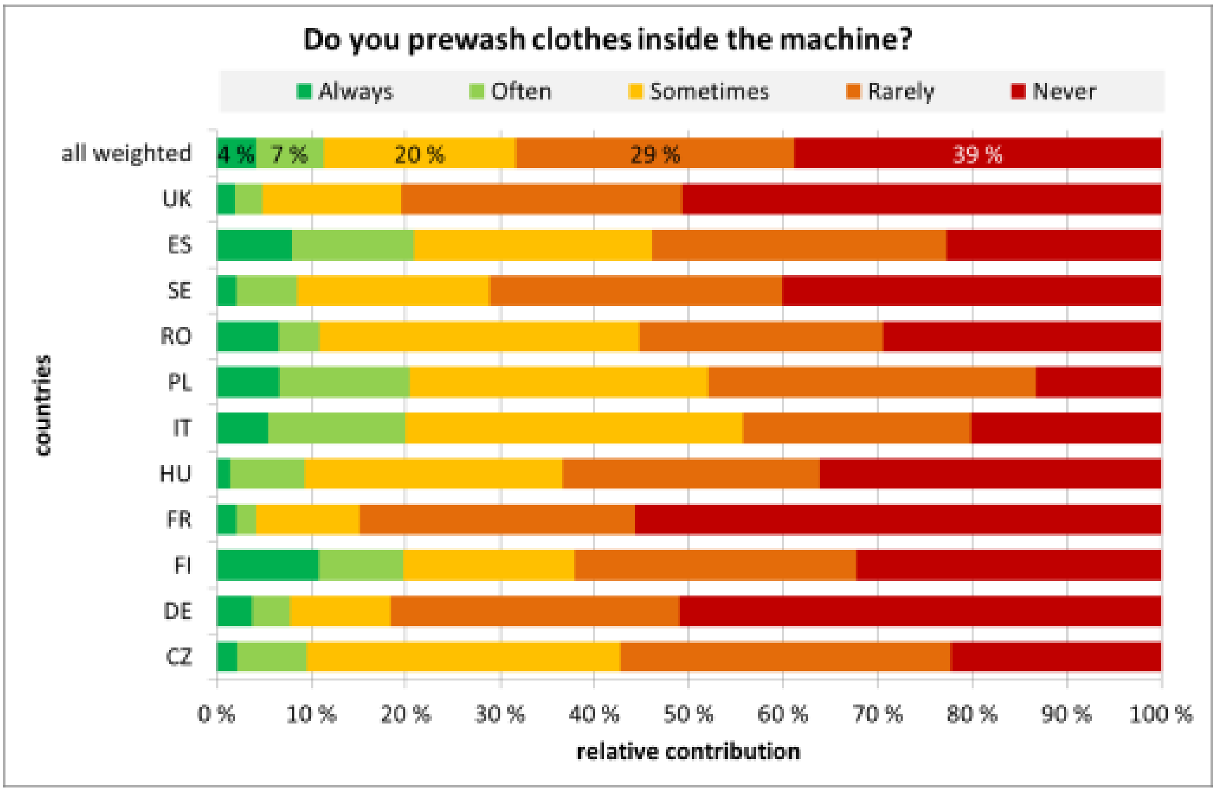


Figure 3.10: Prewashing clothes inside the machine; source: (Alborzi et al. 2015)

Washing detergent

On average, over 50% of the respondents use mostly 'Liquid' detergents for washing their clothes, 36% use 'Powder' and 12% use 'Tablets/Caps/Pads' (Figure 3.11), but the usage differs a lot between countries. Usage of 'Liquid' detergents in Italy (71%), France (69%) and Spain (67%) is more common than other kinds of washing detergent. 'Powder' detergent is the dominant kind of washing detergent in Sweden (70%), Romania (65%) and Poland (63%). It is important to note that the usage of 'Tablets/Caps/Pads' in the UK and France is more common than in other countries; over 22% of respondents use these kinds of detergent in the countries mentioned.

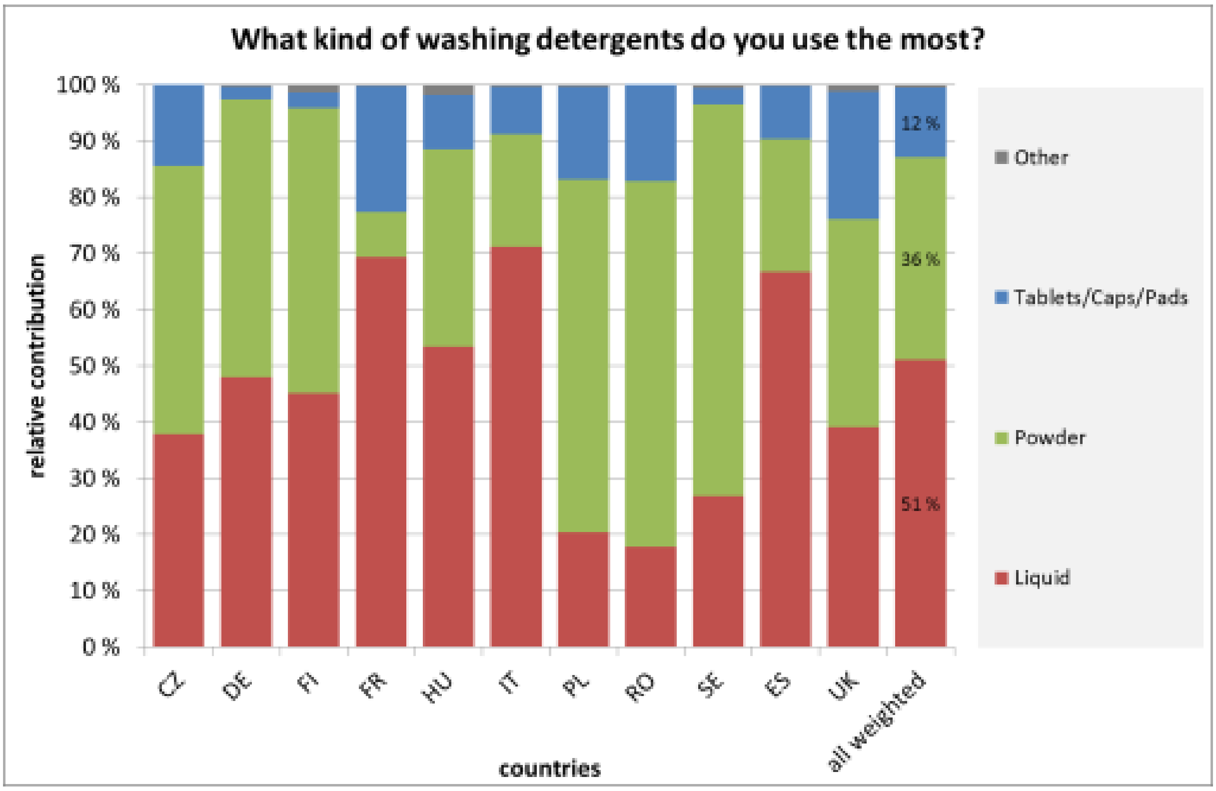


Figure 3.11: Kinds of detergents most used; source: (Alborzi et al. 2015)

Average washing temperature

The average washing temperature per wash cycle for European countries is 42.3 °C, calculated with nominal coded temperature obtained from the question about the frequency of washing programmes used per week (Figure 3.12). However, the washing temperature varies between different countries. Spain, for instance, has the lowest average washing temperature of 37.9 °C, while Finland has the highest of 45.1 °C.

The lower average washing temperature of Spanish households in comparison to other countries participated in the survey is explained by the high usage of low temperature programmes, e.g. Cotton 20 °C / Cold wash, whereas the higher average washing temperature in Finland and Sweden is related to the common use of high temperature programmes like Cotton 60 °C (Table 3.8).

Washing programmes used

The results of the survey show a clear dominance of the cotton wash programme over all other washing programmes; 62% of all washing programmes used is cotton (Figure 3.13); the normal cotton programmes sum up to 26%, with 'Cotton 40 °C' as most used programme (selected by 15% of the respondents) and 'Cotton 60 °C' selected by 11% of respondents). The standard cotton programmes on the other hand make up 17% of the total number of washing programmes used, which is about one third of all 'Cotton 40 °C' and 'Cotton 60 °C' washing programmes used. It is important to note that the 'Standard cotton programme' and 'energy-saving' programme may differ from each other as there was no request to declare the energy-saving programme on the panel in the old energy labelling regulation. Therefore, the frequency of use of 'Standard cotton programme' as defined in the new ecodesign regulation may not be truly represented by these results.

The share of programmes such as 'Synthetic/Easy care 30 °C/40 °C' and 'Quick wash/Short' is 11% and 13%, respectively. Figure 3.13 shows that the washing programmes least used are 'Cotton 90 °C' (5%) and

'Cotton 20 °C' (4%). Table 3.8 shows the usage of different washing programmes per country. Results indicate that Spanish households follow a completely different washing programme usage pattern compared to other countries.

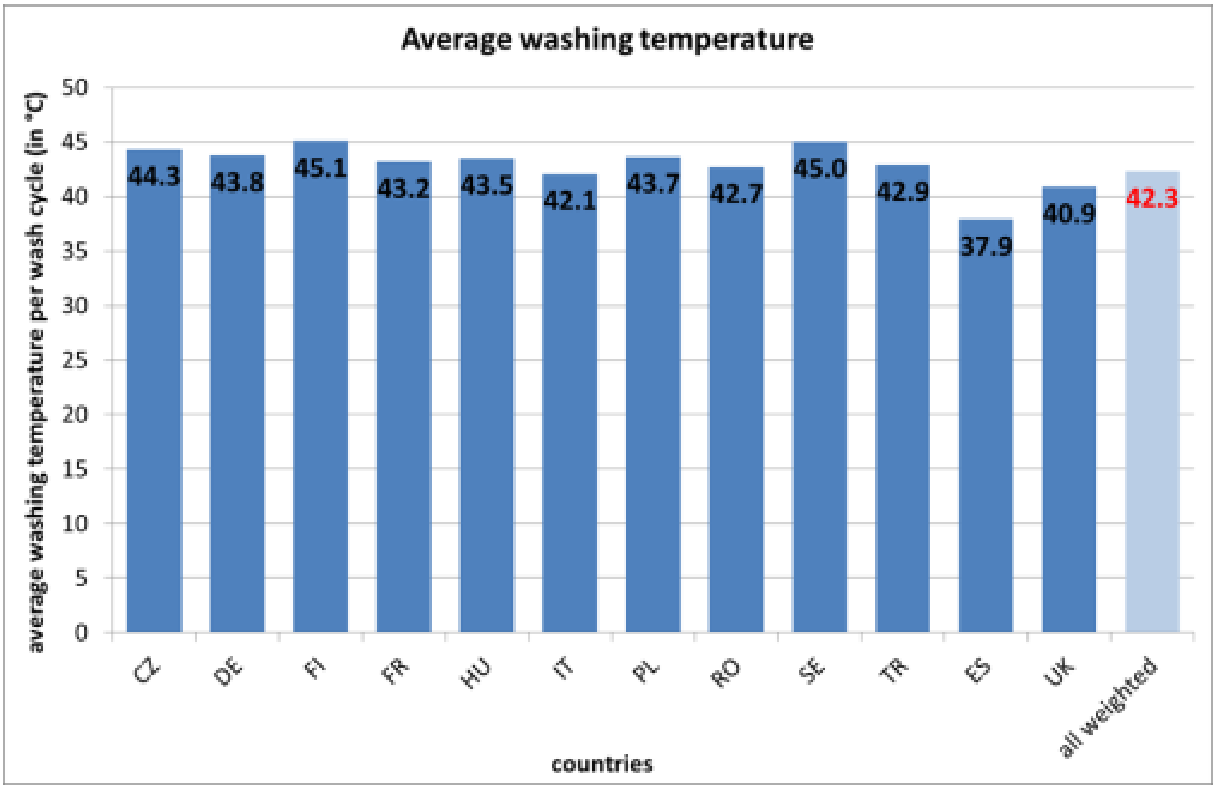


Figure 3.12: Average washing temperature per wash cycle; source: (Alborzi et al. 2015)

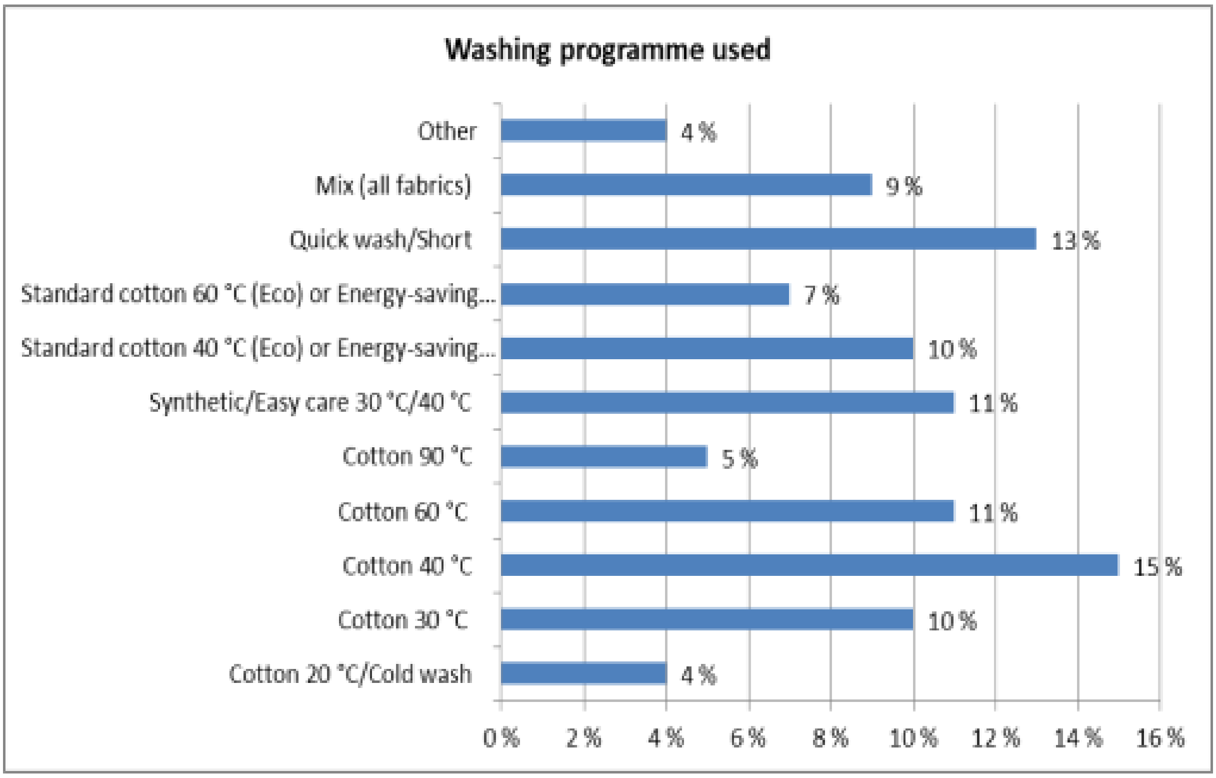


Figure 3.13: Washing programmes used; source: (Alborzi et al. 2015)

Table 3.8: Usage of different washing programmes in different countries; source: (Alborzi et al. 2015)

Country	CZ	DE	FI	FR	HU	IT	PL	RO	SE	ES	UK
Washing programmes	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles	% of wash cycles
Cotton 20 °C/ Cold wash	2	2	0	3	2	5	2	3	1	13	3
Cotton 30 °C	7	11	4	12	6	11	7	7	5	11	12
Cotton 40 °C	20	17	23	17	16	12	15	13	22	8	18
Cotton 60 °C	14	14	19	11	10	10	10	10	18	5	9
Cotton 90 °C	5	5	3	6	4	5	5	5	4	4	4
Synthetic/ Easy care 30 °C/40 °C	11	11	6	10	11	12	11	12	7	12	12
Standard cotton 40 °C (Eco) or Energy-saving programme	12	9	6	10	15	10	13	10	10	9	11
Standard cotton 60 °C (Eco) or Energy-saving programme	7	7	6	6	10	8	9	7	8	6	5
Quick wash / Short	12	11	10	11	13	12	13	15	12	17	15
Mix (all fabrics)	7	8	18	8	8	10	9	12	8	12	9
Other	4	4	4	4	4	5	5	5	5	5	3

Age of the washing machine versus the washing programme used

Figure 3.14 illustrates small differences between the age of a washing machine and the usage of different washing programmes. According to the results, the frequency of using the 'Standard cotton 40 °C' (Eco) or 'Energy saving programme 40 °C' per week and 'Standard cotton 60 °C' (Eco) or 'Energy saving programme 60 °C' is slightly higher in younger washing machines than in older ones (Figure 3.14). This may be related to the introduction of the so-called 'Standard Cotton programme' since the implementation of the new Energy label.

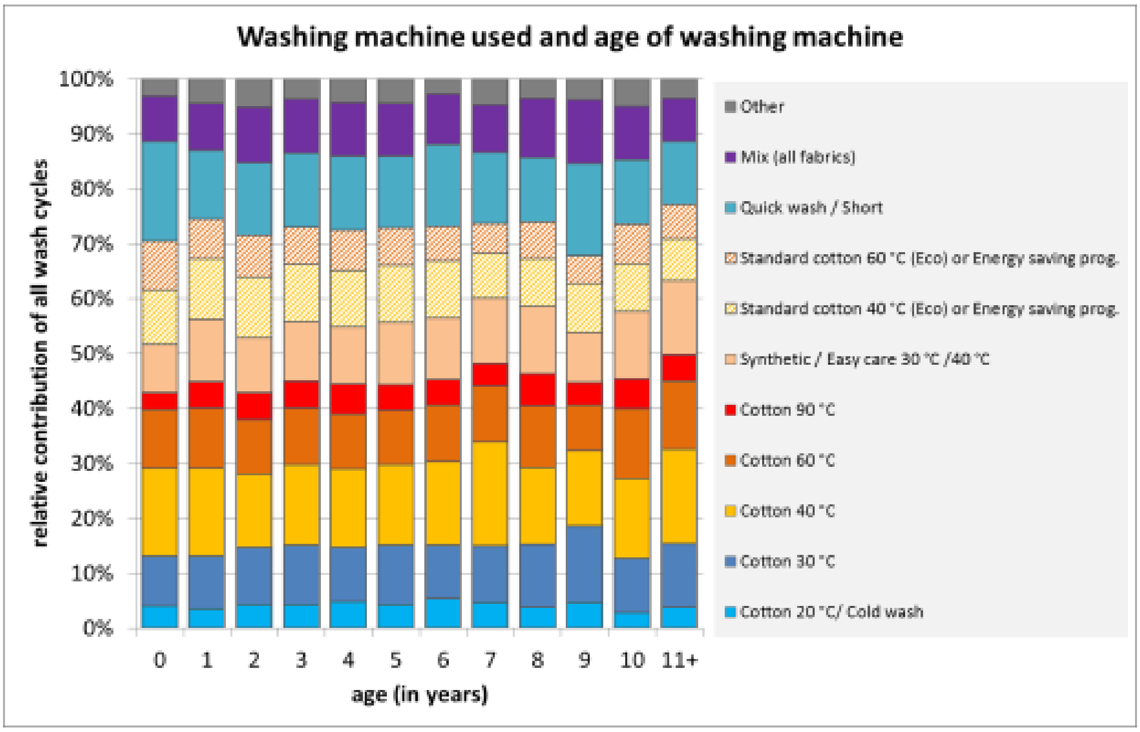


Figure 3.14: **Correlation between the washing programmes used and the age of machine; source: (Alborzi et al. 2015)**

The respondents were also asked about the washing programmes most used for washing different kinds of clothes. The results of the survey indicate that higher temperatures ('Cotton 60 °C' and 'Cotton 90 °C') are mostly used for washing towels and bed-sheets, while lower temperatures are frequently used for washing shirts and blouses (Figure 3.15). Referring to the results of the survey, 'Standard cotton 60 °C' is mostly used for washing bed-sheets and towels and rarely used for washing shirts and blouses.

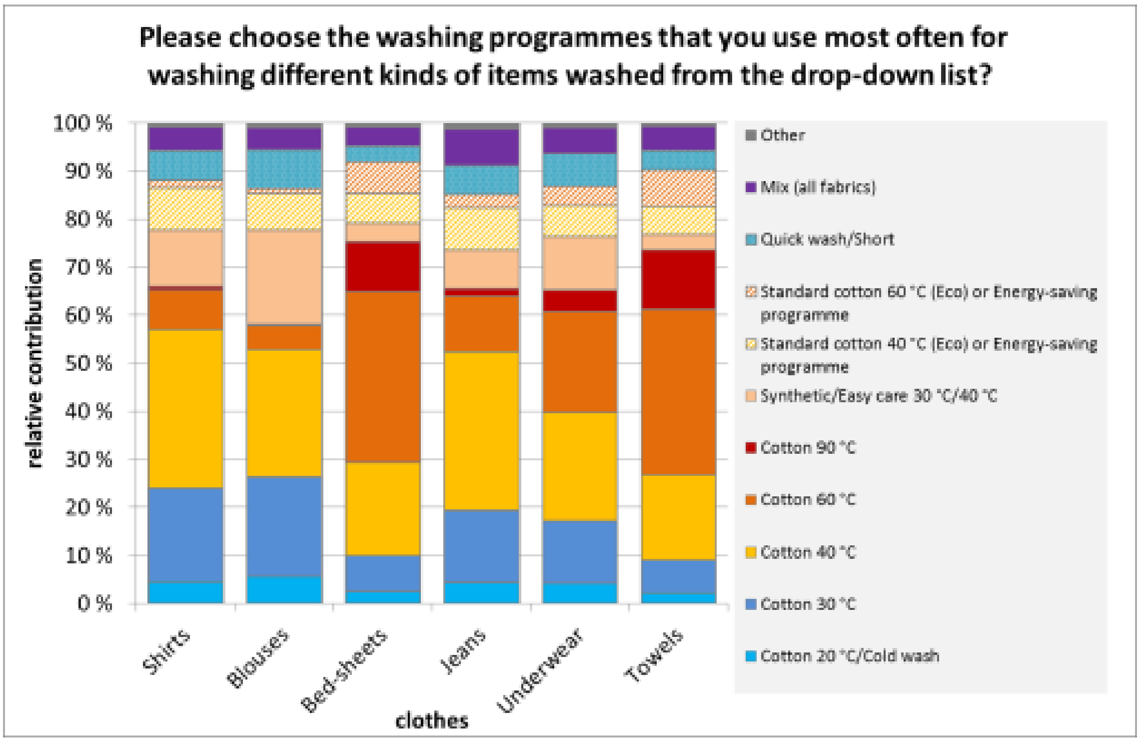


Figure 3.15: **Washing programmes most used for washing different kinds of clothes; source: (Alborzi et al. 2015)**

Approximate duration of the washing programme

When respondents were asked to ‘Please choose the approximate duration of the washing programme that you use from the list below’, surprisingly, they indicated that the duration for ‘Standard Cotton 40 °C (Eco) or Energy-saving programme’ and ‘Standard Cotton 60 °C (Eco) or Energy-saving programme’ is less than the duration of ‘Cotton 40 °C’ and ‘Cotton 60 °C’. Around 30% of respondents, for instance, mentioned that the duration of ‘Standard Cotton 60 °C (Eco) or Energy-saving programme’ is less than one hour, while around 17% of respondents mentioned that the duration of ‘Cotton 60 °C’ is less than one hour. About 74% of respondents also claimed that the duration of the ‘Standard Cotton 60 °C (Eco) or Energy-saving programme’ is less than two hours. It seems that there are some misunderstandings among consumers regarding the duration of these programmes. This can also be explained by the fact that Eco programmes on old washing machines usually run shorter compared to the standard programmes on new washing machines.

In reality, the ‘Cotton 60 °C’ programme needs between two and three hours and the ‘Standard Cotton 60 °C programme following the new regulation can run for three to five hours. Longer cycle time opens up the possibility of washing at lower temperatures with the same washing result and can, therefore, increase the energy efficiency. This approach saves considerable energy. The reduced temperatures are compensated for by longer cycle durations (cf. also section 4.4.1).

Figure 3.16 illustrates that only a negligible number of respondents use the programmes taking more than three hours in real life. As this refers to the use of the ‘Standard Cotton 60 °C or the energy saving programme’ an additional analysis was done using the stated age of the washing machine to differentiate between washing machines falling under the new Ecodesign regulation (age ≤ 3 years) and older ones (Figure 3.17). This reveals that the consumers perceive only minor differences (less than 10% shift) in the length of the programme selected in this category.

Therefore, the frequency of use of the standard cotton programmes at 40 or 60 °C (Figure 3.13) defined as the basis for the present Energy label is probably much lower than foreseen during the preparation of the regulation itself. Perhaps consumers just choose some additional time reduction option when selecting those programmes.

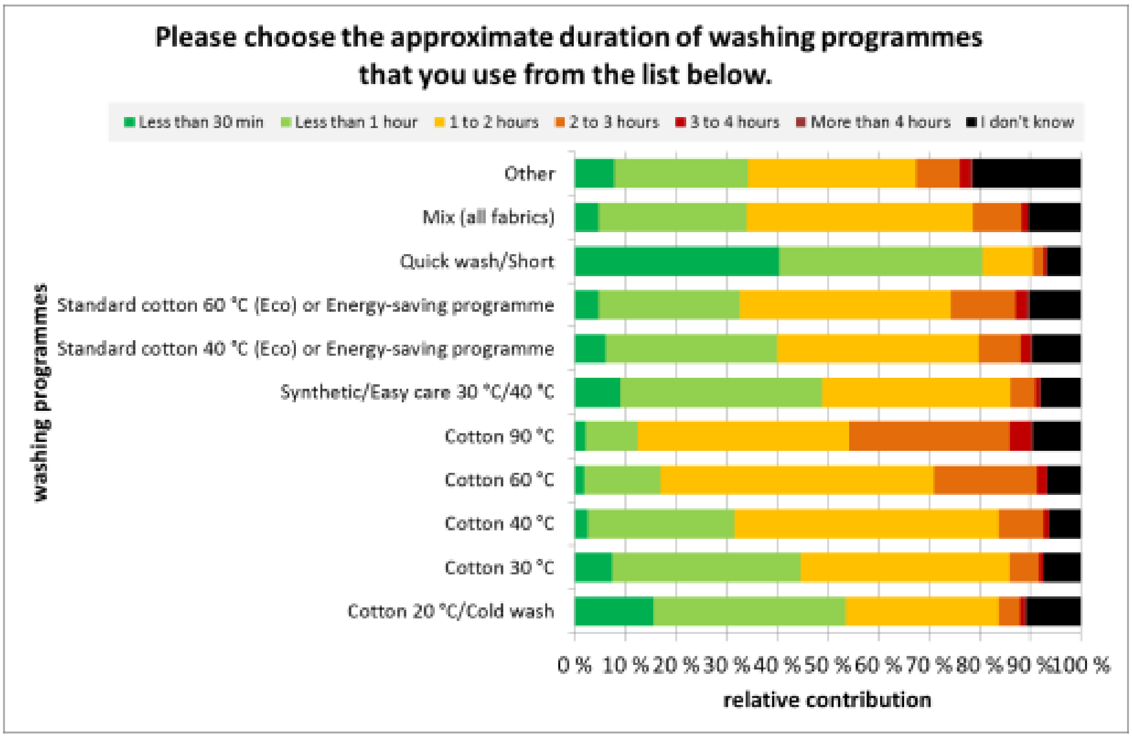


Figure 3.16: Approximate duration of the washing programmes; source: (Alborzi et al. 2015)

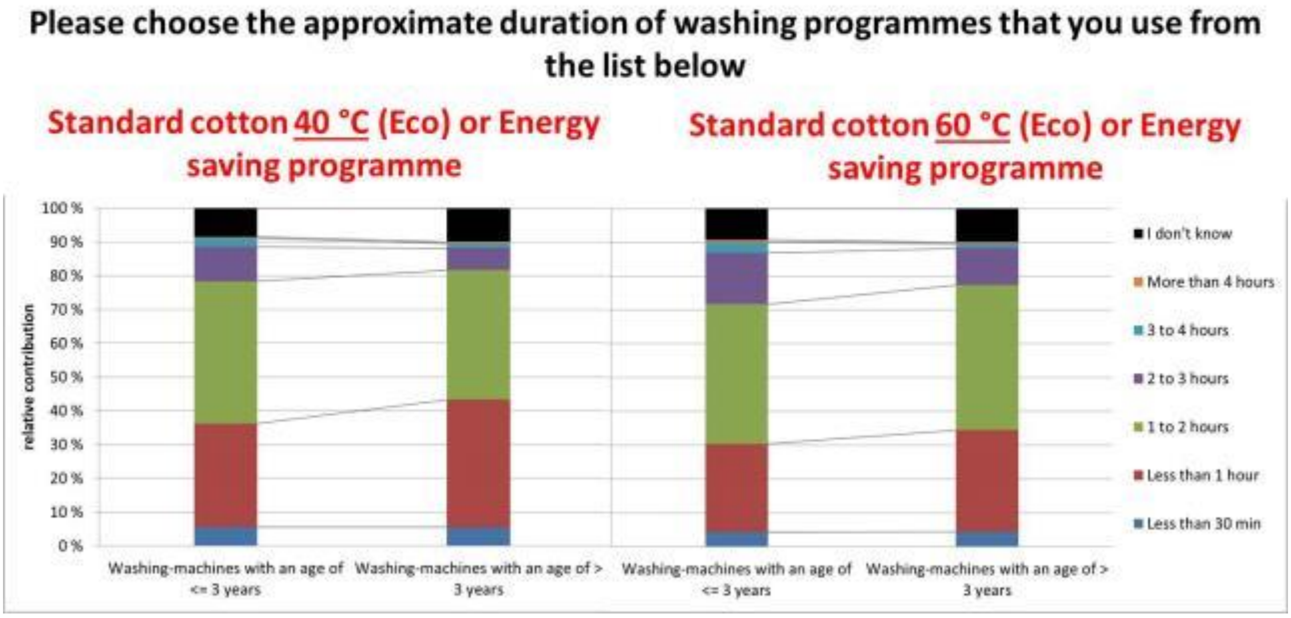


Figure 3.17: Correlation between the age of washing machine and the length of the standard cotton or energy saving programme indicated by the consumer; source: (Alborzi et al. 2015)

Washing programmes with long cycles

In response to the question 'What is your opinion of washing programmes with long cycles?' (multiple answers allowed), 38% of respondents indicated that they 'don't believe that a washing programme with a long cycle is energy-saving' (Figure 3.18). These results confirm that consumers often believe in less energy consumption of short programmes. Figure 3.18 shows that 27% of respondents have 'no problems with a washing programme with long cycles'. Additionally, 29% of respondents indicated that they don't like the washing machine running when they are not at home. Furthermore, fear of damaging the clothes, deterring them from completing all the laundry in the time that they have and disturbing the neighbours are some other opinions of respondents about washing programmes with long cycles. It is important to note that only 15% of respondents admitted that they 'understand a long cycle can be energy-efficient'.

Washing programmes with short cycles

When respondents were asked 'What is your reason for using a short programme?' (multiple answers allowed), over 60% of respondents indicated that their 'laundry is only slightly dirty' (Figure 3.19). Interestingly, 'to save energy and water' was the reason for using a short cycle programme for around 40% of respondents. Consumers' misunderstanding about less energy consumption of short programmes is also confirmed by this result. The other reasons for using a short programme included not having time (14%) and washing 'Out of habit' (7%). Furthermore, around 14% of respondents 'don't use short programmes'.

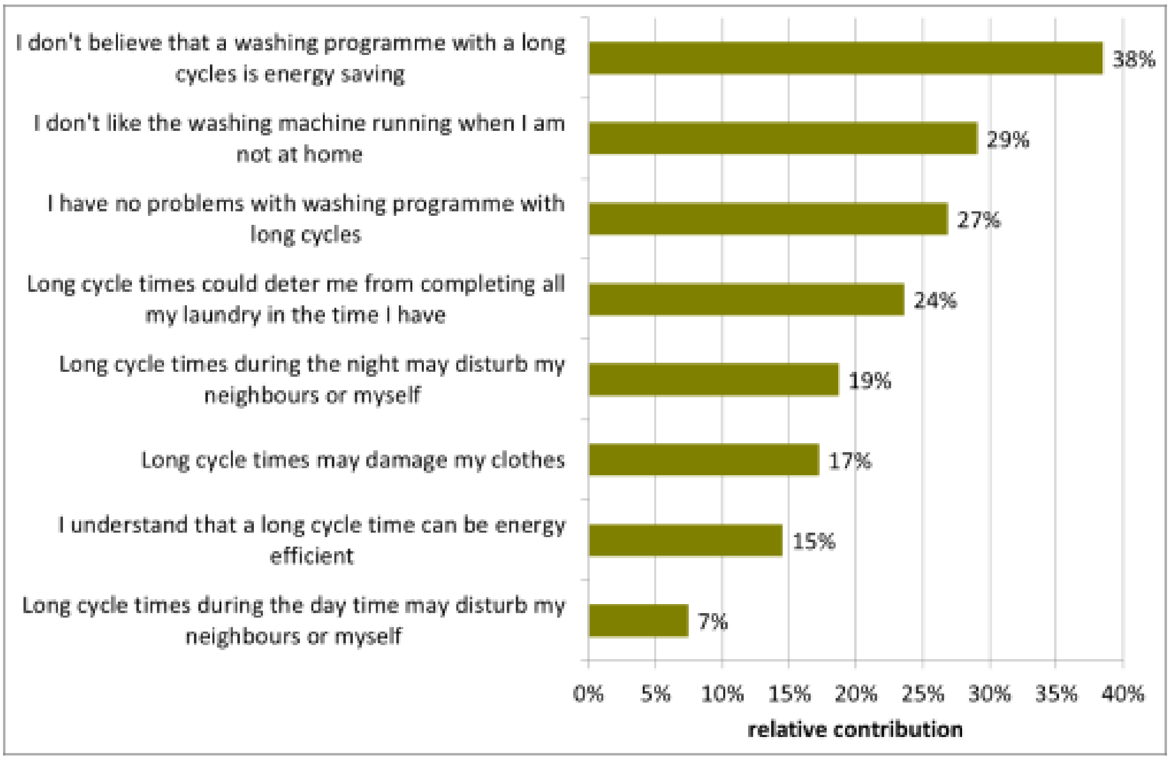


Figure 3.18: Opinion of washing programmes with long cycles (weighted n = 4,843); source: (Alborzi et al. 2015)

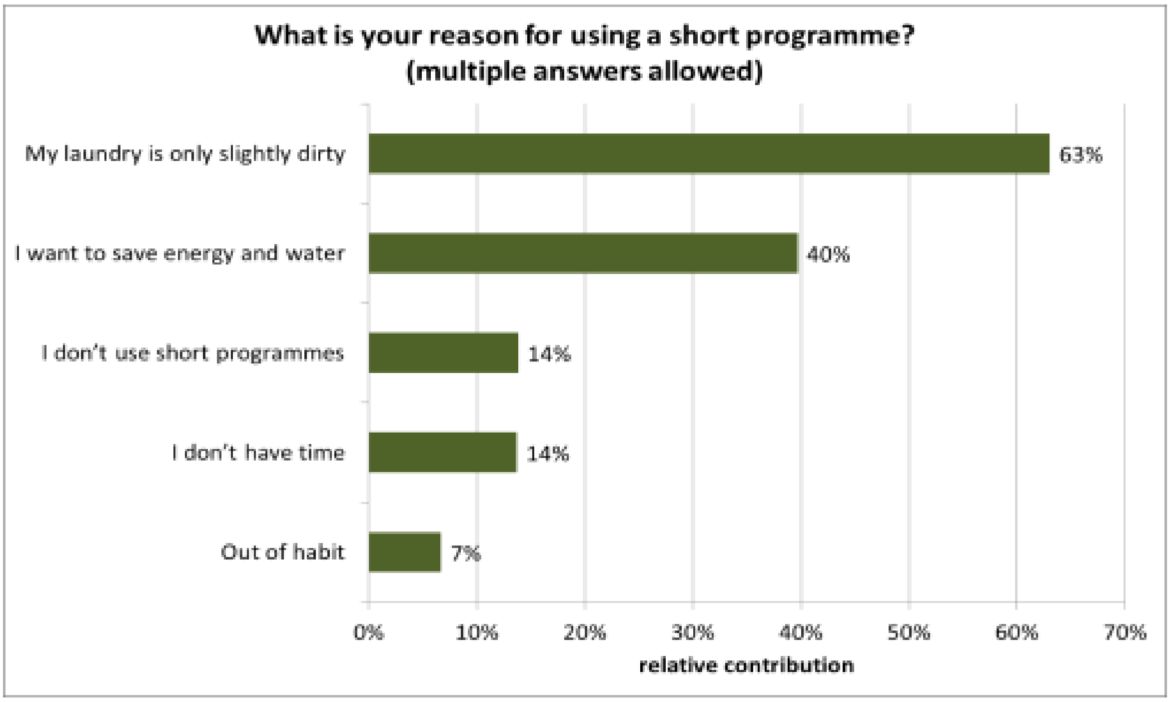


Figure 3.19: Reasons for using a short programme (weighted n =4,843); source: (Alborzi et al. 2015)

Trends to lower washing temperatures

As most of the washing machines on the market do not reach the nominal temperature mentioned for standard programmes in order to save energy, and the name of the programme does not always reflect the real temperature, respondents were asked about their decision if they knew that an energy-saving washing programme (e.g. cotton 60 °C) washes at a lower temperature (e.g. 50 °C). Around 65% of them mentioned that they would 'Continue using this programmes as long as the results are good' and around 26% of them said they would choose another programme (Figure 3.20). In addition, they were asked, 'how much deviation from the nominal temperature of the programme is acceptable to you?' As Figure 3.21 shows, 5 to 10 °C deviation from the nominal temperature is acceptable for 40% of respondents and for around 8% of them 'No deviation' is acceptable (Figure 3.21).

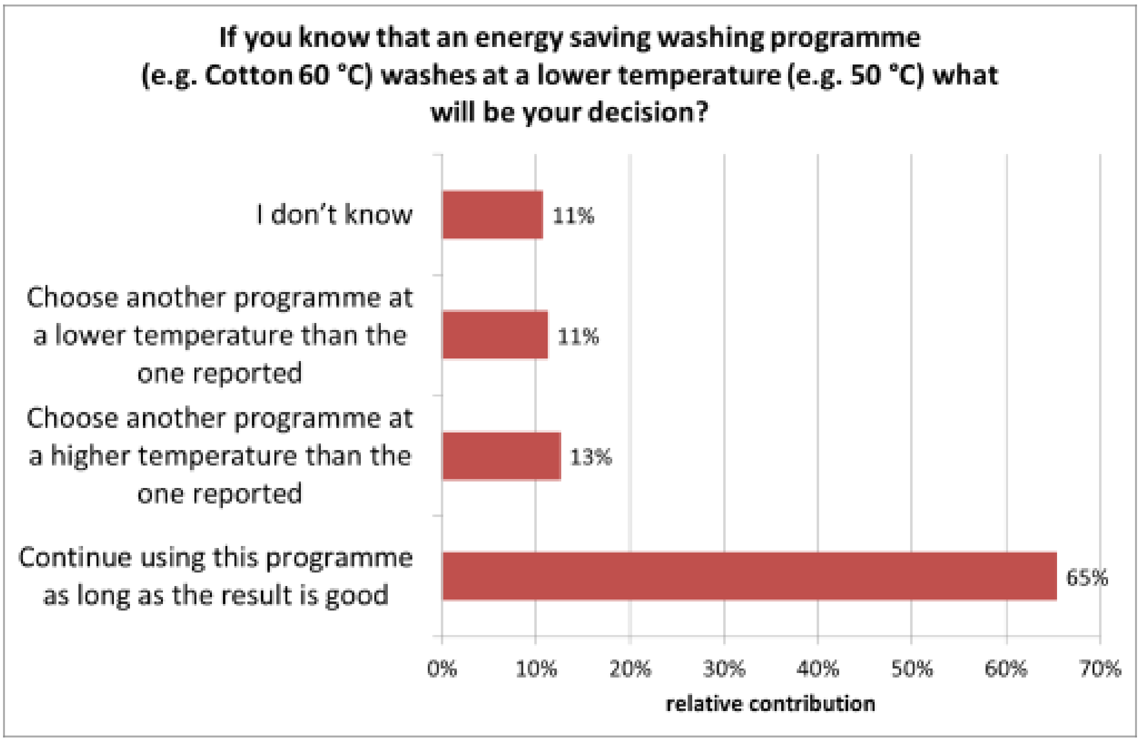


Figure 3.20: **Acceptance of an energy-saving programme which washes at a lower temperature than the nominal one (weighted n = 4,843); source: (Alborzi et al. 2015)**

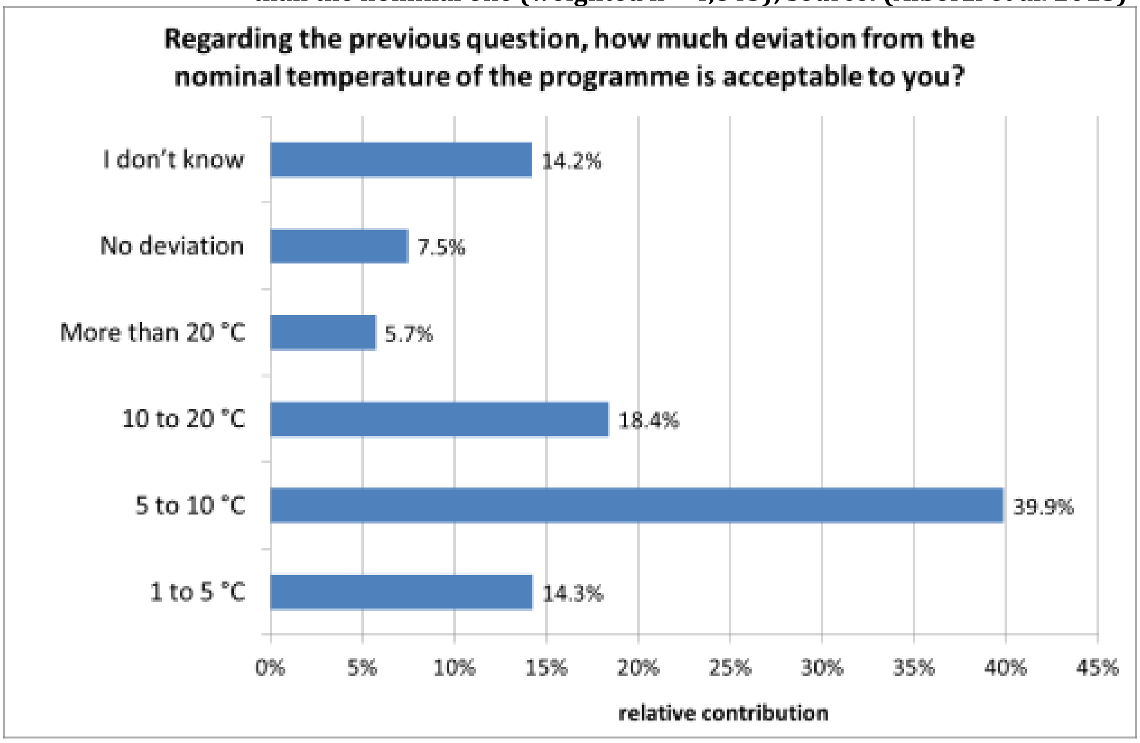


Figure 3.21: **Acceptance of deviation from the nominal temperature of the programme (weighted n = 4,843); source: (Alborzi et al. 2015)**

Delay start function

Respondents were asked, ‘Does your washing machine have a “delay start” function?’ This function was defined as follows: Delay start function allows you to set the programme to automatically start later. As Figure 3.22 shows, 57% of respondents claimed that they have a ‘delay start’ function on their washing machines and about half of them use it often or sometimes. Moreover, the group of people using the ‘delay start’ function were asked about the ‘Reasons for using delay start function’. The reasons are mostly related to ‘To let the machine finish it’s cycle shortly before I get home’, ‘To let the machine run when the electricity tariff is cheaper’ or ‘To let the machine run when it’s more convenient for me’ (Figure 3.23).

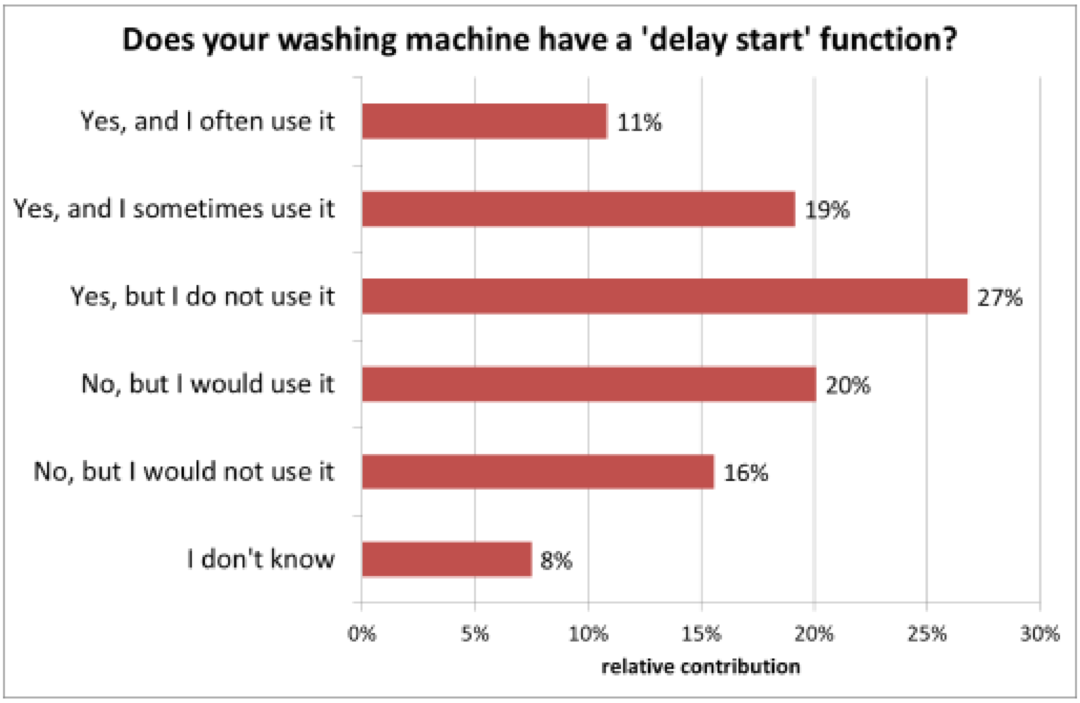


Figure 3.22: Delay start function and its usage (weighted n = 4,843); source: (Alborzi et al. 2015)

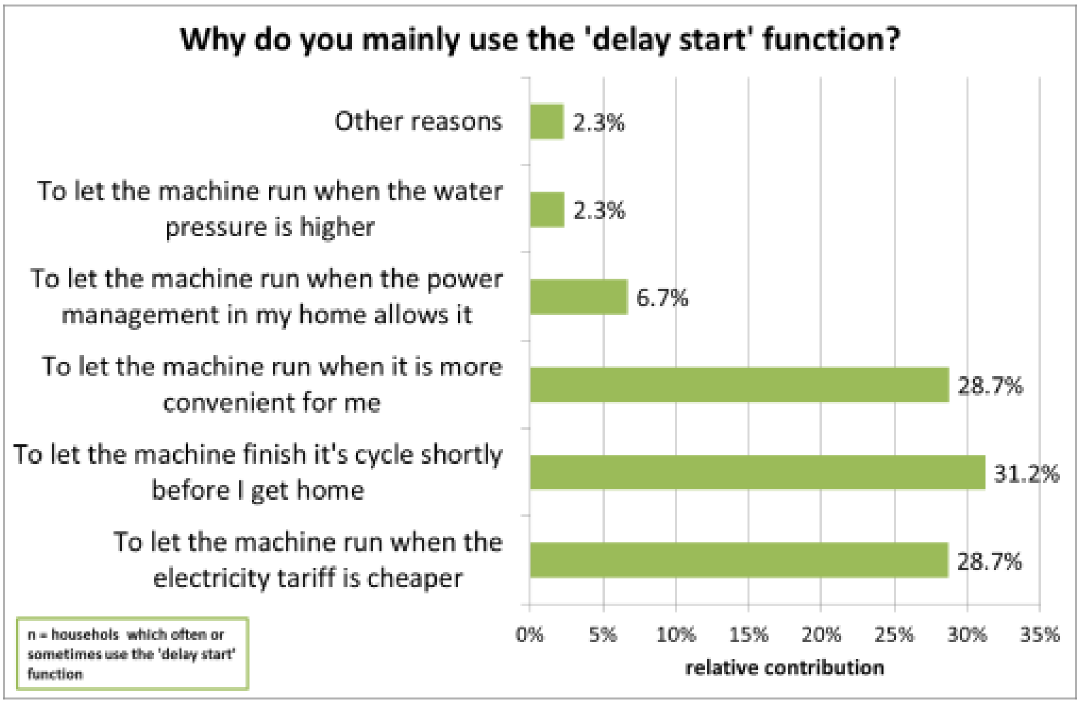


Figure 3.23: **Reasons for using the delay start function (weighted n = 1,454); source: (Alborzi et al. 2015)**

Importance of the characteristics of a washing programme

Additionally, respondents were asked about the importance of diverse characteristics of a washing programme in general: the following characteristics (see Figure 3.24) were given to respondents and they were asked to sort them based on the priority from 1 (most important) to 11 (least important). As the results of the survey show, the most important characteristics of a programme are the 'Cleaning result' and 'Energy-saving', while 'Disinfection' and 'Spin-drying' seems to be the least important characteristics of a programme (Figure 3.24).

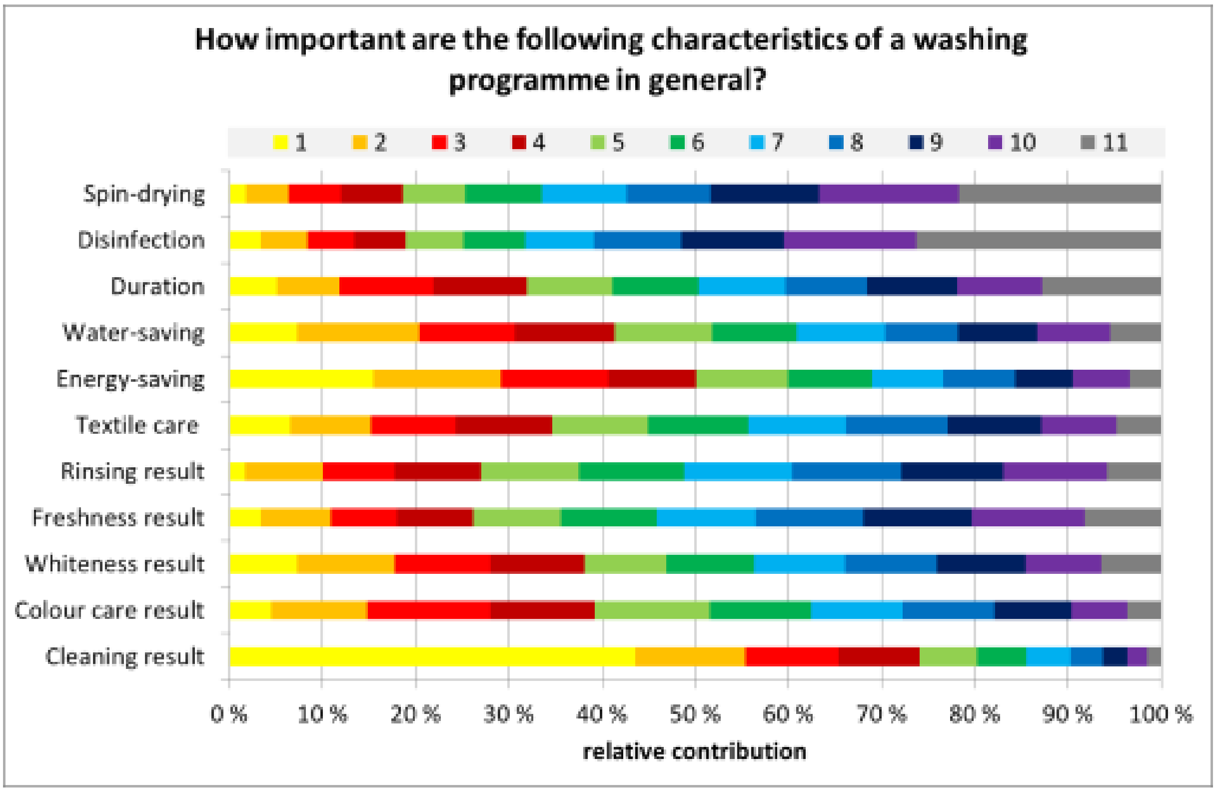


Figure 3.24: **Importance of characteristics of a washing programme in general; source: (Alborzi et al. 2015)**

Disinfection versus temperature

In order to find out whether the relation between disinfection and temperature is understood by respondents or not, a detailed analysis was done. The group of respondents who considers disinfection as an important characteristic of washing programme was selected and the frequency of using 90 ºC programmes was assessed in this group. Results illustrate that usage of 90 °C programme is higher in this group than in the group of respondents who did not chose disinfection as an important criteria of a washing programme.

Spin speed and drying behaviour

In the 2015 consumer survey, the maximum spin speed of European washing machines is on average 1,170 rpm (Figure 3.25), while, based on the results of the 2011 survey, European consumers dried their laundry at an average spin speed of 941 rpm (cf. section 3.1.1.2). Figure 3.25 shows that there are huge differences between the maximum speeds of washing machines used in different countries. The maximum spin speed of the machines used in Germany, the UK and Sweden is higher than in other countries. Germany has the highest maximum spin speed at 1,316 rpm and Italy has the lowest at 996 rpm.

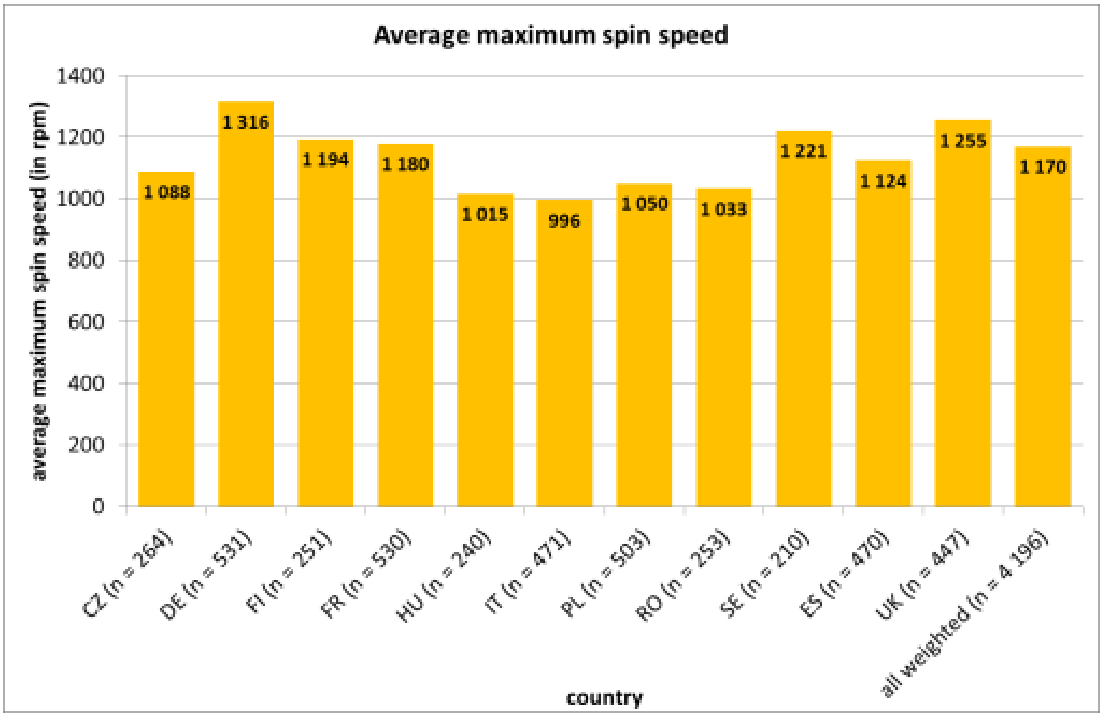


Figure 3.25: **Average maximum spin speed (in rpm); source: (Alborzi et al. 2015)**

In addition, respondents were asked to indicate how they dry their textiles in summer and winter, assuming that the drying behaviour is the same for half of the year. Based on the results obtained, on average, 50% of drying in summer takes place outside, on a clothes line (Figure 3.26). The usage of this method of drying decreases in winter to 19%. The preferred option for drying the clothes in winter seems to be inside the house, in a heated room (41%). Moreover, results of the survey show that a tumble-drier is used more often in winter (19%) than in summer (11%).

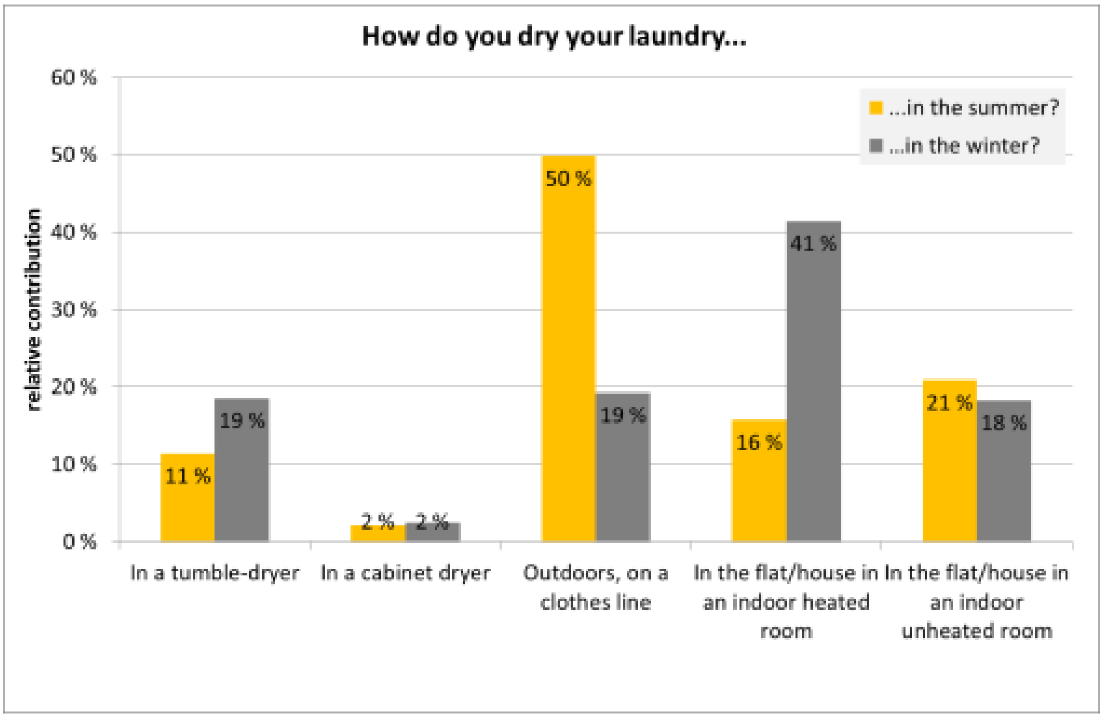


Figure 3.26: **Methods of drying clothes in summer and winter (weighted n = 4,843); source: (Alborzi et al. 2015)**

Switching off the appliance

When respondents were asked, 'Do you switch off your appliance after the programme has ended?', an average of around 86% of the respondents indicated that they always switch off the appliance. In some cases the appliance switches itself off automatically (13%) and in other cases, switching off is done manually (73%). Figure 3.27 illustrates that there are quite different attitudes regarding switching off the appliance between countries. Only 42% of respondents, for instance, always switch off their appliance after finishing the programme in the Czech Republic and 33% of respondents never switch off the washing machine after the programme is ended.

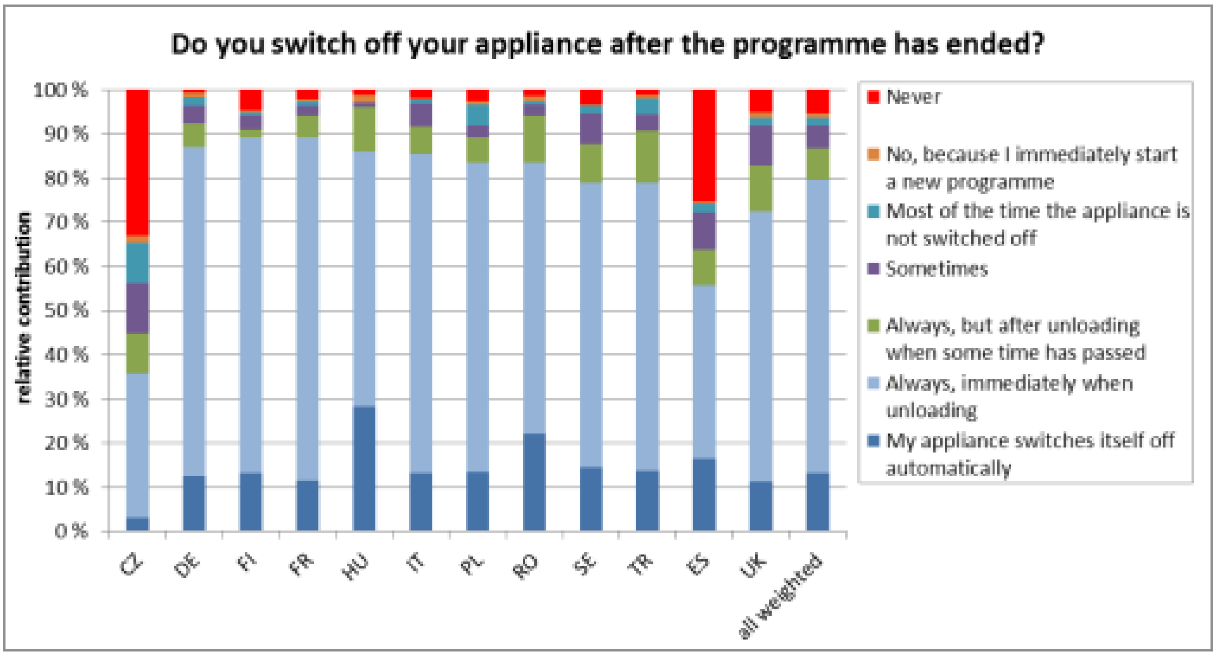


Figure 3.27: **Switching off the appliance after the programme has ended; source: (Alborzi et al. 2015)**

Energy-saving programme

In response to the question, 'Can you recognise the energy-saving programme on your washing machine?', 72% of respondents indicated that they recognise the energy-saving programme on their machine and 55% of them use this programme. In addition, respondents who could recognise the energy-saving programme were asked, 'How do you identify the energy-saving programme?' Around 11% of respondents identify the energy-saving programme from the arrow which is on the panel of the machine and around 73% of respondents recognise it because there is an indication/name, e.g. standard cotton, Eco (Figure 3.28).

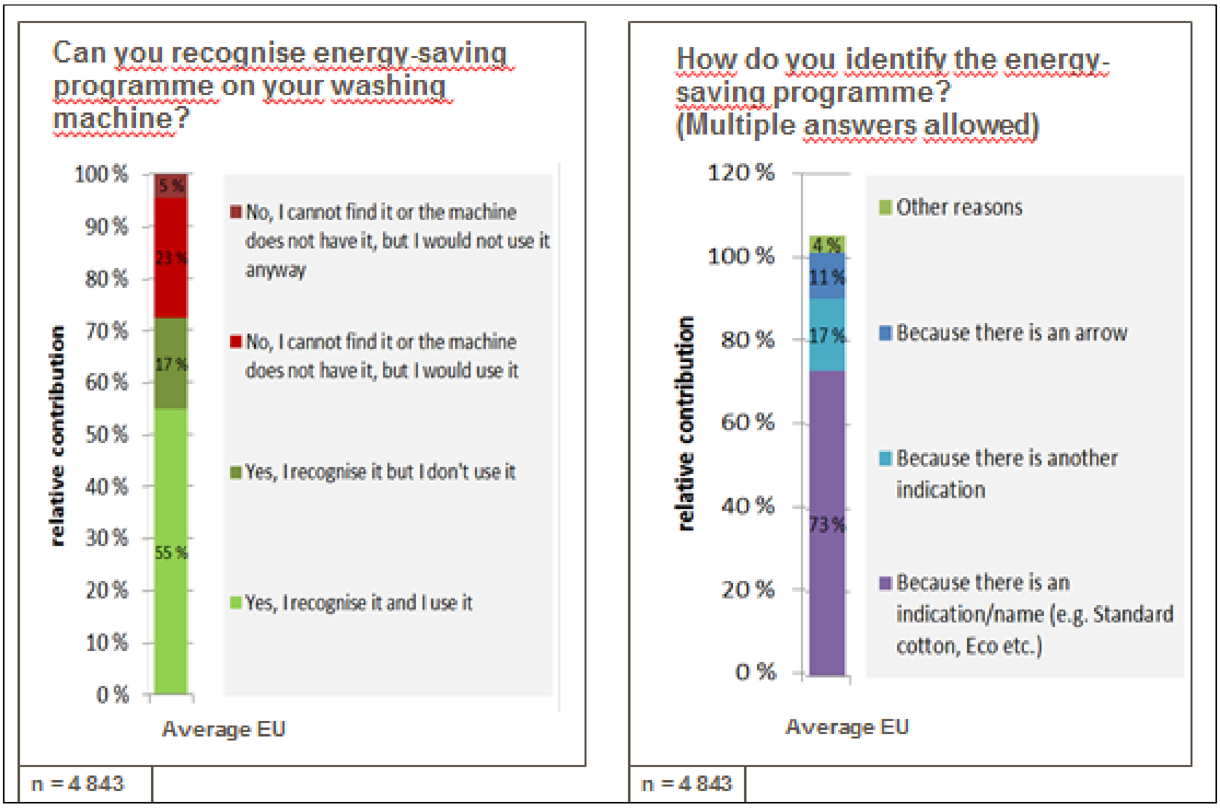


Figure 3.28: **Recognition of the energy-saving programme and the method of identification; source: (Alborzi et al. 2015)**

'Age of washing machine' versus 'usage of energy-saving programme' and 'how to identifying the energy-saving programme'

Figure 3.29 shows that the recognition of the energy-saving programme of younger washing machines is better than of older washing machines. In a one year old washing machine, for instance, around 11% of respondents mentioned that they could not recognise the energy-saving programme, while in washing machines being 10 years old or older, the share of respondents not being able to recognise the energy-saving programme was around 44%. An increase in the recognition of the energy-saving programme may be related to generic Ecodesign requirements according to Regulation EU 1015/2010 which requires displaying the standard programme on the front of the machine or the standard programme indicator (an empty arrow) on a panel.

Figure 3.30 shows that recognition of the energy-saving programme by name or indication on the younger washing machines is better than on older washing machines. Surprisingly, about 10% of respondents with a washing machine aged 10 years or older recognized the energy-saving programme by an arrow. This is a clear hint that many users do not like to blame themselves for not recognizing the energy-saving programme, since such an arrow was not presented on the machines at that time. The recognition of the energy-saving programme by another indication (not name and arrow) seems to be better on the older washing machines.

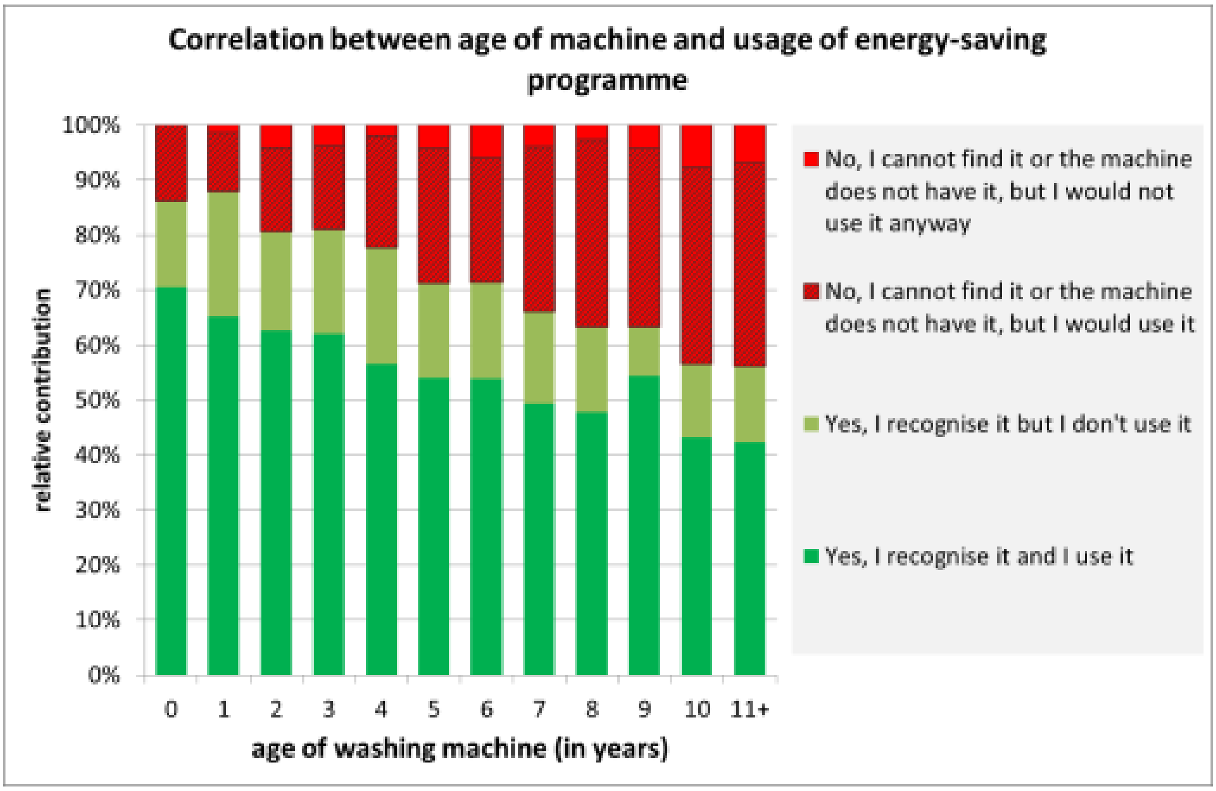


Figure 3.29: **Correlation between the age of the machine and the usage of the energy-saving programme; source: (Alborzi et al. 2015)**

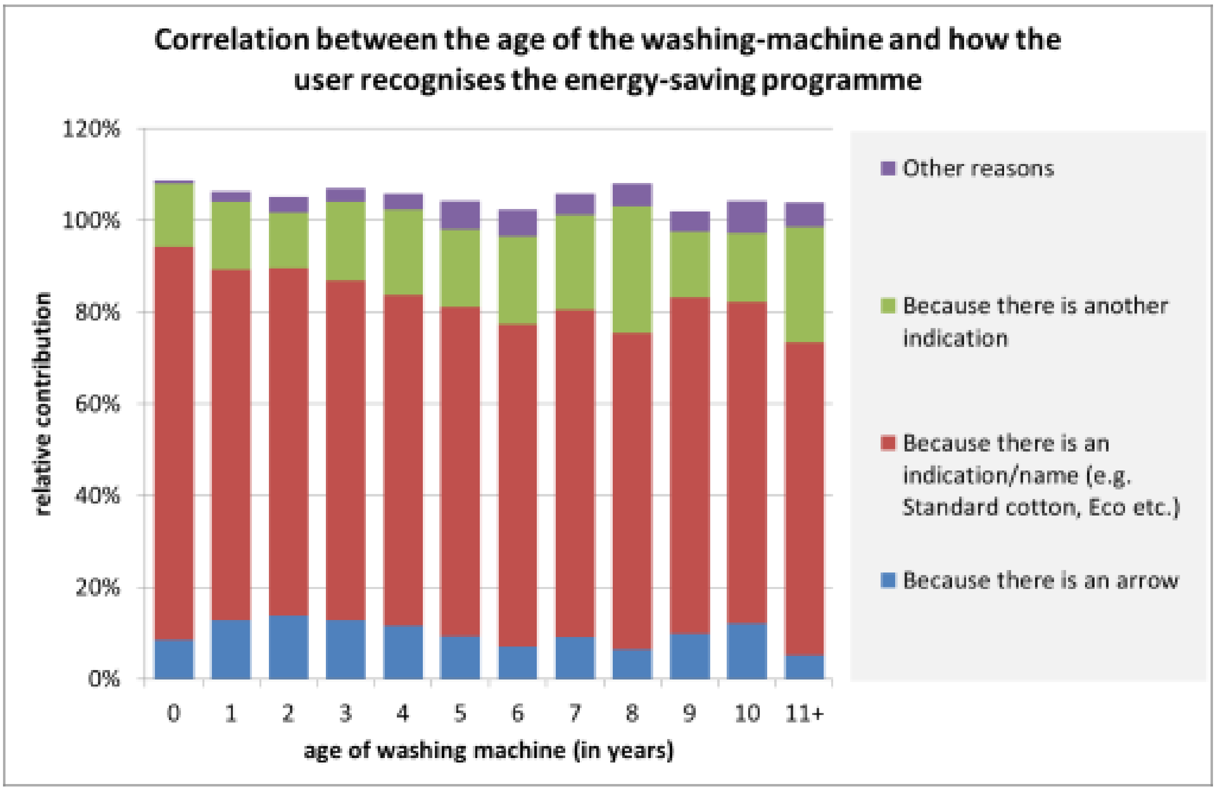


Figure 3.30: **Correlation between the age of the washing machine and how the user recognises the energy-saving programme; source: (Alborzi et al. 2015)**

Respondents were also asked about their expectations whether washing machines with the highest Energy label efficiency class available on the market are able to implement savings on one programme or all of the programmes. Figure 3.31 illustrates that 89% of the respondents indicated that they would expect a washing machine with the characteristics mentioned to be able to save energy and water or only energy in all of the programmes, while only 11% of respondents mentioned energy and water or energy in some selected programmes. Therefore, it seems that consumers may not know that the information on the Energy label is only for some selected programmes and not for all programmes. Generally, consumers expect to have an energy efficient washing machine, not only an energy efficient programme.

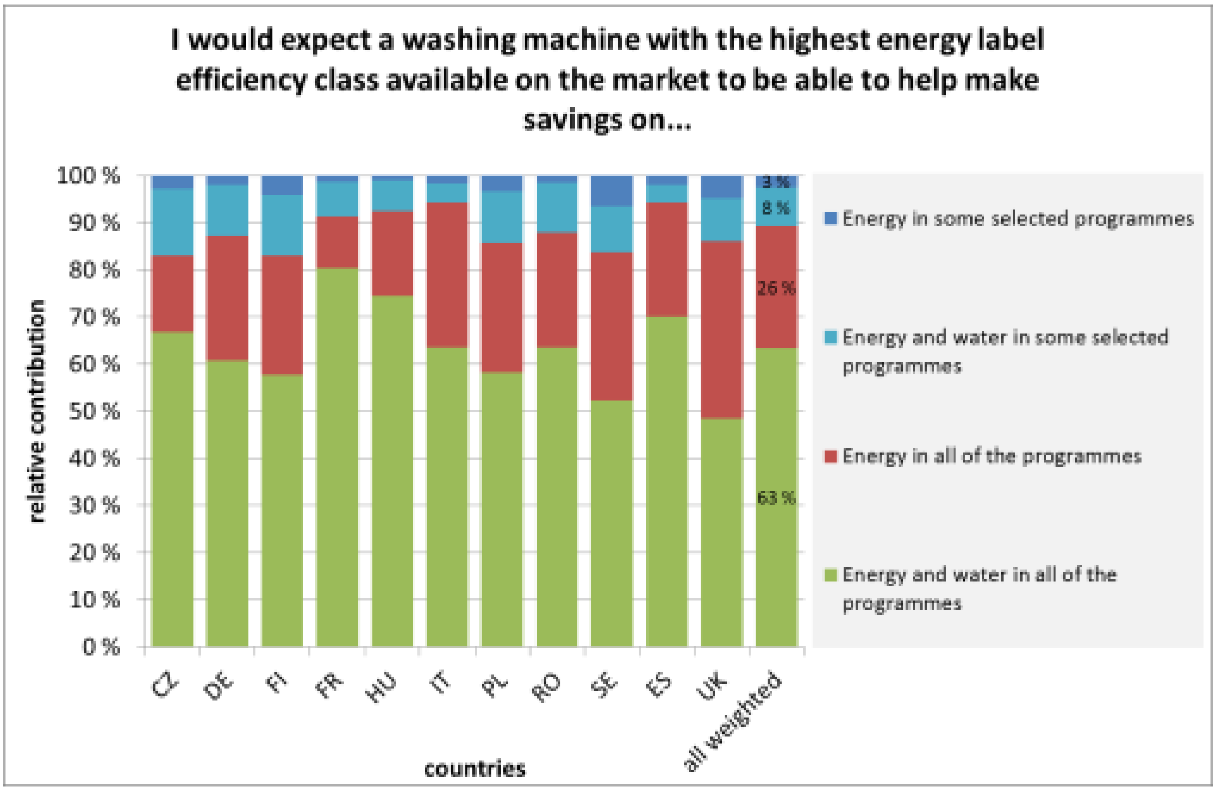


Figure 3.31: Expectation about a washing machine with the highest Energy label efficiency class to save energy in some or all programmes; source: (Alborzi et al. 2015)

Programme options

The respondents were asked the question 'Which of the following options would you use if doing so would enable you to save energy/or money?' Around 72% of respondents indicated that they use the 'energy-saving programme offered by machine' (Figure 3.32). The second most chosen option was 'Using more of the washing machine's capacity/or wash with full loads' (66.3%). 'Changing drying habits' and 'Using lower temperature programmes' appear to be the third (57.6%) and fourth (51.7%) preferred options, respectively, for the respondents.

The results of 'Accepting longer programme cycles' and 'Using an external hot water supply from renewable sources' were approximately equal and they were the least popular options selected by respondents (Figure 3.32).

Different hypothetical programmes with various temperatures, energy consumptions and durations were presented to the respondents and they were asked to choose one of these programmes if all of them lead to identical washing results. Figure 3.33 shows that around 42% of the respondents chose the hypothetical programme with a temperature of 60 °C, energy consumption of 1.0 kWh and duration of two hours (higher temperature, more energy consumption and shorter duration), while around 13% of the respondents chose a temperature of 30 ºC, energy consumption of 0.4 kWh and a duration of five hours (lower temperature, less energy consumption and longer duration). It can be concluded from this that washing temperature and wash cycle duration are more important to consumers than the energy consumption. Further analysis would be needed to find out which of these factors affected the consumers' decision for choosing these options.

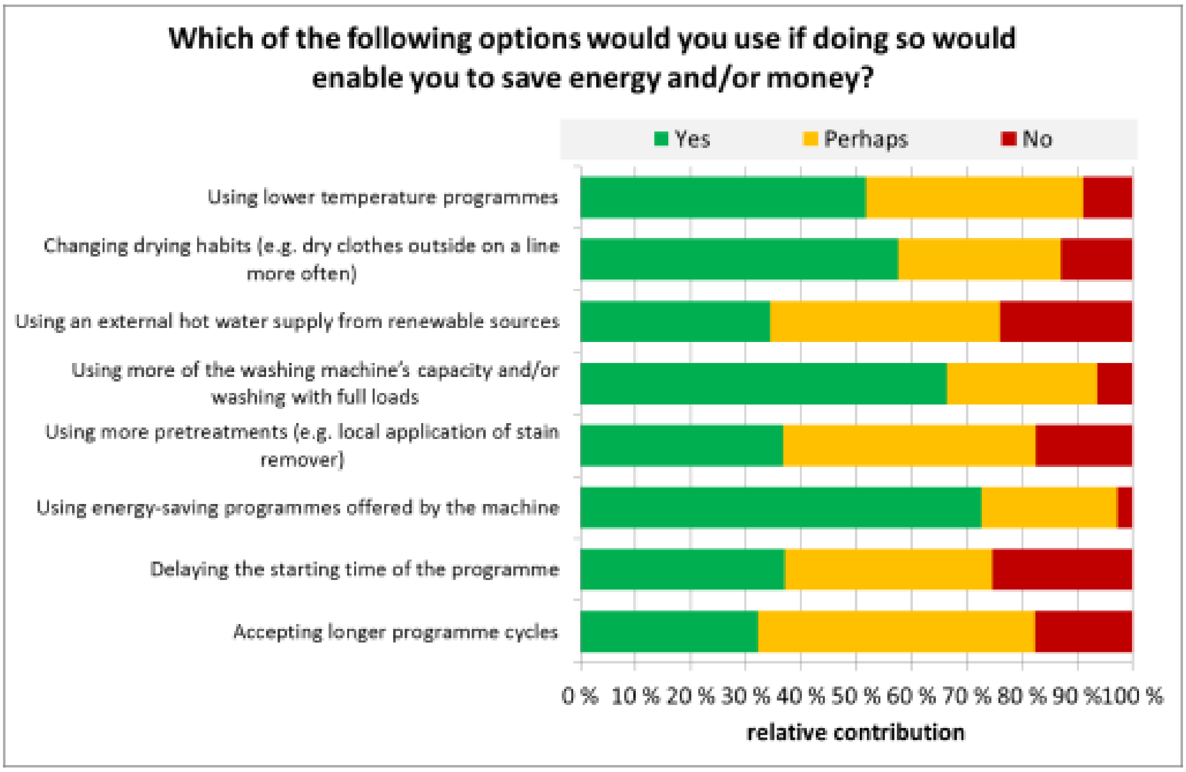


Figure 3.32: **Usage of possible options to save energy and/or money; source: (Alborzi et al. 2015)**

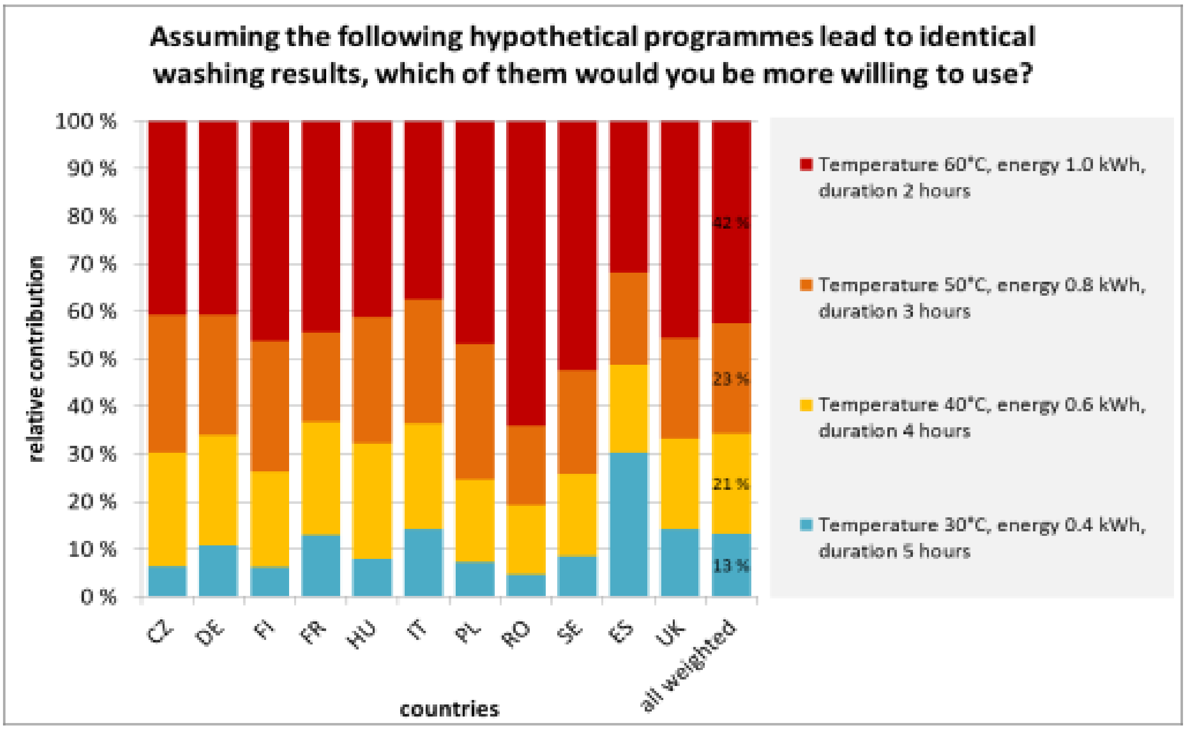


Figure 3.33: **Different hypothetical programmes and consumers' willingness to use; source: (Alborzi et al. 2015)**

Summary of the 2015 consumer survey on washing machines

To sum up, the main outcomes of the 2015 consumer survey on washing machines are:

- The six most important features that respondents would take into account before purchasing a washing machine based on priority were, in descending order, 'Low energy and water consumption and associated bills', 'Purchase price', 'Simple and easy to use', 'Expected rinsing results and washing performance', 'Low noise emission' and 'Short programme duration'.
- The most important characteristic of the washing programme is the cleaning result.
- Energy and water consumption information given per cycle is preferred to giving the information per annum.
- Average wash temperature per washing cycle is 42.3 °C.
- Average load capacity of a washing machine is 6.5 kg.
- A total of 62% of all washes are cotton wash programmes.
- Eco programmes make up 17% of the total number of programmes, but about one third of all programmes are cotton 40 °C and 60 °C. This result does not reflect the frequency of use of the 'standard cotton programme' as defined in the Ecodesign regulation. Consumers seem to have a different understanding of 'eco programmes'.
- A total of 55% of households use energy-saving programmes at least sometimes.
- There are some misunderstandings regarding the expectation of what an energy-saving programme can deliver. Around 40% of respondents do not believe that a long washing programme saves energy.
- Short programme duration is one of the priorities of consumers when deciding to buy a new washing machine. In addition, the duration of the washing programmes used for majority of respondents is less than three hours.
- Consumers are interested in finding washing performance and consumption values per cycle additionally on the Energy label. There is also some interest in the lifetime of the machine.
- The Energy label would need some improvements to allow the majority of consumers to really understand and being able to use the information provided.

3.1.1.2. Consumer survey on washing machines use in 2011 by University of Bonn

In 2011, over 2,000 European households of 10 European countries (Czech Republic, Finland, France, Germany, Hungary, Italy, Poland, Spain, Sweden, and the UK) were interviewed by the University of Bonn about their washing and drying behaviour and their opinion about energy issues in general (Schmitz & Stamminger 2014). Questions handled in the user survey cover initially

- Type and sources of information supporting purchase decisions;
- Purchase criteria.

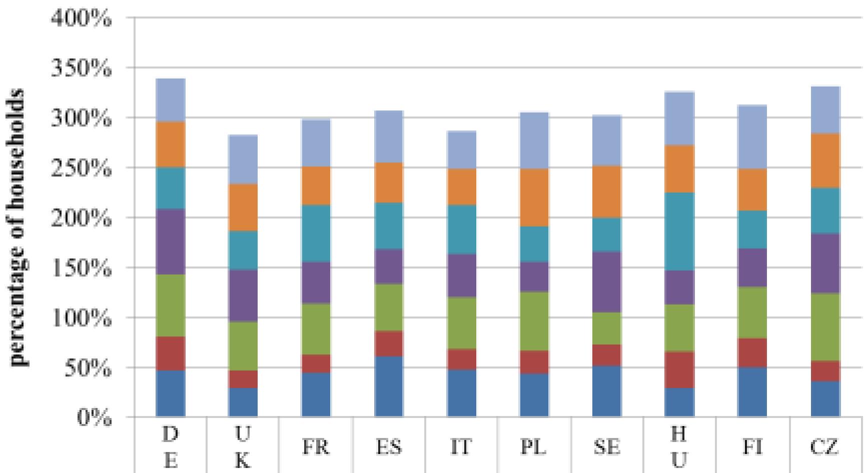
As washing machines are appliances which are operated on consumer demand only, the consumption of resources in the use phase is determined by the following factors:

- Frequency of operations;
- Load size used;
- Amount and type of detergent used;
- Availability and selection of programme and options/features, including the programme temperature, under real conditions of use.

A selection of the most significant results in relation to these factors is presented in the following.

Type and sources of information supporting purchase decisions

When the consumers were asked in 2011 about the sources of information they would consult before buying a new appliance (multiple answers were allowed), the main source of information mentioned by them was visiting internet websites of manufacturers (52%) (Figure 3.34). The second main source of information is own experience (50%). Information on the Energy Label is important for influencing the buying decision for about 50% of the participants of the survey. Information on the Energy Label, advice and experience of friends and test reports from consumer organizations are of approximately similar importance. Interestingly, consumers seemed to pay less attention to product brochures, Energy Labels and sales representatives.



	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
Own experience	43%	49%	47%	52%	38%	57%	50%	54%	63%	47%
Advice and experience of friends	46%	47%	38%	40%	37%	57%	52%	47%	42%	54%
Information on the energy label	42%	39%	57%	47%	49%	36%	33%	78%	38%	46%
Test reports from consumer organisations	66%	52%	42%	34%	43%	30%	61%	34%	39%	60%
Manufacturers' internet sites	62%	49%	51%	47%	52%	59%	32%	47%	51%	68%
Manufacturers' brochures	34%	18%	18%	25%	21%	23%	21%	37%	29%	20%
Recommendation and advice from a sales representative in a shop	47%	29%	44%	61%	48%	44%	52%	29%	51%	36%

country

Figure 3.34: Source of information consulted to support a purchase decision for a new household appliance (according to (Schmitz & Stamminger 2014))

The consumers were also asked to indicate which information they would expect to see on the Energy Label (up to four multiple answers were allowed from the list provided).

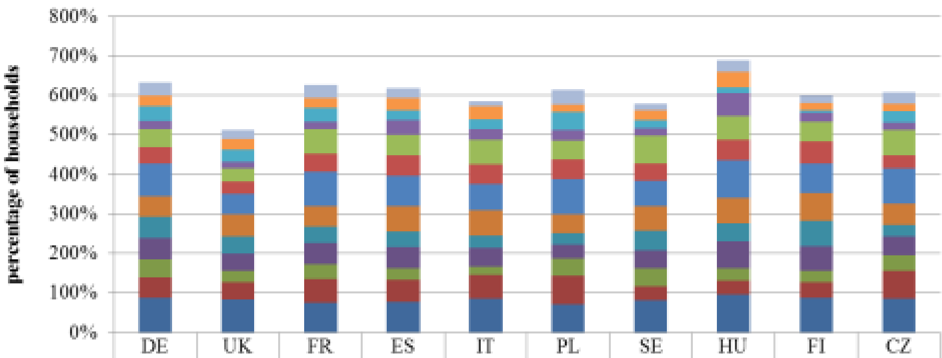
Information on the energy efficiency class (83%) and on the water consumption (78%) were considered very important (Figure 3.35). In addition, more than half of the respondents chose options which are already listed on the Energy Label, such as capacity (59%), noise emission (54%) or cleaning/washing performance (51%). Spin/drying performance (43%) and information on the programme duration (46%) were slightly less frequently answered in 2011.

With respect to the energy consumption, consumers seemed to prefer receiving information on the consumption per cycle (52%) rather than on the annual consumption levels (35%).

Other information resulted to be less interesting, as for example:

- Information about all programmes and features of the appliance or indication about the programme and temperature used for the assessment (selected by approximately 26% of the consumers).
- Financial aspects, such as yearly running costs or running cost per cycle (selected by about 26% of the respondents.

Moreover, significant differences between countries can be observed (Figure 3.35).



	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
Yearly running costs	34%	23%	34%	25%	11%	37%	16%	30%	19%	29%
Programme and temperature used for the assessment	27%	28%	24%	31%	33%	18%	26%	40%	18%	18%
Running costs per cycle	37%	32%	34%	25%	26%	45%	19%	13%	7%	29%
Detailed information on all the programmes	22%	17%	20%	36%	27%	27%	20%	59%	22%	19%
Noise emission	45%	31%	62%	52%	61%	50%	69%	60%	49%	64%
Programme duration	42%	32%	46%	52%	50%	50%	43%	52%	57%	34%
Water consumption	84%	51%	86%	78%	67%	88%	64%	95%	75%	88%
Capacity	52%	57%	52%	64%	63%	49%	64%	64%	70%	54%
Spin/drying performance	53%	44%	42%	39%	31%	28%	48%	46%	64%	29%
Cleaning/washing performance	55%	43%	53%	55%	47%	36%	47%	68%	63%	48%
Energy consumption per year	45%	29%	37%	29%	21%	43%	45%	31%	28%	38%
Energy consumption per cycle/day	52%	44%	59%	56%	60%	73%	33%	36%	40%	71%
Energy efficiency class	88%	82%	76%	77%	86%	70%	82%	95%	87%	86%

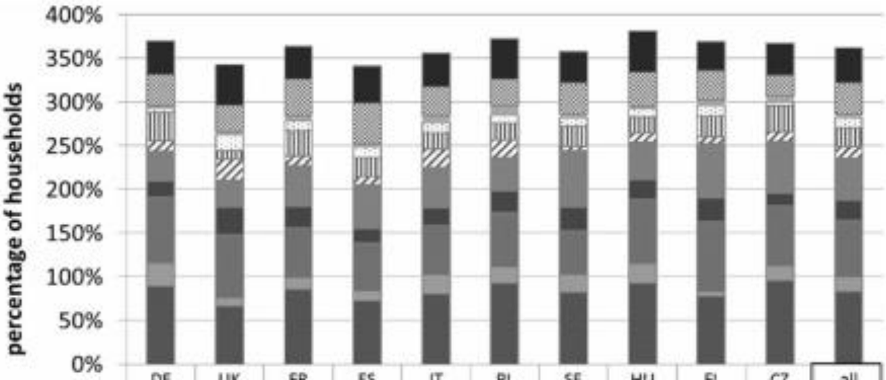
country

Figure 3.35: Information expected on the Energy Label (multiple answers allowed) (according to (Schmitz & Stamminger 2014))

Purchase criteria

In 2011, a very low water and energy consumption was the most important aspect for the consumers when they plan to buy a new appliance (84%). A very good washing performance also had a high priority for over 60% of those respondents. Nearly half of all participants to the survey indicated that they pay attention to a low operating noise emission of the appliance. Accordingly, a lot of consumers not only looked at the low purchase price of the machine (40%) but also at the good assessment results on the Energy Label (35%). Almost one quarter of the consumers indicated that they pay attention to a good textile protection and short programme duration as well.

The other criteria analysed through the survey, such as low detergent consumption or a large number of different (washing) programmes and (appliance) options, were only mentioned by 13 and 16% of the consumers, respectively. The attributes with the least importance were a higher capacity of the appliance (11%) and an innovative aesthetic design (5%). The answers of consumers from different countries were also considerably different.



	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ	all
Low purchase price	38%	47%	38%	43%	39%	47%	36%	47%	33%	37%	40%
Good assessment results on the energy label	35%	29%	41%	46%	33%	30%	36%	39%	33%	24%	35%
Innovative aesthetic design	1%	4%	6%	3%	7%	10%	4%	3%	5%	6%	5%
Higher capacity of the appliance	7%	18%	11%	13%	13%	10%	9%	9%	14%	5%	11%
Good dishes-/ textile protection	32%	10%	30%	22%	18%	19%	23%	18%	23%	29%	23%
A large number of different (washing) programmes and (appliance) options	13%	24%	11%	9%	21%	20%	6%	11%	8%	12%	13%
Low operating noise emission	34%	31%	46%	50%	47%	38%	64%	43%	62%	59%	48%
Short programme duration	18%	32%	25%	16%	20%	24%	27%	23%	27%	15%	23%
Very good cleaning /washing performance	75%	72%	56%	55%	56%	62%	50%	74%	80%	69%	65%
Low detergent consumption	26%	10%	13%	12%	22%	18%	20%	22%	5%	17%	16%
Low water and/ or energy consumption	89%	67%	86%	72%	81%	93%	83%	93%	78%	95%	84%

Figure 3.36: Attributes with high importance for the consumer when buying a new household appliance (Schmitz & Stamminger 2014)

Frequency of operation

According to the results of the studies being carried out by University of Bonn in 2006 and in 2011, the average number of washing cycles in Europe has decreased from 4.0 to 3.8 cycles per week in 2011, which corresponds to an annual average of 198 wash cycles per household (n= 2,290 households).

Trends towards lower frequency of use of washing machines are supported also by other studies, despite of the methodological differences in terms of data gathering:

- An historic analysis by Kemna and Stamminger (Kemna & Stamminger 2003) reports that until the early 1980s, there were around 277 wash cycles per machine per year and this frequency decreased to around 234 in 2005 (4.5 cycles per week).
- The International Association for Soaps, Detergents and Maintenance Products (A.I.S.E.) survey (A.I.S.E. 2011c), (see next section) indicates that the average weekly wash frequency in 2011 could be around 3.5 cycles per household per week, which corresponds to an annual average of 182 wash cycles per household.
- ‘Data from the Water Energy Calculator reports that households use the washing machine on average 4.7 times each week, lower than previously used data (5.5 times per week)’ (Energy Saving Trust 2013).

The reason for a continuous reduction of wash cycles per year per machine is most likely related to a combination of demographic factors (the average household size has decreased during that period) and machine characteristics (the average capacity of a new washing machine has increased, from about 4.8 kg in 1997 to 7.04 kg in 2013). This trend has started around 2002 and is continuing, and is expected to lead to further reduction in the wash frequency.

In the following the average number of washes per household for each country is shown (Figure 3.37). As it can be seen, in 2011 the average number of wash cycles per week ranged from 3.5 (France, Czech Republic and Sweden) to 4.1 (Italy, Poland and the UK).

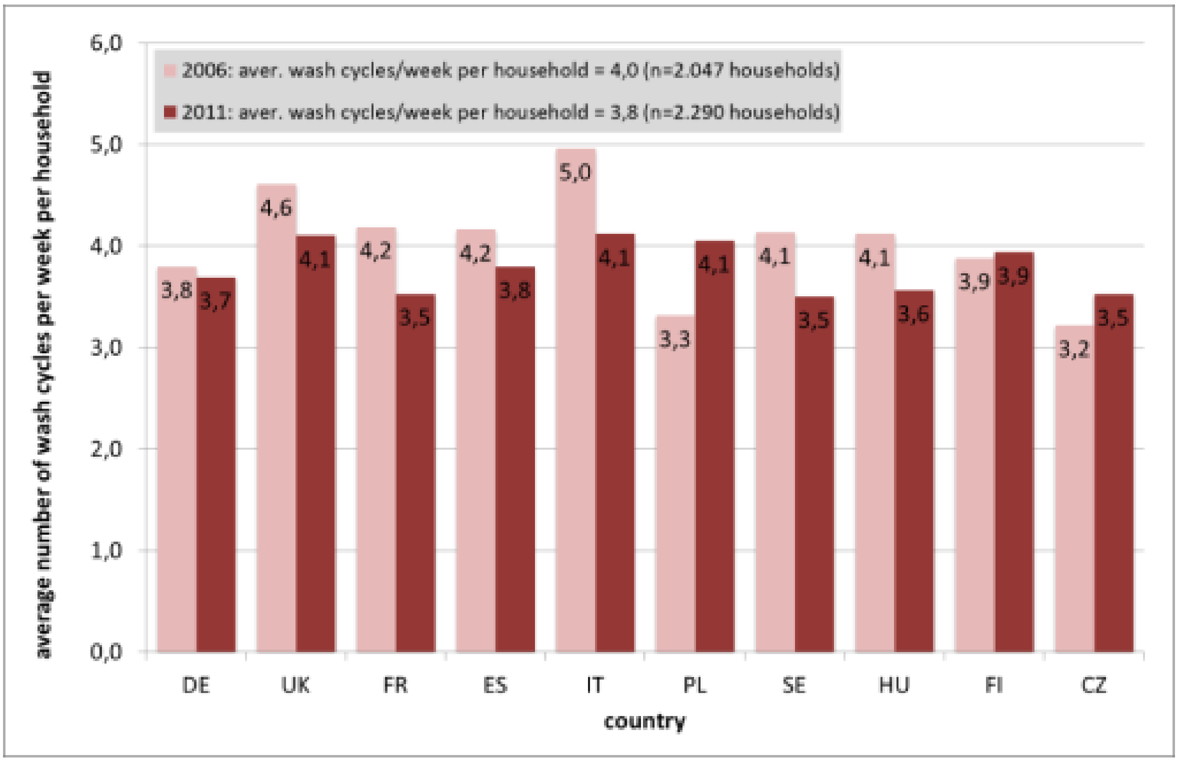


Figure 3.37: **Average number of wash cycles per week per household per country in 2011 compared with a similar study done in 2006 (according to (Schmitz & Stamminger 2014))**

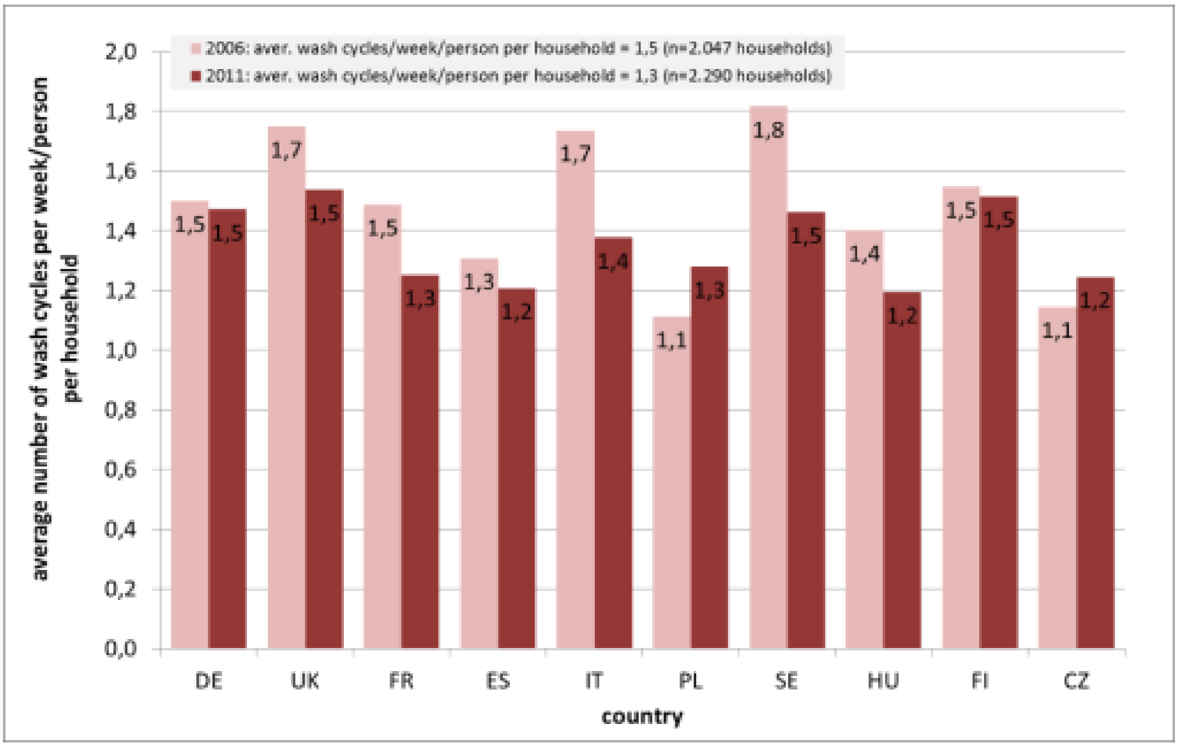


Figure 3.38: **Average number of wash cycles per person per household (according to (Schmitz & Stamminger 2014)**

As the household size may be different from country to country, it may be more relevant to compare the number of wash cycles per week per person living in a household. This calculation shows that this number lies between 1.2 (Czech Republic, Hungary and Spain) and 1.5 (Finland, Sweden and the UK) (Figure 3.38). The average of wash cycles per person per week is 1.3 for the year 2011 (n=2,290 households). An average decrease of 0.2 wash cycles per person per week is registered if these results are compared with those of a similar study which was carried out within Lot 14 in 2006 (ISIS 2007b).

Selected programme temperature and cold washes

Figure 3.39 shows a clear preference, for almost 2,290 consumers from 10 countries, of washing at 40 °C.

On average, around 40% of washes are done at 40 °C (Figure 3.39). However, the washing temperatures are quite variable in different countries. For instance, in Spain almost 40% of the washes are done at cold temperatures. In other countries more than 50% of the washes are done at 40 °C (especially in Sweden and Finland) (Figure 3.39). Also, in the United Kingdom and France the share of wash temperatures of 30 °C reached nearly 35% of all wash cycles (Figure 3.39). For the United Kingdom there was an increase of 19% for the 30 °C programme in comparison with the results of Lot 14 in 2006 (ISIS 2007b). Washing at cold or 20 °C temperature is found to be done mainly in Spain and overall in 7% of the sample.

The second most used temperature is 60 °C. On average, around 19% of washes are done at 60 °C. 5% of the washes are instead done at 90 °C programme.

The average of these nominal washing temperatures is 43.3 °C (Figure 3.40). In comparison to the results for the year 2006 (ISIS 2007b) the average washing temperature decreased about 1.6 °C. The reason of this reduction is related to more frequent use of colder temperatures (like 30 °C) and the decrease (2-3%) of the use of 60 °C and 90 °C programmes.

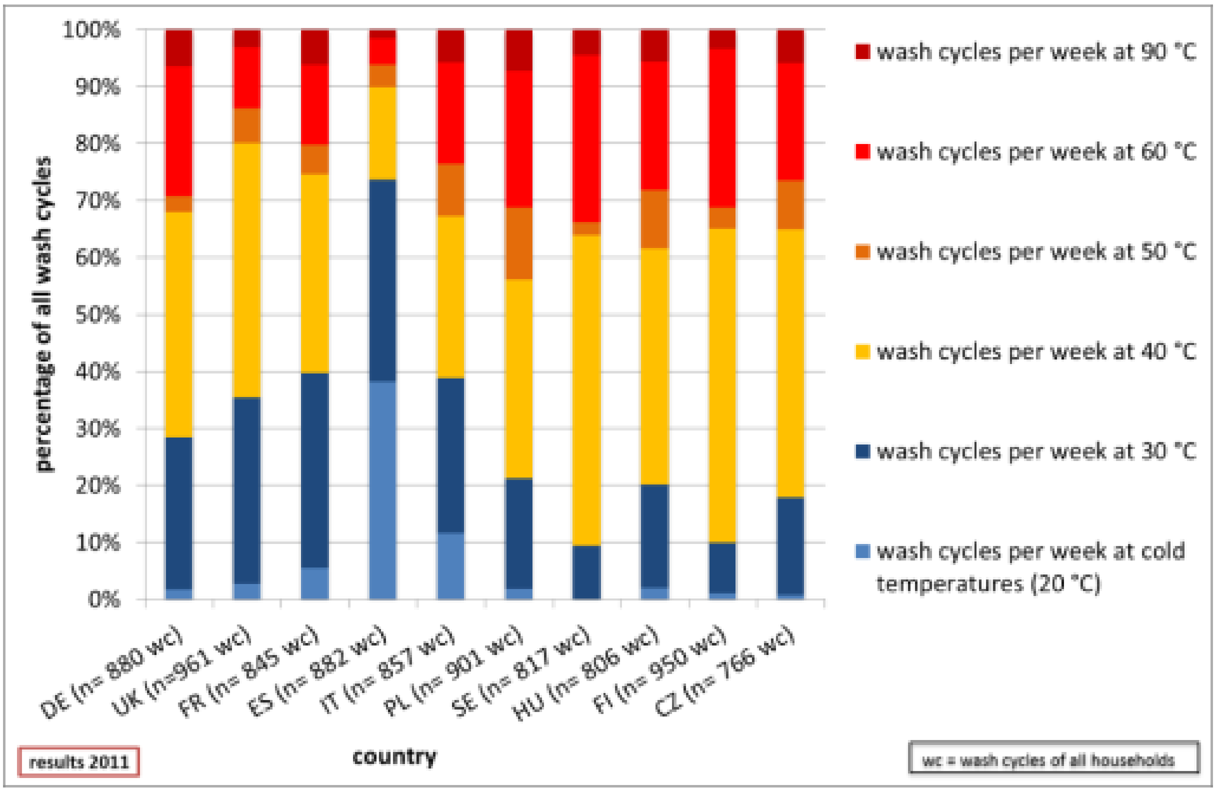


Figure 3.39: Relative frequency of wash temperatures used 2011 (according to (Schmitz & Stamminger 2014))

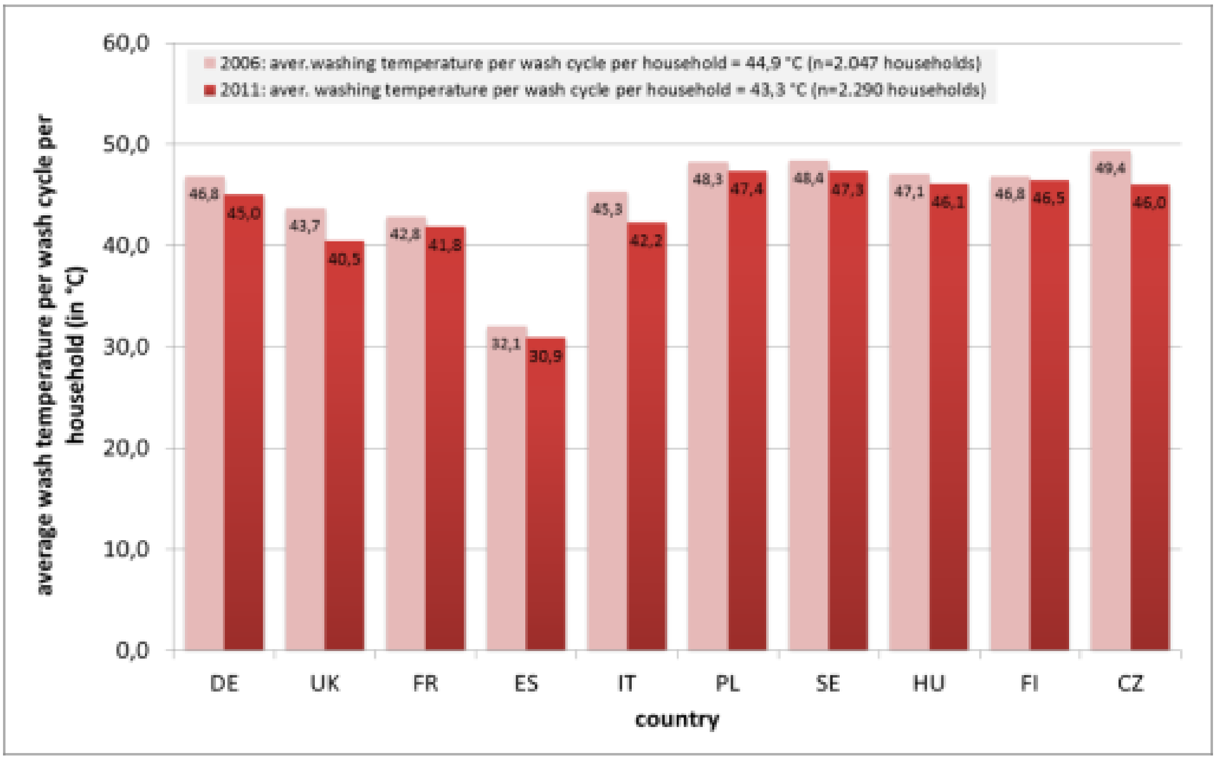


Figure 3.40: **Average wash temperature per country for year 2006 and 2011 using the nominal temperature values of 20 °C, 30 °C, 40 °C, 50 °C, 60 °C and 90 °C for calculating the average (according to (Schmitz & Stamminger 2014)**

Programme options

Referring to the question 'Which of the following options would you use if doing this would enable you to save energy and/or money?' which was asked in the user survey carried out by Bonn University in 2011, 80% of respondents answered that they would select economy programmes (Table 3.9).

The results for the options accepting longer programme cycles and delaying the starting time of the programme were approximately equal; over 40% of respondents indicated they would choose both options.

Using an external hot water supply was the least popular option: only 26% of the respondents would consider this option whilst almost 30% of them were against this option.

Table 3.9: **Usage of possible options to save energy and/or money (according to (Schmitz & Stamminger 2014))**

		DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
		% of all hh	% of all hh	% of all hh	% of all hh	% of all hh	% of all hh	% of all hh	% of all hh	% of all hh	% of all hh
Using an external hot water supply	y	23	35	19	22	35	31	23	33	27	14
	p	44	43	44	41	38	45	47	34	48	38
	n	34	22	37	36	27	25	30	34	26	48
Accepting longer programme cycles	y	49	44	46	34	45	28	58	34	51	52
	p	36	41	33	48	38	39	30	45	38	38
	n	15	15	21	19	17	32	13	22	12	11
Delaying the starting time of the programme	y	42	49	59	37	55	22	46	51	35	45
	p	38	37	29	45	26	44	38	38	46	39
	n	20	14	11	18	19	34	16	11	18	17
Using economy programmes	y	84	79	86	82	58	85	82	91	71	81
	p	14	21	12	16	28	14	17	8	27	19
	n	2	0	2	2	14	1	2	1	2	0

Some of the previous findings are supported by the results of the washing programmes and options/features chosen. The research by Bonn University (Figure 3.41) shows the average use of washing programmes by respondents. The washing programme chosen showed a clear dominance of the "cotton-type" programmes (cotton/linen and mixed, i.e. a mixture between cotton other types of textiles): more than 50% of the consumers mentioned these programmes to be used always or often.

Programmes for easy-care, delicate or synthetic laundry appeared to be used more rarely, and programmes for washing silk and wool articles even more seldom.

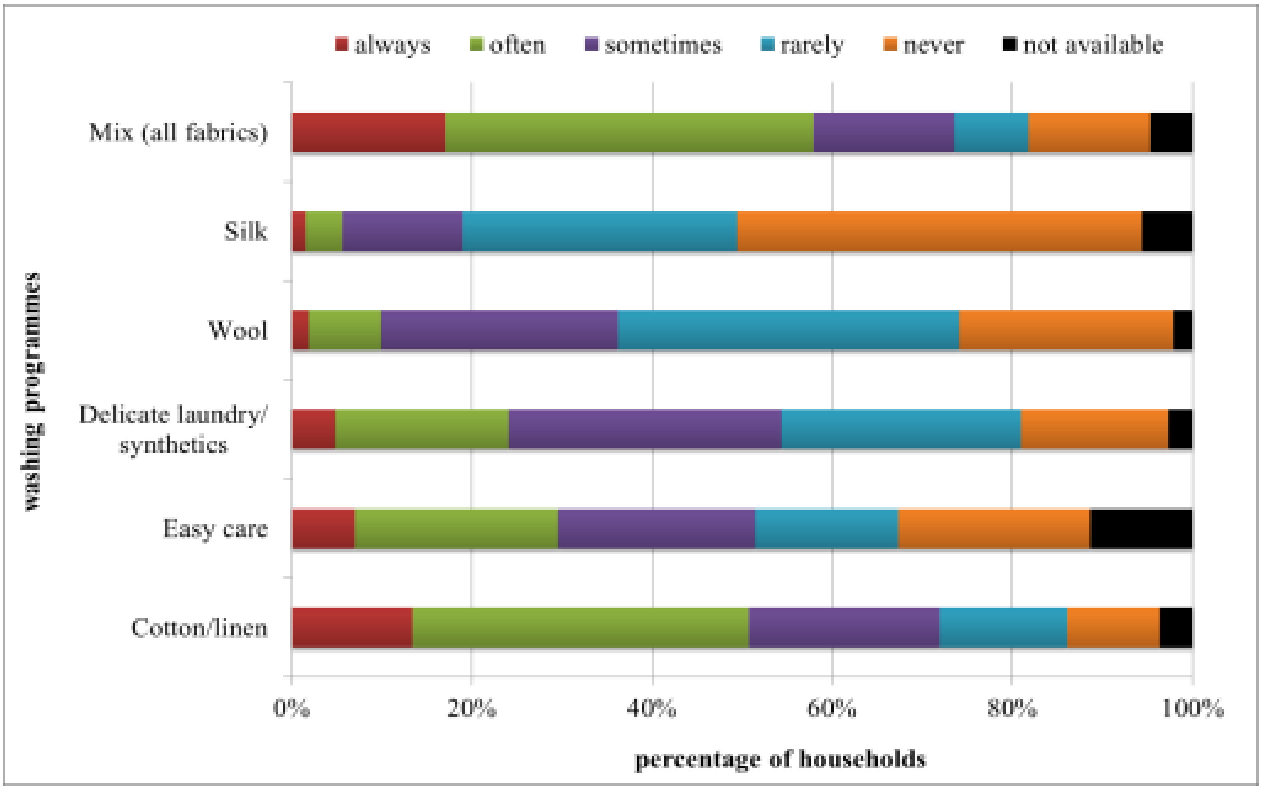


Figure 3.41: Average use of washing programmes (according to (Schmitz & Stamminger 2014)

As there are other programme options available on washing machines, actual water and/or energy consumption levels may be affected by the selection of these options. The results of the question about possible ways for saving energy and money are given below. Energy saving/eco wash was found to be the most frequently used option or programme, followed by quick wash/time-saving wash and soft wash (Figure 3.42). In particular, it should be noted that the quick wash/time-saving programme is often demanding for more energy, although this depends on the specific appliance. Programme options which consume more energy (stain wash/intensive wash) or water (extra rinse, additional water) are used "always" or "often" only by approximately 11-12% of the respondents.

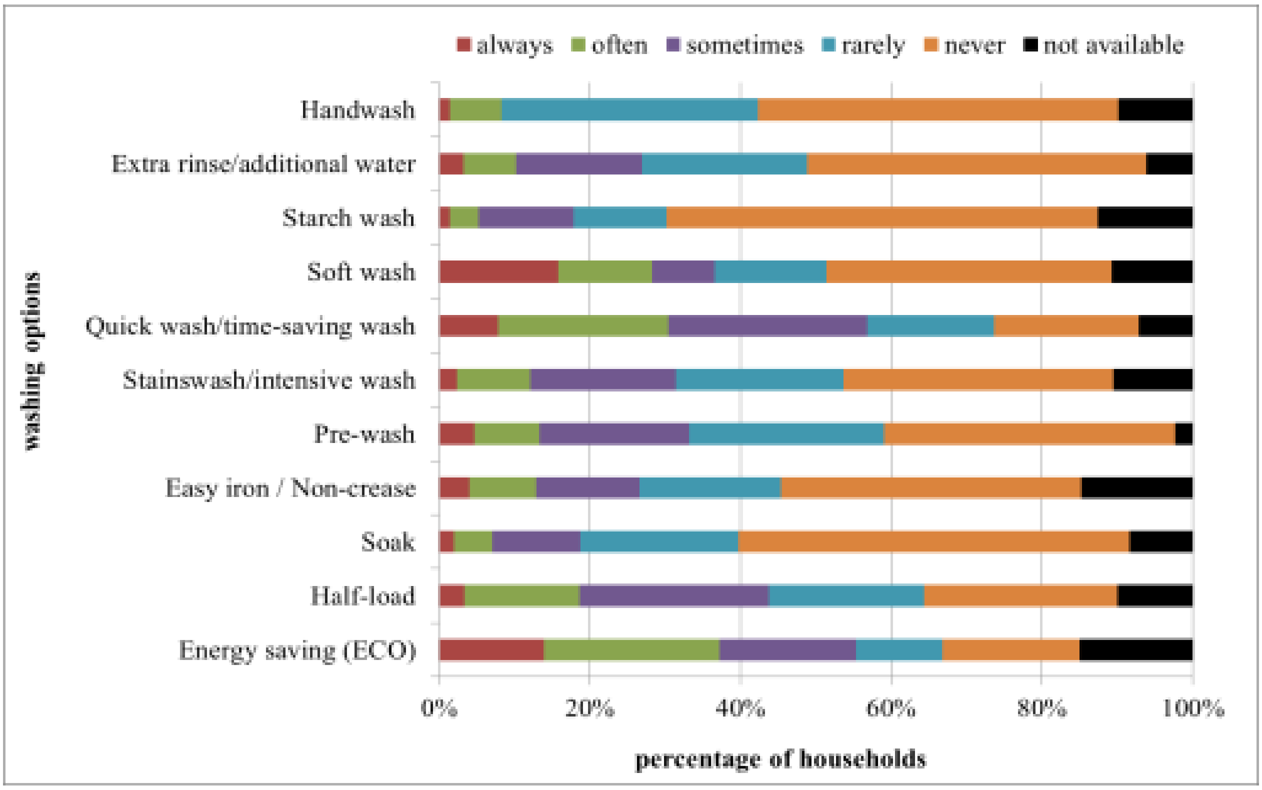


Figure 3.42: **Washing options chosen in 2011 (n=2,290 households) (according to (Schmitz & Stamminger 2014))**

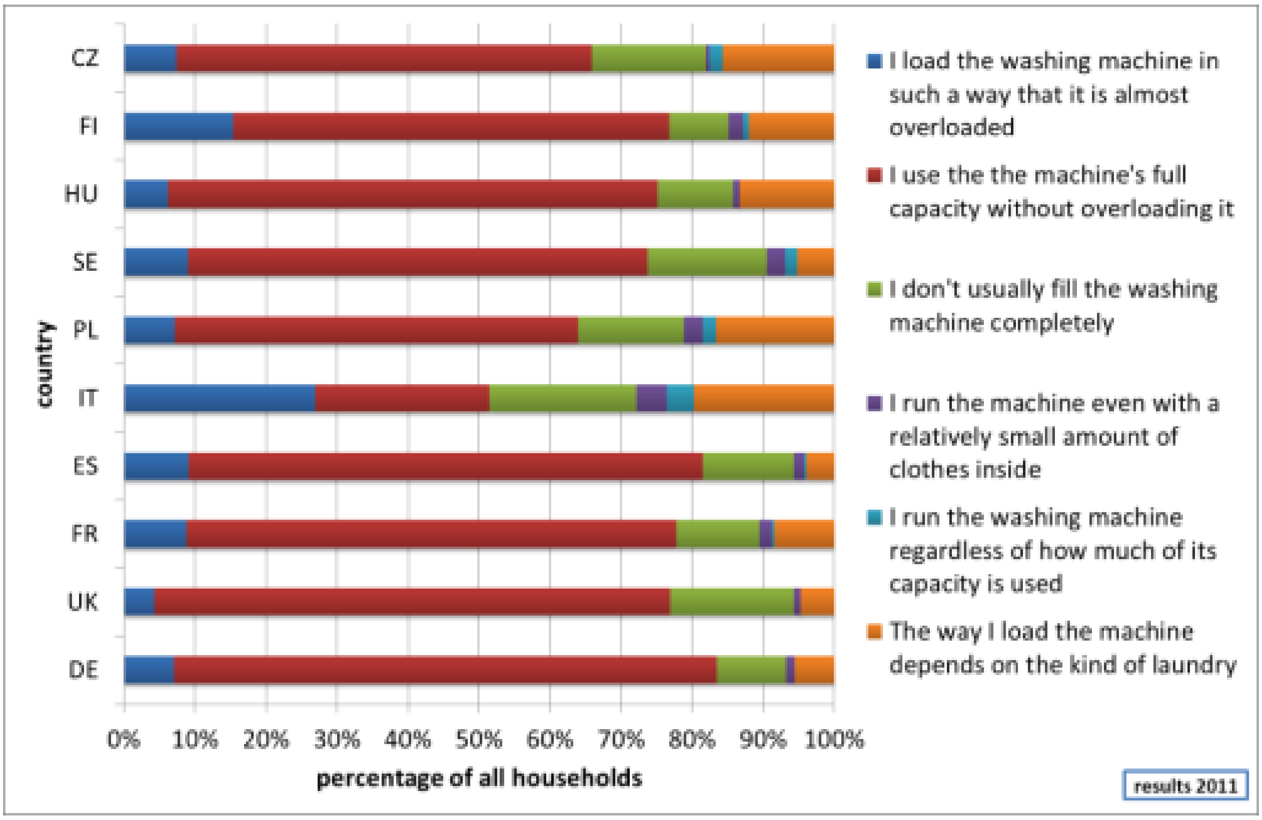


Figure 3.43: **Consumer loading behaviour (according to (Schmitz & Stamminger 2014))**

Loading

The information included in the Energy Label of a washing machine is based on a weighted average of full load and partial load cycles. The actual energy and water consumption of the appliance is related to the level of use of the capacity of the washing machine.

Results of the survey carried out by the University of Bonn in 2011 show that almost 60% of respondents claimed to use the full capacity of their washing machine, although they normally do not have the possibility to check if this is really the case (Figure 3.43). Approximately 10% of the participants in the survey mentioned that the kind of laundry influences the amount of load they wash. Around 13% of respondents mentioned that they don't usually fill the machine completely. It is important to note also that 10% of respondents admit to overload the machine.

Spin speed and drying behaviour

The analysis of the responses related to the selection of the spin speed (options allowed in the 2011 survey from the University of Bonn: no spin and from < 400 rpm to > 1,300 rpm) shows that a spin speed between 1,000–1,300 rpm is used in nearly 40% of all spin drying cycles (Figure 3.44). A spin speed between 600-900 rpm is chosen for over 30% of all spin drying cycles, while only in 14% of the cycles the laundry is dried with a spin speed over 1,300 rpm. On average, European consumers dry their laundries at a spin speed of 941 rpm (taking the average of a spin speed class for the calculation) (Figure 3.45).

The frequency of use of different spin speed classes has huge differences among countries. For instance, while in Italy, Spain, Poland and Hungary over 60% of the spin cycles are at 900 rpm or less, in Germany, Sweden and the UK more than 60% are above 900 rpm (Figure 3.44). Furthermore, it was indicated that "no spin" is applied to much less than 10% of all washes. This suggests that other ways of drying are sometimes used.

There are different ways for drying the laundry. Participants to the 2011 survey from the University of Bonn were asked to indicate how they were drying their textiles in summer and in winter, assuming that the drying behaviour was the same for half of a year. As the answering options were given in terms of 'always', 'often', 'sometimes', 'rarely' and 'never', these choices were transformed into a percentage scale of 100%, 75%, 50%, 25% and 0%, respectively, and normalised to reach 100% for the sum of all answers given by an individual. In other words, this means that if a person indicated same frequency for two options, the same weight would have been assigned for the normalisation.

Large seasonal differences were registered as well as differences in the drying practice between the analysed countries. According to the responses obtained, on average, 55% of drying in summer takes place outside, on a clothes line (Figure 3.46). The use of this drying method decreases in winter to about 40%. In winter time the preferred option seems to be the drying of clothes inside the house, in a heated room (51%).

The differences between seasons and the drying behaviour per country show an apparent correlation with statistics related to the ownership and use of tumble dryers (Table 3.10). The largest use of tumble dryers takes place in Germany, Sweden and the UK. The same countries present the highest rates of ownership of this appliance.

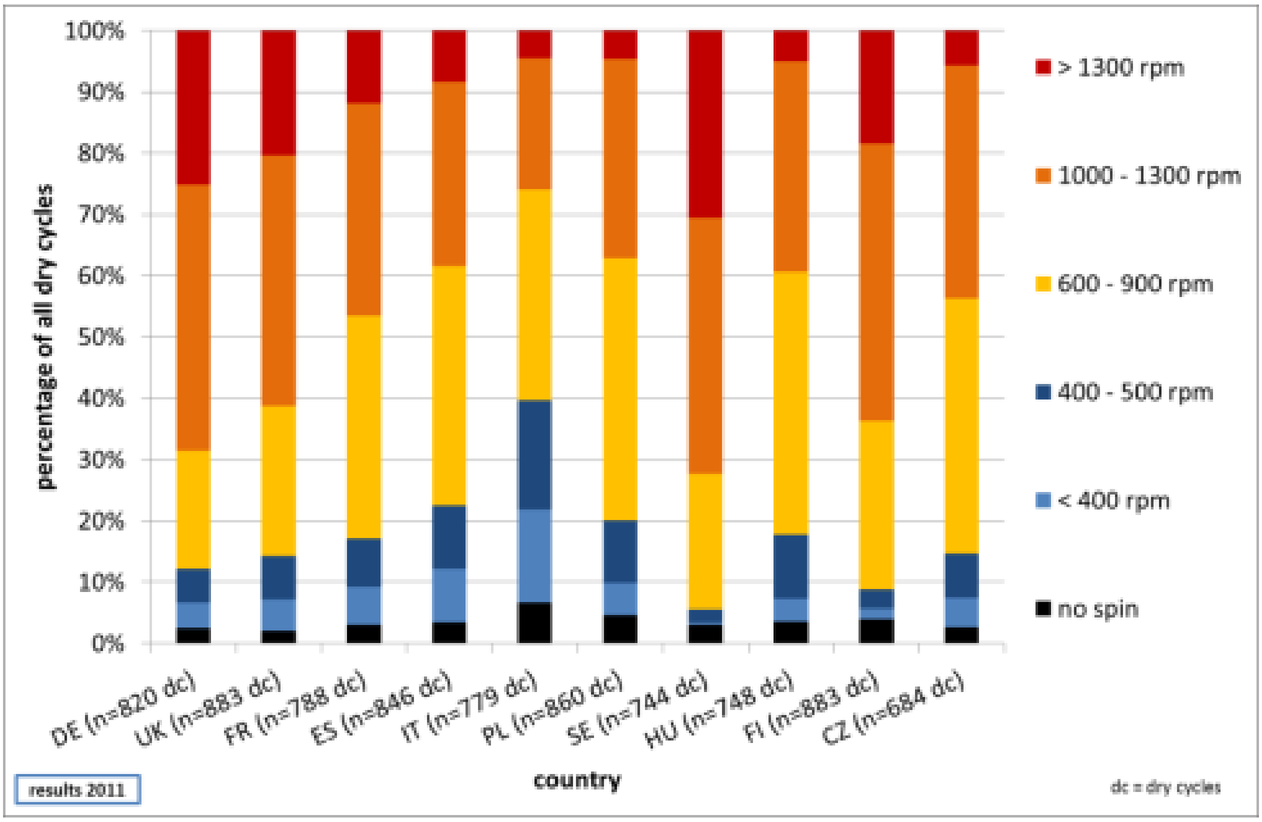


Figure 3.44: **Relative frequency of spin speed classes (according to (Schmitz & Stamminger 2014))**

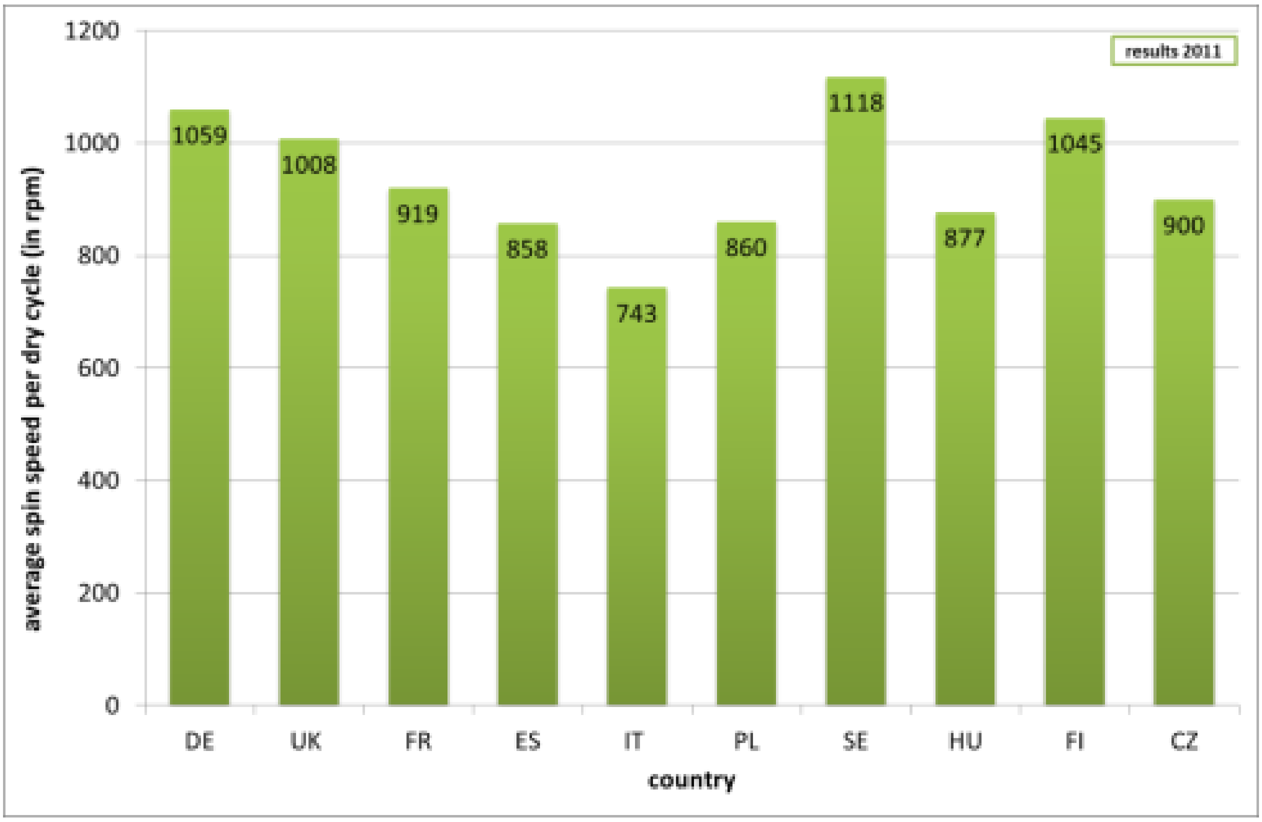


Figure 3.45: **Average spin speed per dry cycle for different European countries (according to (Schmitz & Stamminger 2014)**

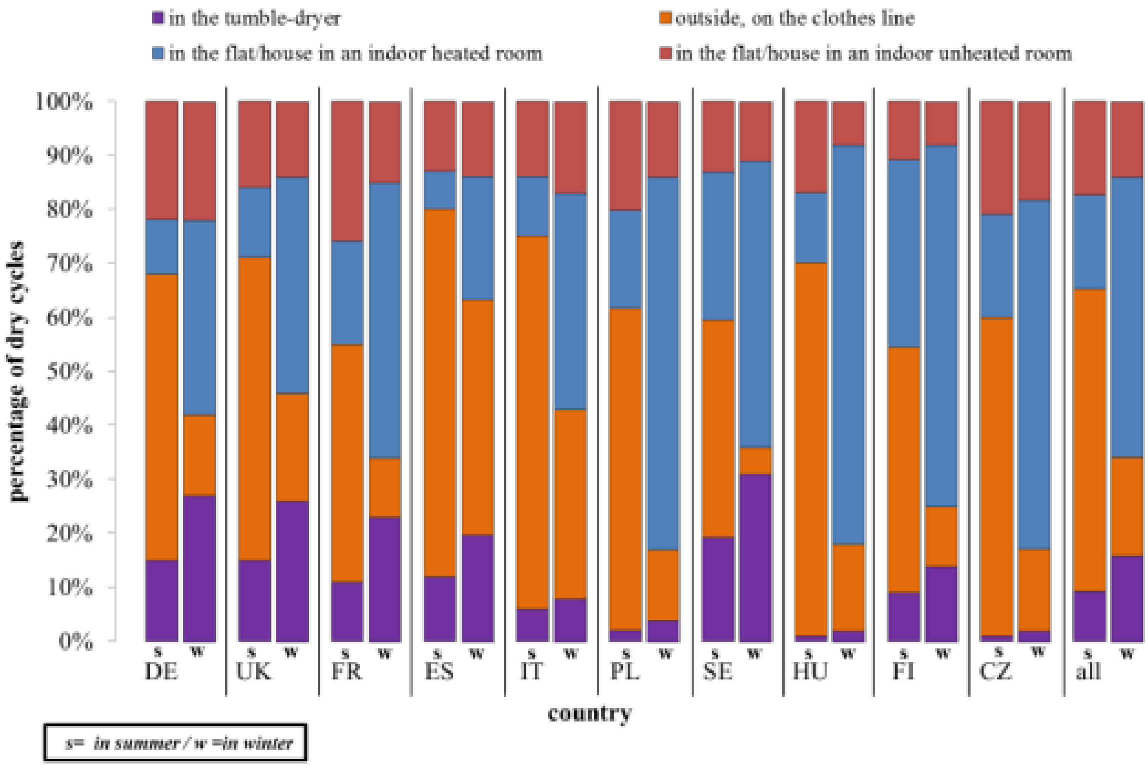


Figure 3.46: **Method of drying the clothes in summer (S) and in winter (W) for different European countries in 2011 (according to (Schmitz & Stamminger 2014))**

Table 3.10: **Equipment with a tumble dryer and the usage in winter and summer per country (according to (Schmitz & Stamminger 2014))**

Question: Which of the following appliances are existent in your household?	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
% of households being equipped with a tumble dryer	47	52	38	33	8	16	52	8	27	3
% of drying cycles of all households per country with using a tumble dryer (in winter)	27	26	23	20	8	4	31	2	14	2
% of drying cycles of all households per country with using a tumble dryer (in summer)	15	15	11	12	6	2	19	1	9	1

Calculated energy consumption

The analysis of the chosen washing temperature and of the number of wash cycles per week results in an average energy consumption of 2.32 kWh per household per week (number of answers =2,290) or 120 kWh per year (Figure 3.47).

The lowest energy consumption was calculated for Spanish households with 74 kWh/year on average. This can be explained by the fact that, among the whole European panel, the lowest average washing temperature was registered for Spain (Figure 3.48). All other countries resulted in an energy consumption of at least 100 kWh/year per household. The maximum values were observed for Poland and Finland (more than 130 kWh/year per household) as a consequence of the high average washing temperature and a high number of wash cycles per week.

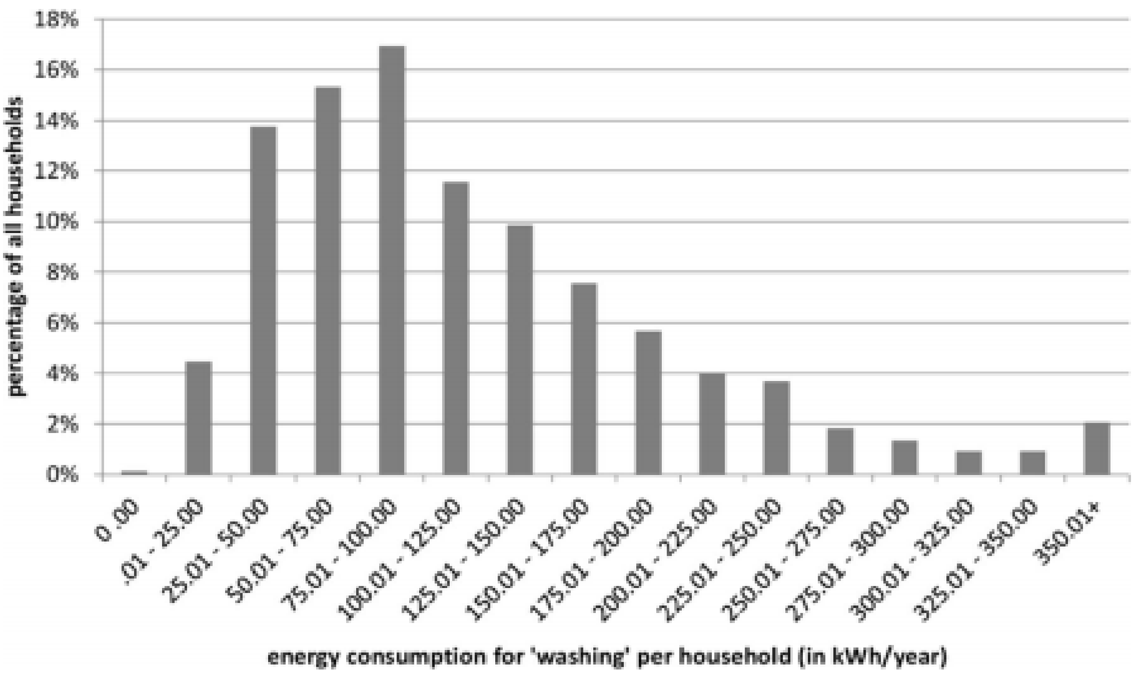


Figure 3.47: **Distribution of energy consumption for 'washing' per household per year (n=2,290 households) (according to (Schmitz & Stamminger 2014))**

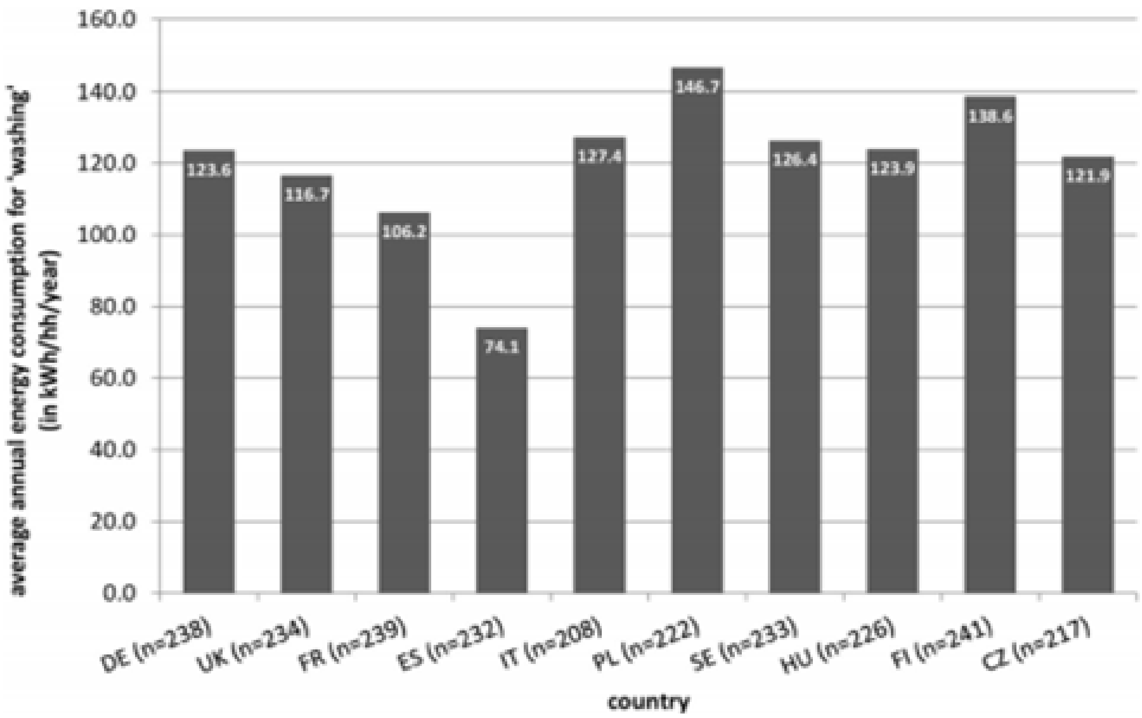


Figure 3.48: **Average annual energy consumption per country for 'washing' in 2011 (according to (Schmitz & Stamminger 2014))**

3.1.1.3. Consumer surveys about laundry and cleaning habits 2011 and 2008 by A.I.S.E

In 2008 and 2011 the International Association for Soaps, Detergents and Maintenance Products (A.I.S.E) has commissioned two online consumer studies about laundry and cleaning habits (A.I.S.E. 2011c) and Laundry Detergents (A.I.S.E 2008). The studies involved inhabitants of 23 European countries. The sample size for both studies was about 200 respondents per country for a total number of 5,249 respondents, Results for questions about number of wash cycles, chosen temperature classes and loading behaviour are shown in the followings.

Frequency of operation

The average number of wash cycles per household resulted to be 3.2 times per week in 2011. Compared to the statistics from 2008, the number of wash cycles per week decreased slightly (-0.1 = -3%). Among the countries tested by AISE, households in Ireland and in the UK presented the highest number of wash cycles per week (about 4.5 and 4, respectively). On the opposite side, laundry appeared to be washed about 2.5 times per week in Turkey and in Czech Republic ((A.I.S.E 2008); (A.I.S.E. 2011c)). In the surveys from the University of Bonn presented above, the average number of washing cycle per household is 3.8 times per week (2011) and 4.4 times per week (2015). This indicates that there is high variability in this parameter.

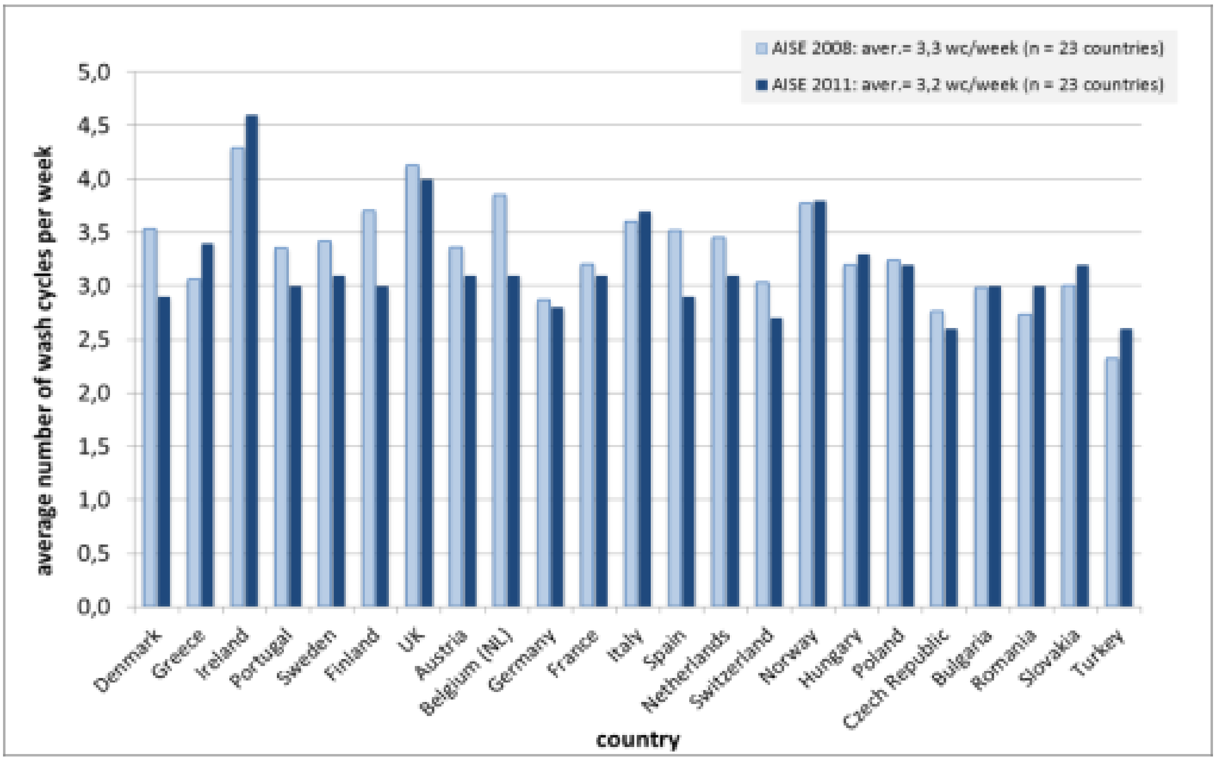


Figure 3.49: **Average number of wash cycles for different European countries (sources: (A.I.S.E 2008); (A.I.S.E. 2011c))**

Wash temperatures

The analysis of selected temperature classes shows that on average the laundry is washed with a temperature of 41.0 °C (Figure 3.49). A slight decrease is detected in comparison to the results for the year 2008 (41.7 °C).

Such result is consistent with the outcomes of the user surveys conducted by the University of Bonn in 2011 and 2015, where an average washing temperature of 43.3 °C (2011) and 42.3 °C (2015) was estimated. Both studies from A.I.S.E and University of Bonn thus indicate that the average washing temperature has decreased, and 40 °C may be a good indicator. Additionally, this also means that the use of lower temperatures is becoming more and more frequent.

Figure 3.50 shows that the percentage of wash cycles for which a temperature below 30 °C was selected was significant and it reached 74% for Spanish households.

According to this study, differences in selection of the programme temperature appeared limited between 2008 and 2011. During the period 2008-2011, the number of wash cycles below 30 °C increased by about 3% at European level (Figure 3.49 and Figure 3.50). The frequency of selection of higher temperature classes decreased. This is particularly the case for the "≥ 60 °C" temperature class, which is selected especially in Scandinavian countries (about 30%) (Figure 3.49 and Figure 3.51).

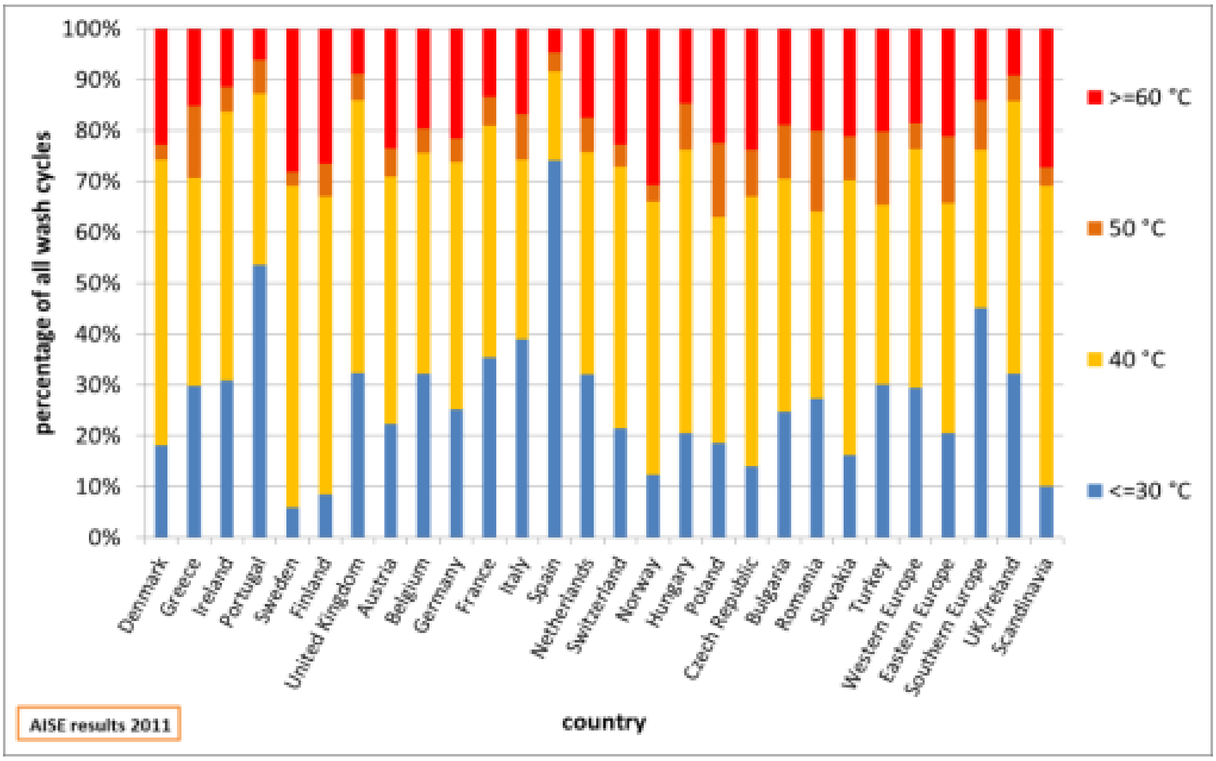


Figure 3.50: **Relative frequency of wash temperatures used in 2011 in different European countries (A.I.S.E. 2011c)**

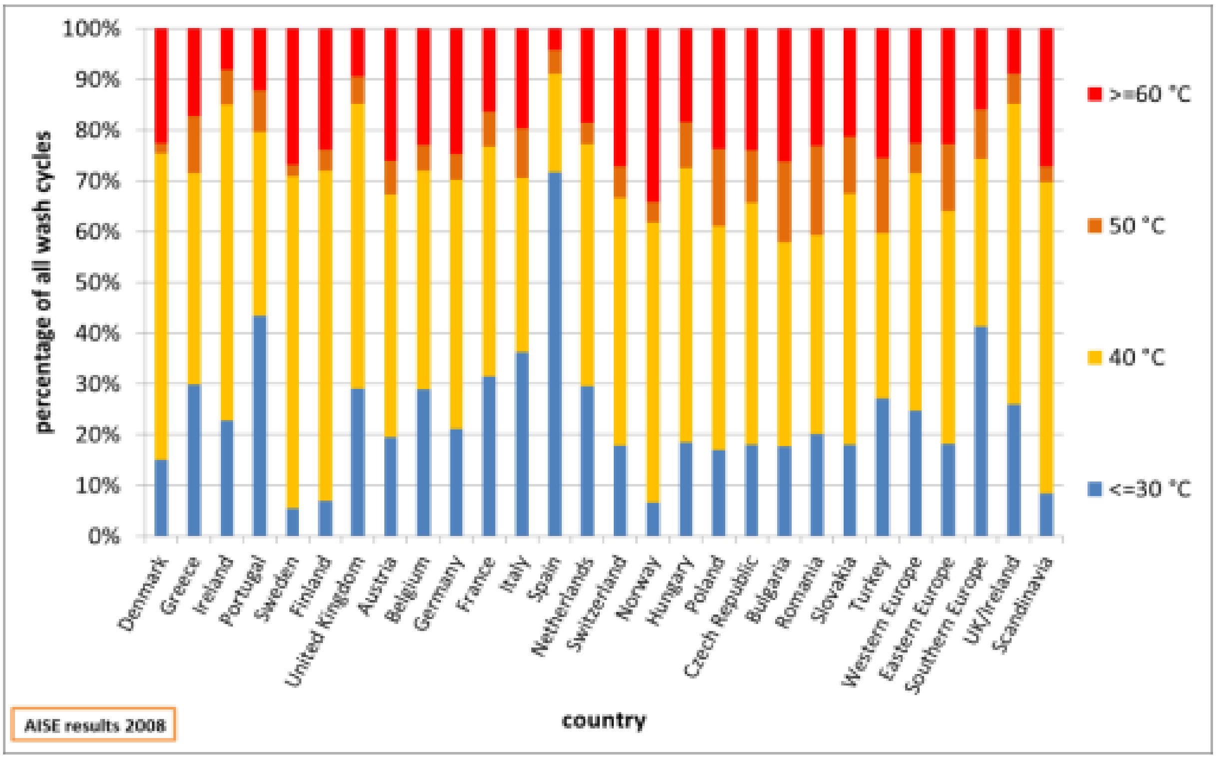


Figure 3.51: **Relative frequency of wash temperatures used in 2008 in different European countries (A.I.S.E 2008)**

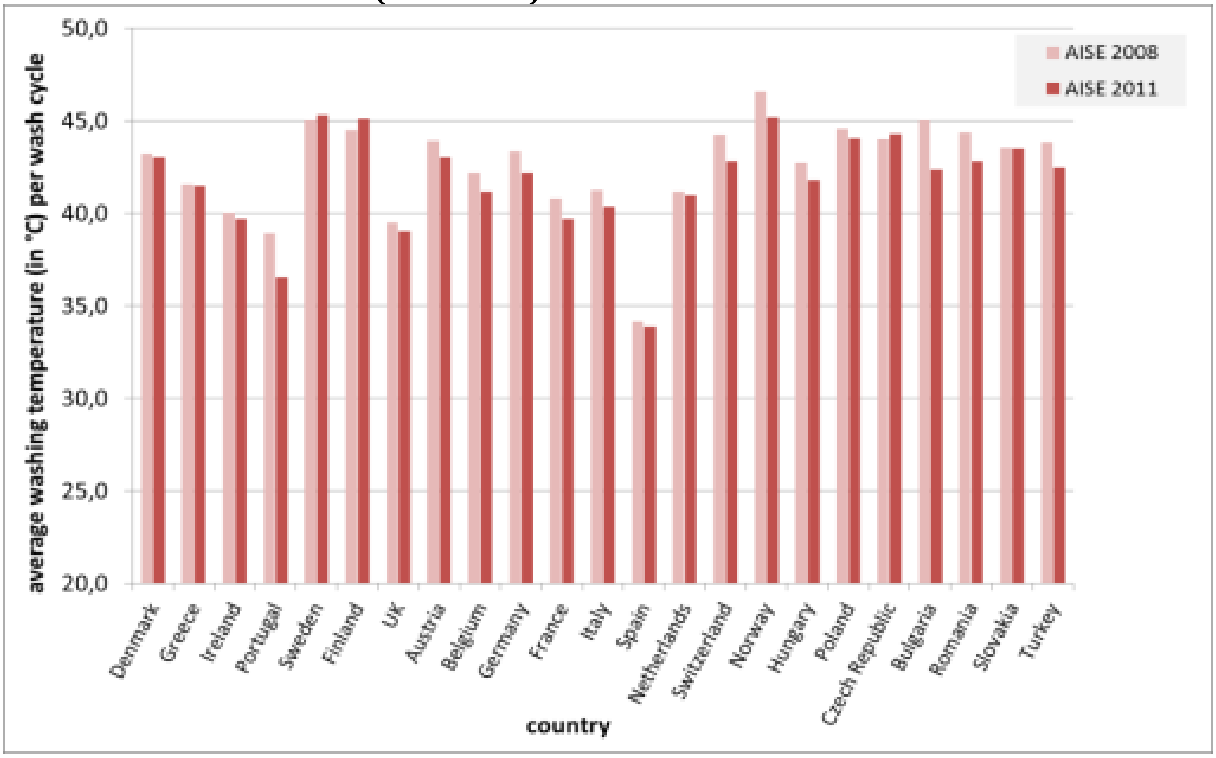


Figure 3.52: Average wash temperature per country for 2008 and 2011 using the nominal temperature values of 30 °C, 40 °C, 50 °C and 60 °C for calculating the average (A.I.S.E. 2011c)

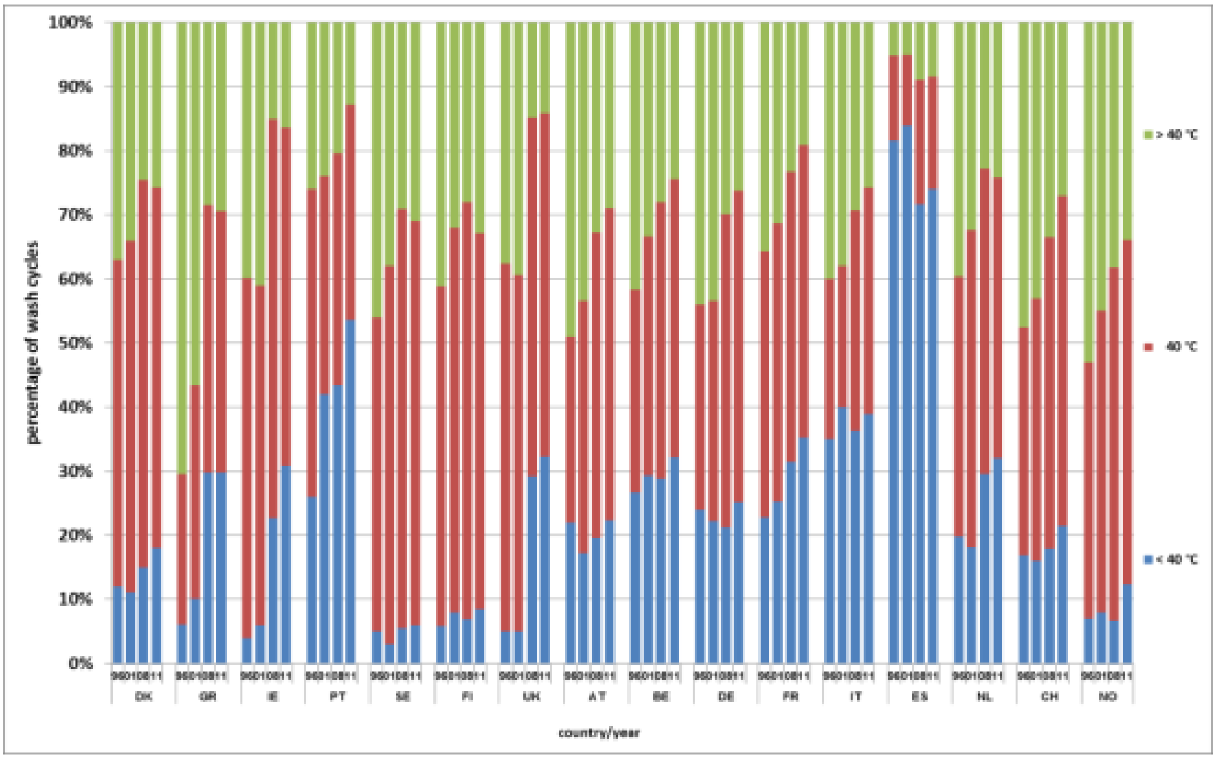


Figure 3.53:Comparison of the washing frequency for temperature ranges < 40 °C, 40 °C and > 40 °C for various countries (compilation by Bonn University based on data from A.I.S.E surveys of 1996, 2001, 2008 and 2011)

Historical data for 17 European countries has been found in former surveys done by A.I.S.E in 1996 and 2001 (IBM 2002). This information has been coupled with A.I.S.E's analyses carried out in 2008 and 2011. Figure 3.53 shows the washing frequency for different ranges of temperature and different European countries. Trends toward reduced use of higher washing temperatures (above 40 °C) can be observed in most countries. In some countries (e.g. Greece, Ireland, the Netherlands, and the UK) the practice of washing at temperatures below 40 °C has increased. For other countries, washing at 40 °C is the most used temperature. In Spain, the largest share of low temperatures below 40 °C can be observed.

The average washing temperature, calculated based on the nominal values of the programs, has also decreased from 1996 to 2011 for most countries (Figure 3.54).

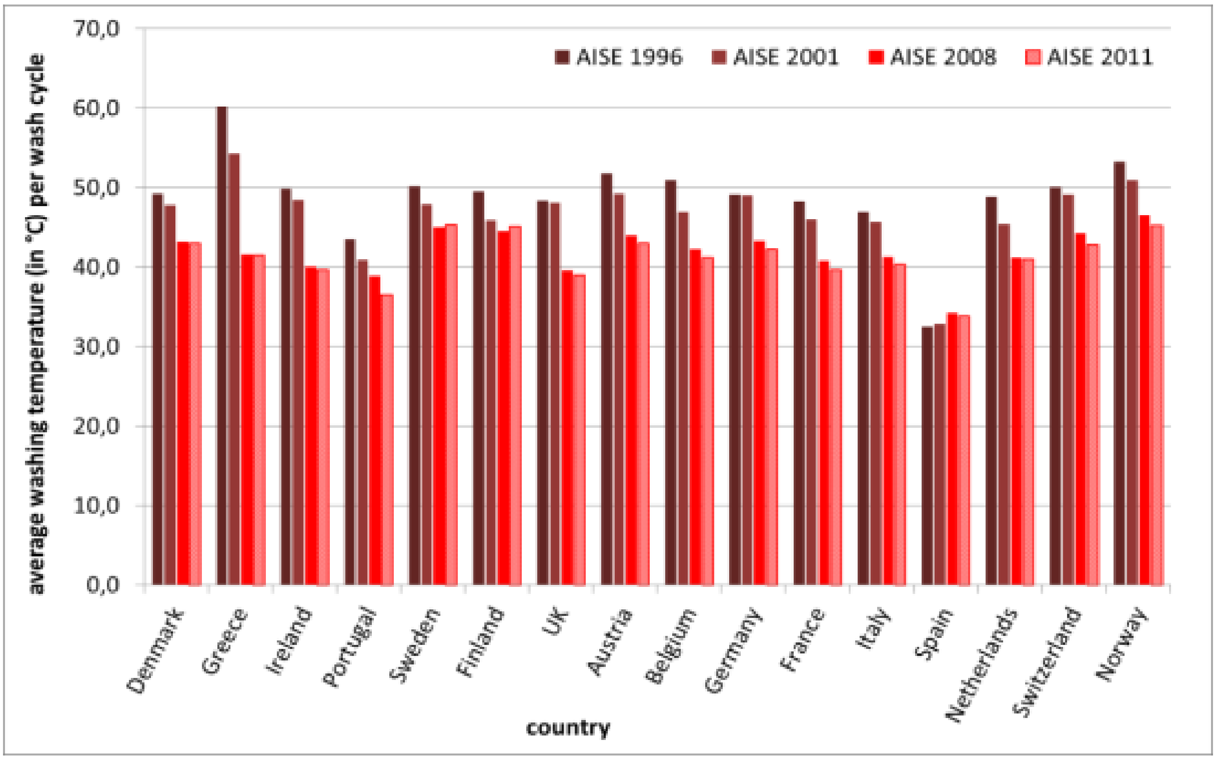


Figure 3.54: **Average wash temperatures for A.I.S.E studies from 1996 to 2011 (compilation by Bonn University based on data from A.I.S.E surveys of 1996, 2001, 2008 and 2011)**

Loading

Figure 3.55 and Figure 3.56 show the loading behaviour of the participants to the surveys run in 2011 and in 2008, respectively. Results illustrate that the majority of consumers in various countries load their washing machines 75 up to 100% full, which seems to be consistent with the results from the surveys run by the University of Bonn in 2011 and 2015.

The only exception appears Slovakia, where over 35% of consumers fill their washing machine less than half full (Figure 3.52). Also, there is no substantial change in the loading behaviour of participants comparing 2008 and 2011 (Figure 3.55).

Figure 3.57 and Figure 3.58 show respondents' opinions regarding the environmental effects of avoiding under-filling their washing machines. Respondents were asked “Which of the following statements do you believe will help reduce your impact on the environment?” One of the answering options was "Avoid under-filling the machine“.

In 2011, consumers from countries as Portugal, Poland or Czech Republic indicated that under-filling the washing machine has weak-neutral impacts on the environment. On the opposite side, consumers from other countries were very sensitive to this environmental issue. For instance, about 90% of the Finnish consumers indicated that the impacts can be significant (Figure 3.57). Results are comparable with those for 2008 (Figure 3.58).

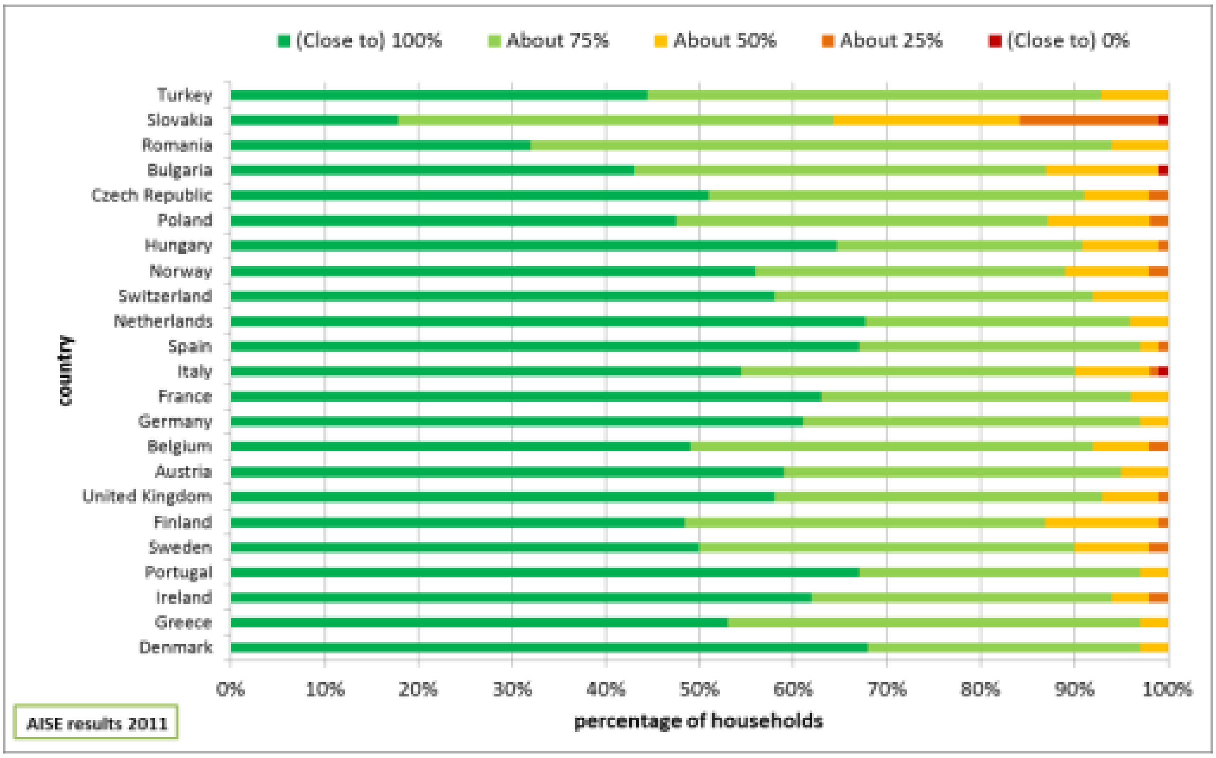


Figure 3.55: **On average, for normal laundry washes, for what percentage of your washes do you consider that the washing machine is "full"? (A.I.S.E. 2011c)**

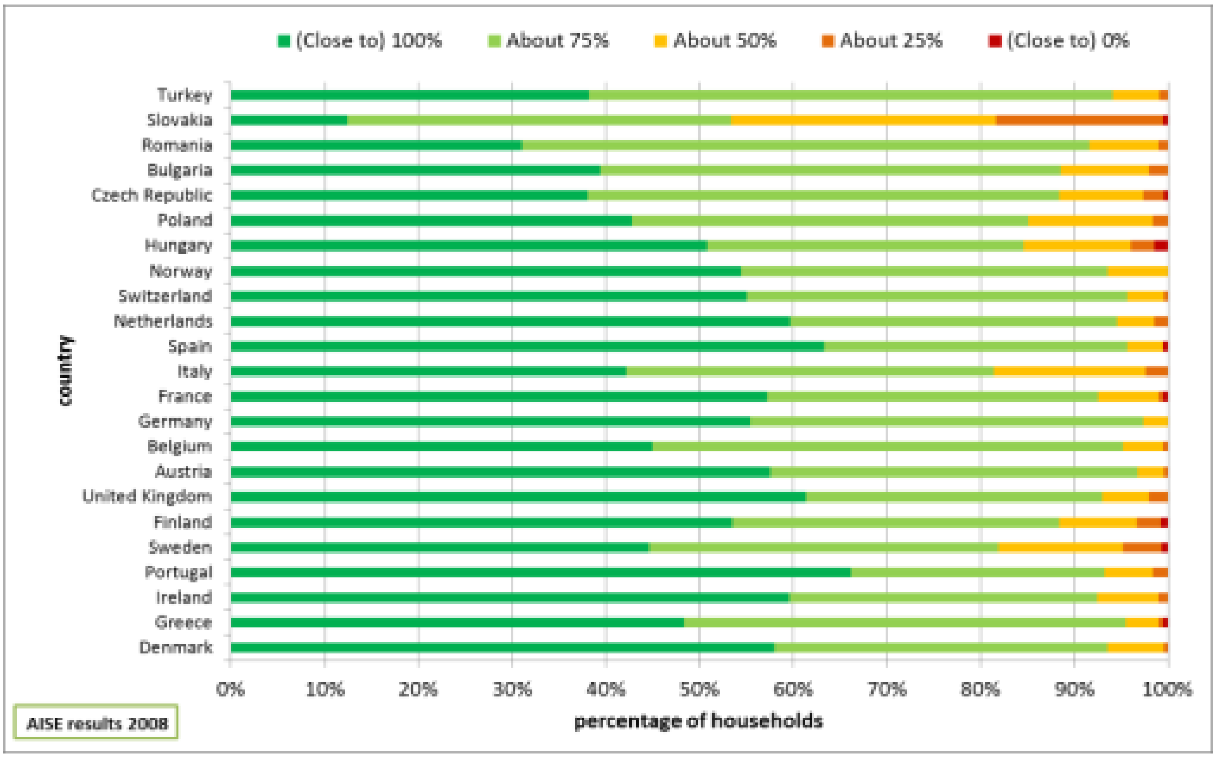


Figure 3.56: **On average, for normal laundry washes, for what percentage of your washes do you consider that the washing machine is "full"? (A.I.S.E 2008)**

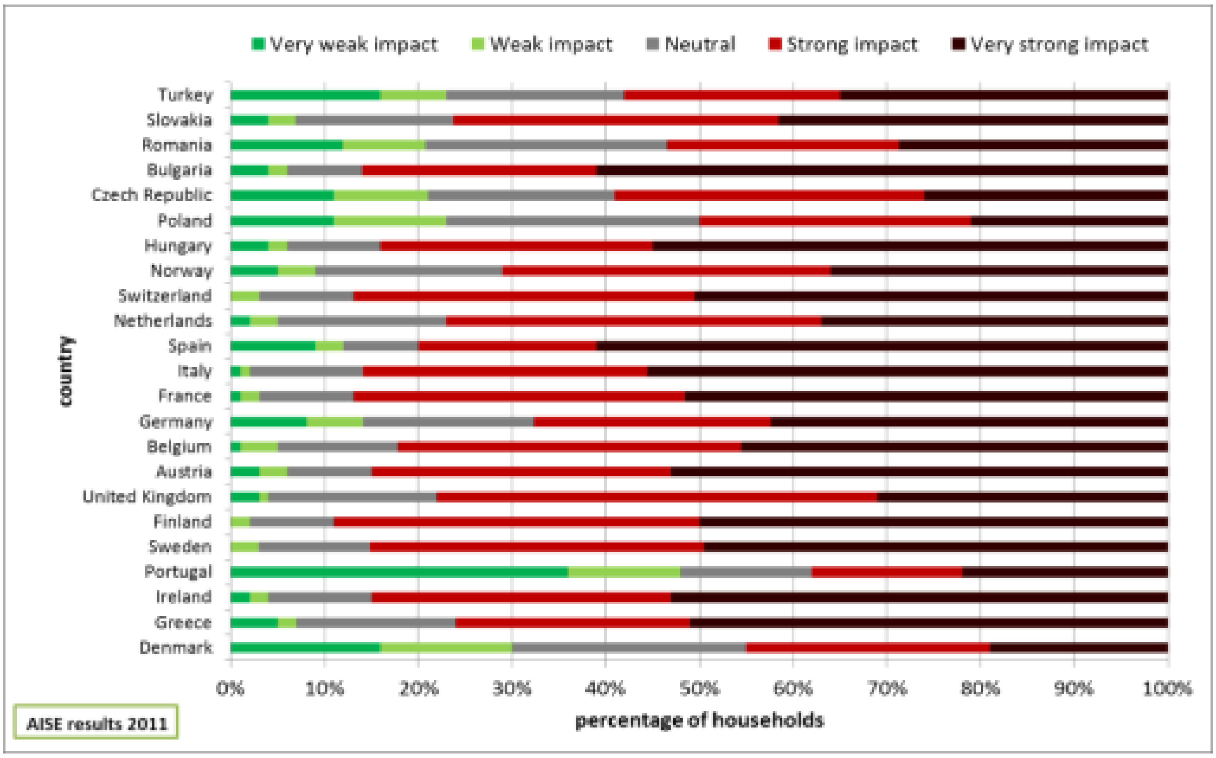


Figure 3.57: **Respondent's belief regarding the effects of avoiding under-filling the machine on the environment (A.I.S.E. 2011c)**

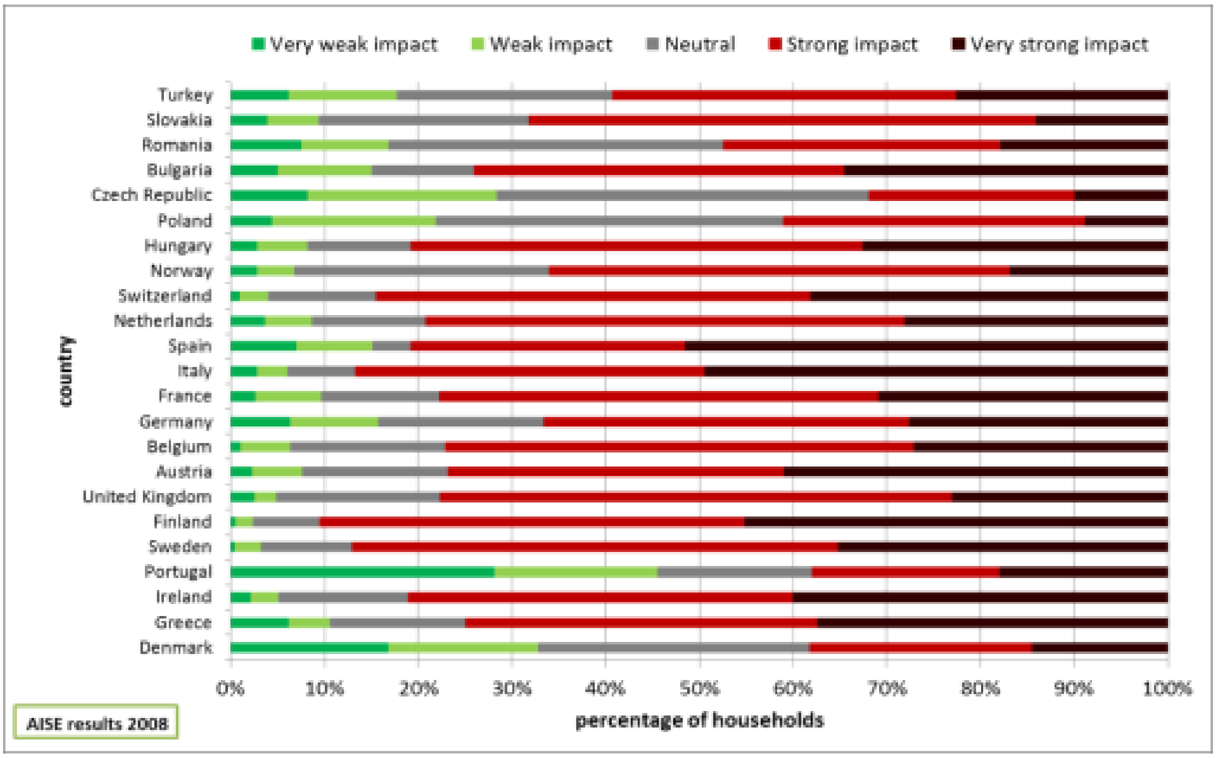


Figure 3.58: **Respondent's belief regarding the effects of avoiding under-filling the machine on the environment (A.I.S.E 2008)**

Both A.I.S.E studies gave the possibility to analyse the correlation between the estimated load of the washing machines and the consumer opinion about the possible consequences for the environment in case of under-filling. Results showed that there is no clear correlation between the consumer awareness about the environmental impacts associated to the filling rate and the actual practice (Figure 3.59). This can be a potential target for consumer information campaigns aimed at establishing the link between the two aspects and at promoting the increase of the washing machine's loading in those countries where it is currently low (e.g. Slovakia or Romania).

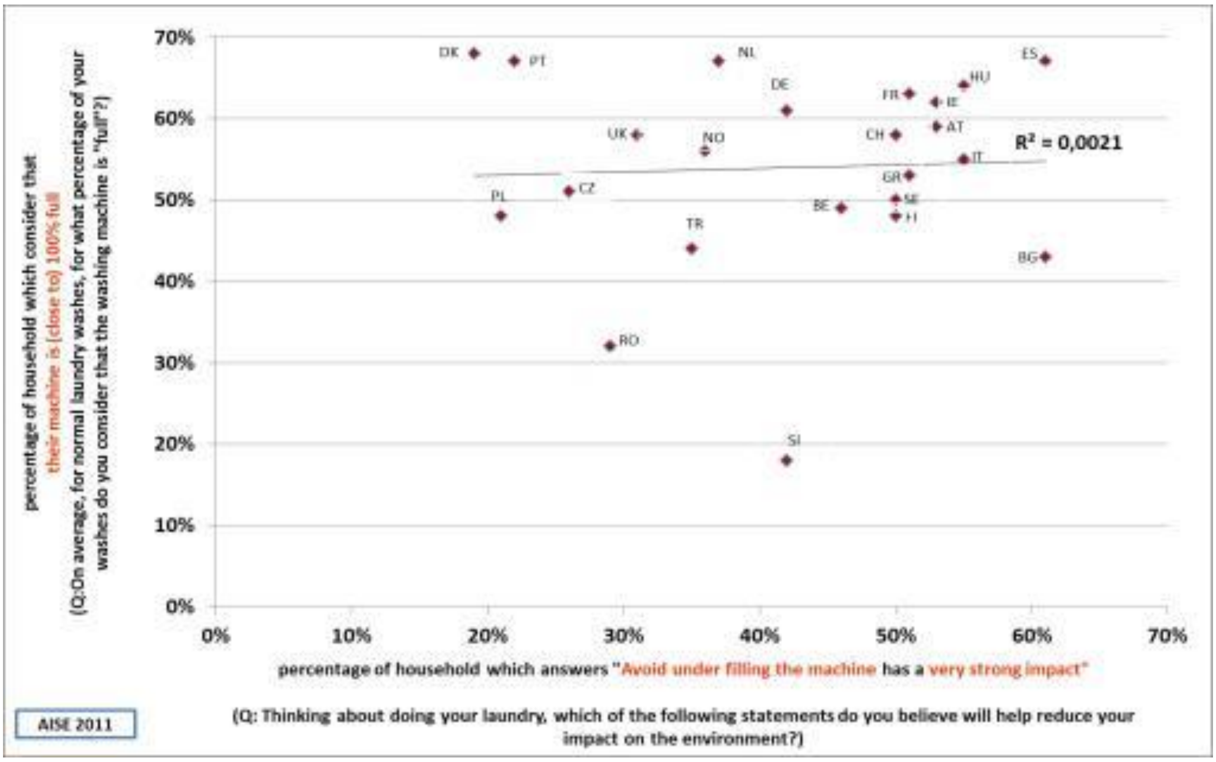


Figure 3.59: **Correlation between estimated load level and impact of "under filling" the machine (A.I.S.E. 2011c)**

3.1.1.4. Further consumer behaviour information

In this section, further information on certain aspects with regard to consumer behaviour on washing machines is presented. They stem from other sources than the consumer behaviour studies conducted by University of Bonn (2015 / 2011) and A.I.S.E. (2011 / 2008).

Programme options

According to the "Omnibus" study (VHK et al. 2014), the UK consumer organization 'Which?' asked 949 people about the kind of washing programme they were using and their frequency of use. The data is organised into people using programmes daily, every few days, once a week, etc. The following programmes are used once a month or more (VHK et al. 2014):

- 40 ˚C cotton programme: 52%
- Quick wash programme: 47%
- 40 ˚C synthetic programme: 46%
- 60 ˚C cotton programme and mixed load: 37%

Of these 949 people, 618 said that they had an eco-setting on their washing machine. 46% of this 618 (286) persons said they never used it and another 11% (71) said they use the eco mode once a month or less.

Selected programme temperatures and low temperature washing

Stakeholders informed that in July 2013 the Energy Savings Trust in the UK published the report “At home with water”, which contains an analysis of information on water use reported by more than 86,000 households in UK (Energy Saving Trust 2013). The responses showed that '…households are using their washing machines at lower temperatures. The vast majority (95%) say that they wash clothes at 30 °C or 40 °C, showing that a shift to cooler temperatures is happening. But there is potential for further savings: only 24% opt for programmes that wash at 30 °C or below’

In 2010, Defra, DECC and the Energy Saving Trust launched a study on the electricity use of English households. The Household Electricity Use Study analysed 251 households across England from 2010 to 2011. 26 of these homes were monitored for a whole year. The rest of the homes (225) were monitored for one month on a rolling basis throughout the trial. The outcome was consolidated in the report “Powering the Nation- Household electricity-using habits revealed" (Owen 2012). According to the report:

‘…From the householders’ diary entries it was found that around half of all washes were performed at 40 ˚C; just over a quarter (26%) was washed at 30 ˚C; another 15% were done at 50/60 ˚C and only two percent at 90 ˚C. Nearly two thirds of washes (64 percent) were claimed to have been ‘full washes’, with 16 percent at half load. There were instances of single garments being washed, but these were relatively rare occurrences. The big surprise in this area is the difference in the various households’ washing habits and frequency of cycles. The single-person household (non-pensioner) had a higher number of cycles and average annual energy consumption than the ‘household with children’ category (300 versus 284 respectively). The household type ‘multiple with no dependents’ is by far the highest group for laundry activities. This could be because households made up of house-sharers may not combine washing in the same way a family unit would.’

Already in 2011 several machines offered a 20 °C cycle (Josephy et al. 2011). In the meantime, some manufacturers have even gone a step further and for their latest generation of appliances created a 15 °C cycle. Thus, even less heating energy is needed. No matter if 20 °C or 15 °C, these cycles are specifically designed for ‘cold wash’ and may include correspondingly optimized mechanics and extended washing time to achieve good washing results. The high energy saving potential of ‘cold wash’ has been recognised also by the EU through the EU Ecodesign Regulation, which states that from December 2013 a 20 °C wash cycle is mandatory for all washing machines put on the EU market (European Commission 2010b).

In Germany, IKW (the industrial branch of the soap and detergent industry) has published historical data on the programme temperatures (Figure 3.59) (IKW 2011). A drastic reduction of washes at 90 °C as well as a continuous increase of washes at low temperatures (e.g. 0 °C and below) can be observed from 1972 to 2010 (Figure 3.59). Average washing temperatures (calculated using the nominal washing temperatures) have dropped from 63 °C to 46 °C in almost 40 years. A linear regression (Figure 3.60) gives a gradient of -0.43 °C per year for the reduction of the average washing temperature in Germany. This is supportive of the indications provided by the University of Bonn and by AISE (cf. sections before).

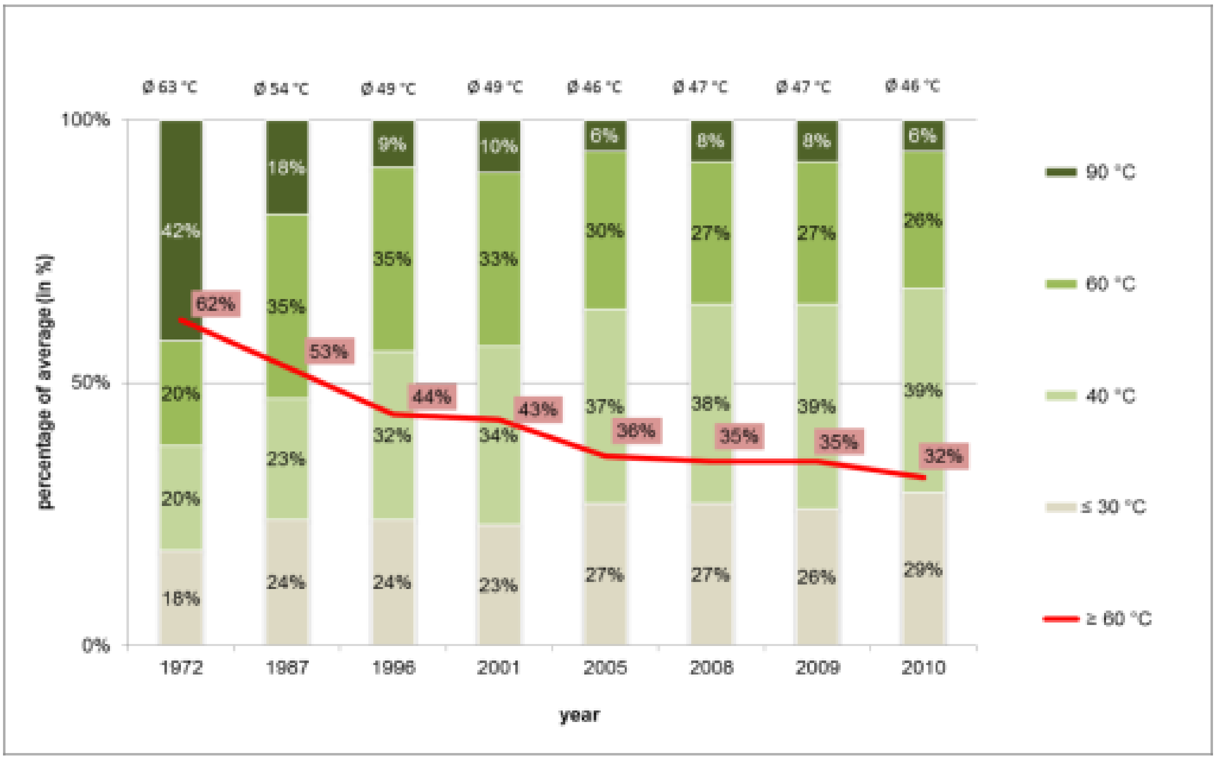


Figure 3.60: **Historical data on washing temperature from 1972 to 2010 for Germany (IKW 2011)**

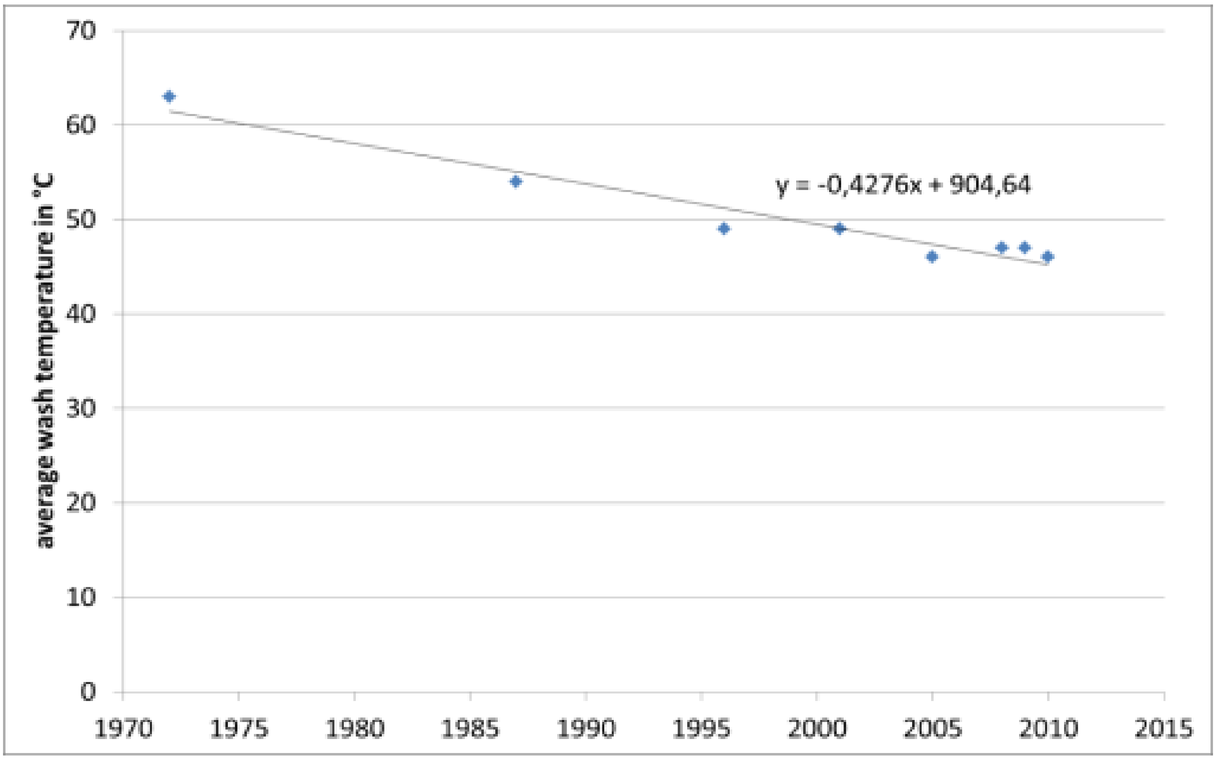


Figure 3.61: **Historical trend of average wash temperature in Germany (compilation by Bonn University based on data from (IKW 2011))**

Type and dosage of detergents

Based on the results of a survey which was carried out by the University of Bonn in 2009 among 334 private households in Germany (Kruschwitz et al. 2014), corresponding to the collection of information for

2,773 wash cycles, it was confirmed that heavy duty detergents with and without bleach were used most frequently.

'Vollwaschmittel' (heavy duty detergent) was used in 50% of the wash cycles and 'Colorwaschmittel' (color detergent) in 43.1%. The use of special detergents was limited (5% for the 'Feinwaschmittel' (light duty detergent) and 1.6% for the 'Wollwaschmittel' (wool detergent).

Concentrated detergents resulted to be the most frequently used (42.6%) followed by liquid detergents (37.1%). Tabs were indicated to be used only in 3.6% of the wash cycles.

For heavy duty detergents, the most commonly used types of detergents were those in powder ('Vollwaschmittel', 56.7%) and the liquid ones ('Colorwaschmittel', 48.5%). Liquid dispensing types were mainly used for special detergents, according to the recommended guidelines.

The soil level was recorded based on a subjective evaluation of 2,662 wash cycles. According to this analysis, 63.5% of laundry was lightly soiled, 27.2% medium soiled and 9.2% heavy soiled.

Samples of tap water were also collected from each household in order to determine the water hardness. Based on the questionnaire, only 124 householders were able to provide an estimation of the prevailing water hardness of the area where they lived at that time, whereas the remaining 112 householders did not know the hardness of the water used. Approximately, only 65.3% of the person interviewed estimated accurately the local water hardness. 17.3% of the total stated their area had higher water hardness than determined by the measurements, whereas 17.4% believed they live in an area with less water hardness than was actually found. According to the detergent manufacturers the dosage should be about 20% higher for a moderately hard water (e.g. that has a hardness of 21°dH, corresponding to 3.80 mmol/l) than for an average hard water area. Nevertheless, the measured average dosage was significantly lower ().

The average amount of detergent which was used for laundry in areas with very hard water was significantly lower from that used in other areas ().

Table 3.11: Arithmetic average amount of detergent per wash cycle and water hardness area

Water hardness area (in dH)	Water hardness area (in mmol/l)	Number of wash cycles	Arithmetic average amount of detergent with standard deviation (in g per wash cycle)
Soft: <7.3	<1.30	583	74.2 + 32.2
Medium; 7.3-14	1.30-2.50	1136	72.9 +35.5
Hard: 14-21.3	2.50-3.80	712	73.1+33.3
Extra hard; >21.3	>3.80	439	69.5+42.0

The amount of detergent used resulted to fluctuate depending on the soil level and on the water hardness of the area: from 58.2 g ± 25.0 g (medium soiled laundry, very hard water) to 81.4 g ± 36.6 g (heavy soiled laundry, soft water). Even if the consumer recognized a difference in the soil level of the laundry, this did not lead him to adjusting of the detergent dosage, at least not for the average of all consumers (Figure 3.49).

Looking at the average dosage of different detergent types, comparable results were obtained for powdered and liquid detergents. Super compact and tab detergents were used slightly more moderately.

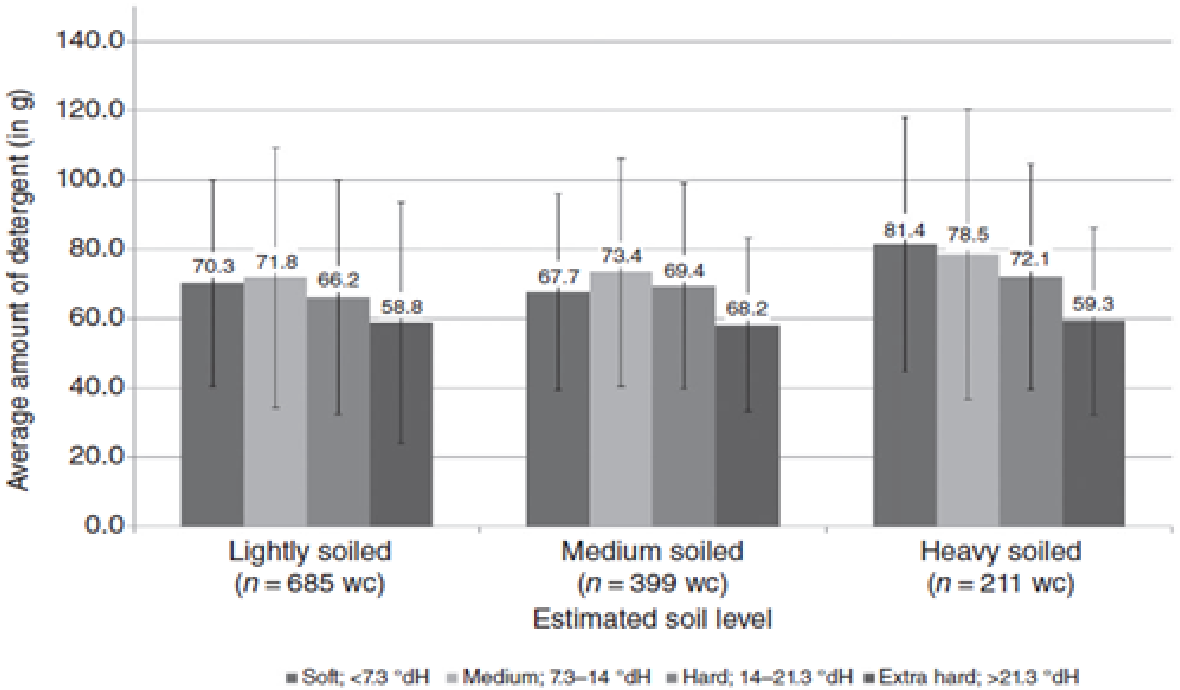


Figure 3.62: **Arithmetic average amount of detergent per soil level and water hardness area only of those households who chose every soil level at least once**

Table 3.12: **Arithmetic average amount of detergent in g per wash cycle and average dosage factor per type of detergent indicating misbehaviour in detergent dosage**

Type of detergent	Number of wash cycles	Arithmetic average amount of detergent with standard deviation (in g per wash cycle)	Arithmetic average dosage factor with standard deviation
Powder	1183	74.6 + 37.9	1.41+0.91
Compact/pearls	460	64.4 +29.5	1.51+0.87
Tabs	100	55.5+25.2	1.38+0.77
Liquid	1030	75.5+34.7	1.38+0.73

Nowadays all known European detergent manufacturers offer detergents designed for the washing temperature range of 15 °/20 °C to 60 °C or 90 °/95 °C. Such detergents exist as heavy-duty detergent (with / without bleach) and colour detergent (Josephy et al. 2013).

3.1.2. Washer-dryers

3.1.2.1. User behaviour survey on washer-dryers 2015 by University of Bonn

Background and Methodology

The following report is based on a DIN Consumer Council study on a user behaviour analysis of owners of a household washer-dryer (Stamminger et al. 2015). With this regard, a semi-representative EU online survey was conducted in April/ May 2015. The washing and drying behaviour of over 1,000 households owning a washer-dryer was assessed. The survey concentrated on four European countries (France, Germany, Italy and the United Kingdom) owning seventy-one per cent of the total number of washer-dryers in Europe. Toluna, a professional market research company located in Frankfurt am Main, Germany, was asked to translate the questionnaires into the relevant languages, recruit respondents from the panel of registered consumers and fulfil the quotas for each country. Qualified persons were chosen following a predefined quota:

- Households possess a washer-dryer
- Involvement in laundry washing is substantial
- Age between 20 and 74 years

The participants were asked about their laundry washing and drying behaviour, the availability and use of the "wash&dry" option (continuous washing and drying in one process), their opinion regarding energy-saving issues and their awareness of information reported on the energy label of a washer-dryer. Demographic data were additionally recorded.

Before starting the analyses, the validity of each dataset was checked with the aid of two criteria. The first was asked in different parts of the questionnaire, but assessed essentially the same information. One asked simply about 'the number of laundry loads washed per week per household' while the other asked about 'the frequency of washing the laundry per week per household'. The latter information was coded into numbers and when summed up, revealed a number of wash cycles per week. Therefore, the difference between both measures was used as one of two indicators for a inconsistent answering of the questionnaire.

The second exclusion criterion was based on the request, 'Please indicate all types of information you are able to identify on the label presented': among all the features given, five of them are not listed on the energy label. If four or all of them were chosen by participants, this criterion was considered to be fulfilled. Datasets were excluded from the following evaluation in the case of giving an inconsistent answer to one of these criteria. After excluding the outlier data, the number of the panel diminished from 1,302 to 1,186. Table 3.13 illustrates the contribution of European countries in the survey.

Data indicated with 'all' are calculated by a simple average of the households participating.

Table 3.13: Distribution of washer-dryers (WDs) in Europe and contribution to this survey (source: (Stamminger et al. 2015); source for number of private households: (Eurostat 2016))

Country	Penetration rates 2014 in % households	Private HH in Mil. (Eurostat 2016)	Private HH with WDs in Mil.	% of total market in 16 countries	Realised number of participants
Czech Republic	2.1	4,607	97	1%	
Hungary	3.3	4,130	136	1%	
Poland	2.9	13,928	404	4%	
Romania	1.0	7,470	75	1%	
Austria	6.8	3,768	256	3%	
Denmark	5.5	2,360	130	1%	
France	5.6	28,091	1,573	17%	278 (23%)
Germany	2.3	39,713	913	10%	193 (16%)
Greece	3.0	4,345	130	1%	
Italy	3.7	25,768	953	10%	163 (14%)
Netherlands	5.4	7,592	410	4%	

Country	Penetration rates 2014 in % households	Private HH in Mil. (Eurostat 2016)	Private HH with WDs in Mil.	% of total market in 16 countries	Realised number of participants
Portugal	8.2	4,063	333	4%	
Spain	2.7	18,329	495	5%	
Sweden	4.8	4,591	220	2%	
Turkey	0.7	20,745	145	2%	
United Kingdom	11.3	28,076	3,173	34%	552 (47%)
All households in the sample		217,574	9,444	100%	1,186 (100%)

Some of the answers needed a coding to allow arithmetic calculations. Forinstance, Table 3.14 shows the coding used for calculating the 'rated capacity' of washer-dryers. 'Rated capacity', is the technical term defined in standardisation and regulations. In order to calculate the rated capacity, the options in the question 'What is the maximum load of laundry in kg which can be washed, dried or washed and dried in your washer-dryer?' were coded with the numbers given in Table 3.14.

Table 3.14: Loading coding (source: (Stamminger et al. 2015))

Maximum load 'washing'		Maximum load 'drying' and 'wash&dry'	
Load capacity	Coded load	Load capacity	Coded load
Up to 5 kg	**5**	Up to 2 kg	**2**
6 kg	**6**	3 kg	**3**
7 kg	**7**	4 kg	**4**
8 kg	**8**	5 kg	**5**
9 kg	**9**	6 kg	**6**
More than 9 kg	**10**	7 kg	**7**
I don't know	**Excluded**	More than 7 kg	**8**
		I don't know	**Excluded**

Results of the EU online survey

A selection of the results of the EU online survey carried out by Bonn University is presented in the following.

Household size

Participants were asked about the number of people living in their household (Figure 3.63). On average, 32% of respondents live in two-person households, followed by 24% who live in one-person households; 19% and 18% of respondents live in four-person and three-person households, respectively. The highest number of people per household, with three or more than three people was seen in Italy. Following the consumer survey analysis, the most single-person households were seen in Germany and France. The distribution of household size in the UK is similar to Germany and France.

The detailed analysis of the answers to the question mentioned results in an average of 2.5 people per household. Italy had the highest average household size (3.4 people), whereas Germany had the lowest average household size (2.3 people) followed by the UK and France (2.4 people). This correlates with figures of 2.3 (UK), 2.2 (France), 2.4 (Italy) and 2.0 (Germany) people per household in 2013 (source: (Eurostat 2014)), and shows, especially for Italy, that households owning a washer-dryer have a higher number of people than average households.

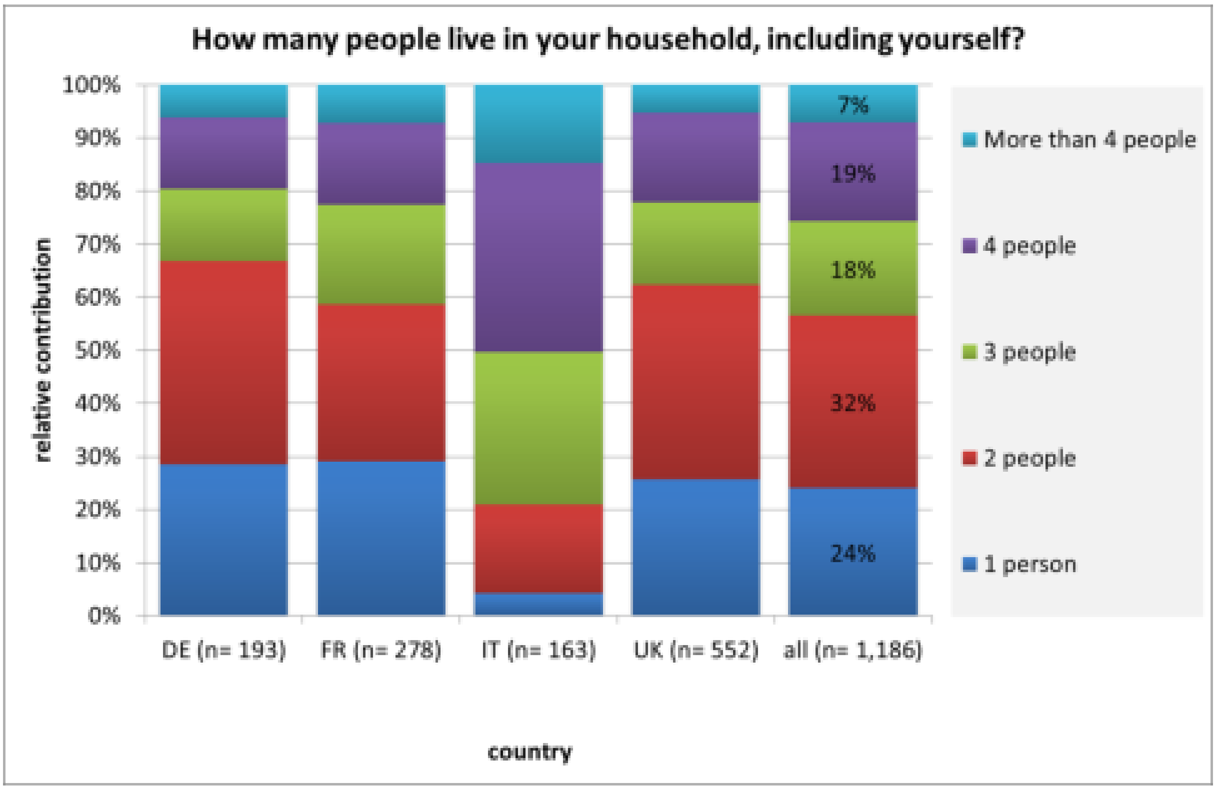


Figure 3.63: Distribution of household size; source: (Stamminger et al. 2015)

Household appliances

Respondents were asked whether they have a washing-machine and/or a tumble-dryer in addition to a washer-dryer, or not (Figure 3.64). Around 13% of respondents owned a washing-machine and tumble-dryer, 8% only an additional washing-machine and 2% a tumble-dryer. These appliances may be used alternatively to washer-dryer. The decision regarding which appliance is used for the actual washing and drying may depend on various factors and was not investigated in this survey. Therefore, figures on frequency of operation of the washer-dryer are calculated for households who own only a washer-dryer.

Italy had the highest share of households having both appliances (washing-machine and tumble-dryer; 26%) or a washing-machine (19%) in addition, while France had the lowest share of households having an additional washing-machine (5%) and an additional washing-machine and tumble-dryer (8%). A plausible explanation might be related to the average household size; for instance, Italy has the largest average household size among the European countries which participated in the survey. Therefore, the need for an additional option to wash and dry their laundry may be higher.

Respondents who claimed to have a washing-machine or tumble-dryer or both in addition to a washer-dryer (n = 276) were asked about the reasons for having these appliances (Figure 3.65). Around 50% of the respondents admitted that the reason for buying an additional appliance was related to their need for an extra option to wash their laundry. Requiring an additional option for drying laundry (37%) and the low purchase price of the secondary appliance (27%), getting the appliance for free (15%) and the appliance's existence in a house before moving in (13%) were other reasons for having a secondary appliance besides a washer-dryer.

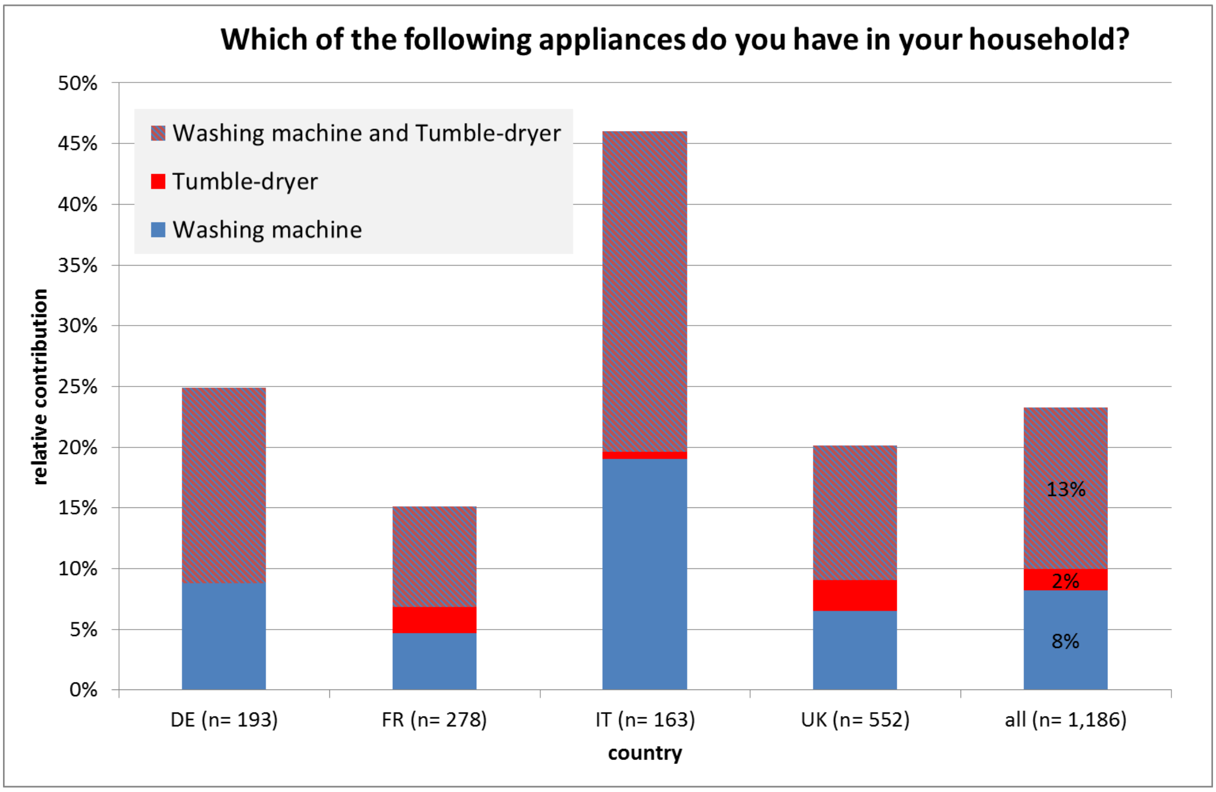


Figure 3.64: **Ownership of an additional washing machine and tumble dryer**

Figure 3.65: **Reason for having additional appliances beside washer-dryer**

Reasons of buying a washer-dryer

The reasons for buying a washer-dryer were checked according to the different size of households. As Figure 3.66 shows, an important reason for buying a washer-dryer in one-person and two-person households is lack of space for two separate appliances, selected by around 63% and 60% of respondents, respectively. Requiring a continuous washing and drying option is increasing with household size and becomes the main argument for households with more than four people.

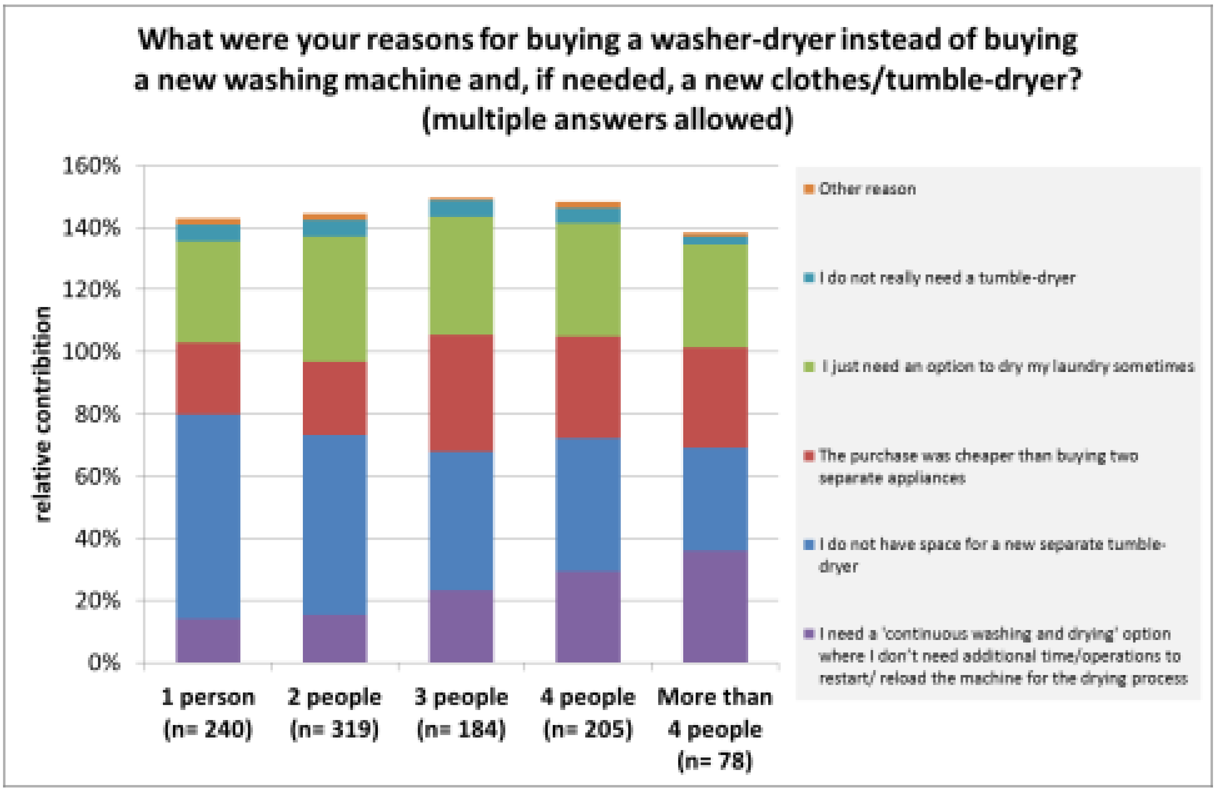


Figure 3.66: **Reason for purchasing a washer-dryer related to different household sizes; source: (Stamminger et al. 2015)**

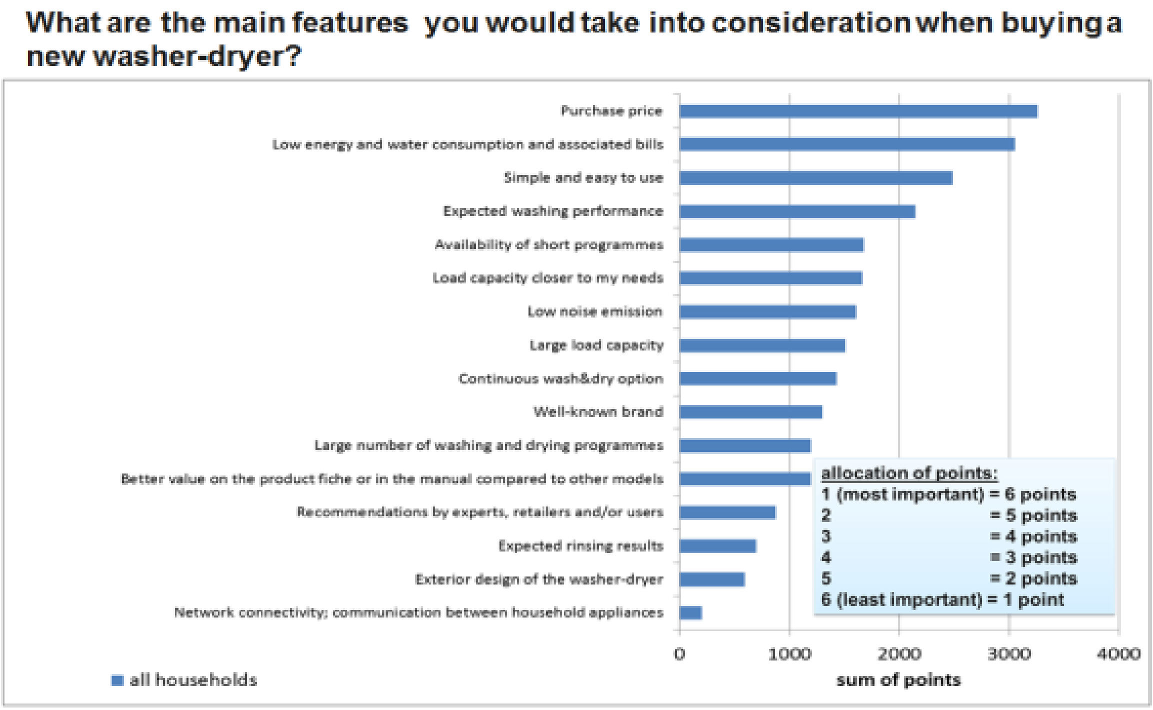


Figure 3.67: **Attributes with high importance for the consumer when buying a new washer-dryer; source: (Stamminger et al. 2015)**

Purchase criteria

When the respondents were asked about the ‘six main features that they would take into consideration when buying a new washer-dryer’ and requested to sort them based on priority, ‘Purchase price’ was the most important aspect for them (Figure 3.67). ‘Low water and energy consumption and associated bills’ and ‘Simple and easy to use’ were the second and third priorities, respectively, among the other options, followed by ‘Expected washing performance’, ‘Availability of short programme’ and ‘Load capacity closer to my needs’. The attributes with the least importance were ‘Network connectivity and communication between household appliances’ and ‘Exterior design of the washer-dryer’.

It is important to note that ‘Continuous wash&dry cycle’ was not selected as top feature taken into account by respondents when buying a new washer-dryer.

Average rated capacity

The average rated capacity of a washer-dryer in this survey is 6.9 kg for washing, 5 kg for drying and 5.3 kg for wash&dry (Figure 3.68). The UK has the highest average rated capacity of a washer-dryer for washing (7.1 kg) and wash&dry (5.5 kg), while Germany has the lowest average rated capacity for washing (6.5 kg) among the European countries which participated in the survey.

Continuous wash&dry option

Respondents were asked about ‘the possibility of washing and drying their laundry in the washer-dryer without having to take out clothes in between cycles (so-called continuous wash&dry option)’. Results indicate that around 89% of a total of 1,186 respondents in the survey have the continuous wash&dry option on their washer-dryer. Figure 3.69 shows that there are little differences between countries; for instance, 93% of washer-dryers in Italy have the continuous wash&dry option, while in Germany and the UK, 87% of machines have this option. This result might be explained through the age of washer-dryers in different countries. Italy has the youngest average age of washer-dryers (3.3 years) while Germany has the oldest washer-dryers (5.3 years) among the European countries participating. This reflects the fact that the wash&dry option was introduced in the market in the last decade. Average age of washer-dryer with wash&dry option and without wash&dry option is 4.3 and 5.3 years, respectively.

Acceptable time for a continuous wash&dry cycle

Participants were asked, ‘How much programme time would you still accept from a continuous wash&dry cycle?’. Around 70% of respondents admitted that they accept a maximum of three hours for the wash&dry cycle (Figure 3.70). These results confirm the fact that saving water and energy is important for consumers but not at the expense of time. Additional analysis shows that there are no major differences regarding accepting programme time from a continuous wash&dry cycle and employment status.

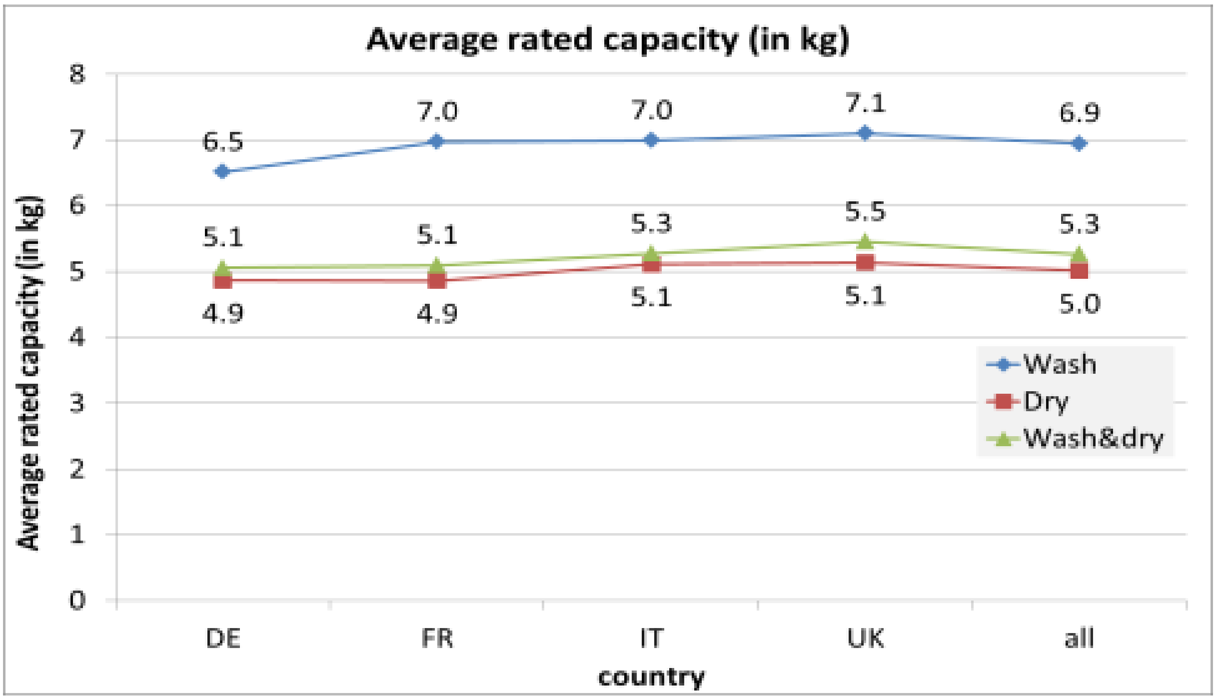


Figure 3.68: **Average rated capacity of washer-dryer (for washing, drying, wash&dry); source: (Stamminger et al. 2015)**

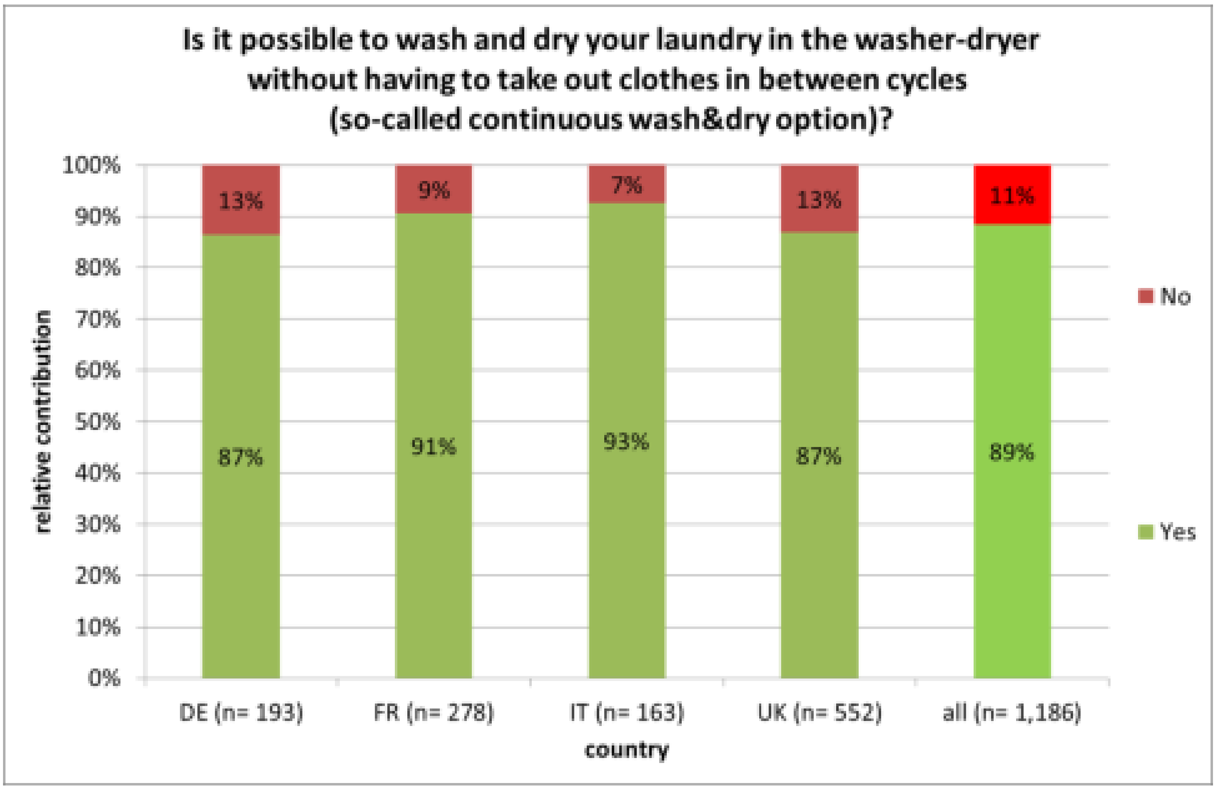


Figure 3.69: **Continuous wash & dry option; source: (Stamminger et al. 2015)**

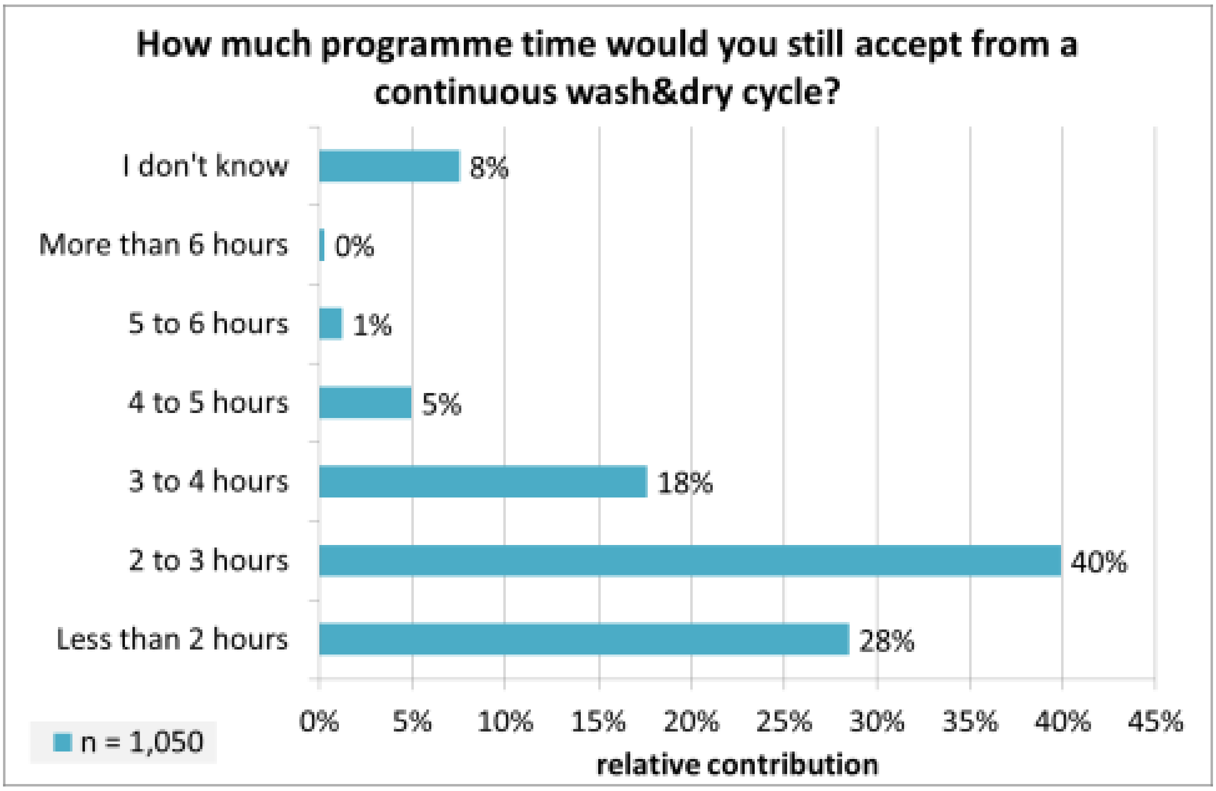


Figure 3.70: Acceptable time for a continuous wash&dry cycle; source: (Stamminger et al. 2015)

Average wash cycles per week

Figure 3.71 shows the average number of wash cycles per week, calculated by summing up the results of the questions, 'How many loads of laundry on average are washed separately (without using continuous wash&dry option) in your washer-dryer per week in your household?' and 'How many loads of laundry on average are treated using the continuous wash&dry option per week in your household?' For the sake of having a uniform sample, answers were taken only of those households who had a washer-dryer with a wash&dry option without any additional appliances.

The average number of wash cycles per week is 4.6. Italian households wash their laundry most frequently: an average of 6.0 wash cycles per week, while German households in this survey have the lowest average of wash cycles per week (4.1), which relates well to the different household sizes (Figure 3.63).

Average drying cycles per week

An average number of drying cycles per week was calculated by summing up the results of the question, 'How many loads of laundry on average are dried separately in your washer-dryer per week in your household?' and 'How many loads of laundry are dried using the continuous wash & dry option per week in your household?' Again here only those households who had a washer-dryer with wash&dry option, but without any additional appliances were taken into account.

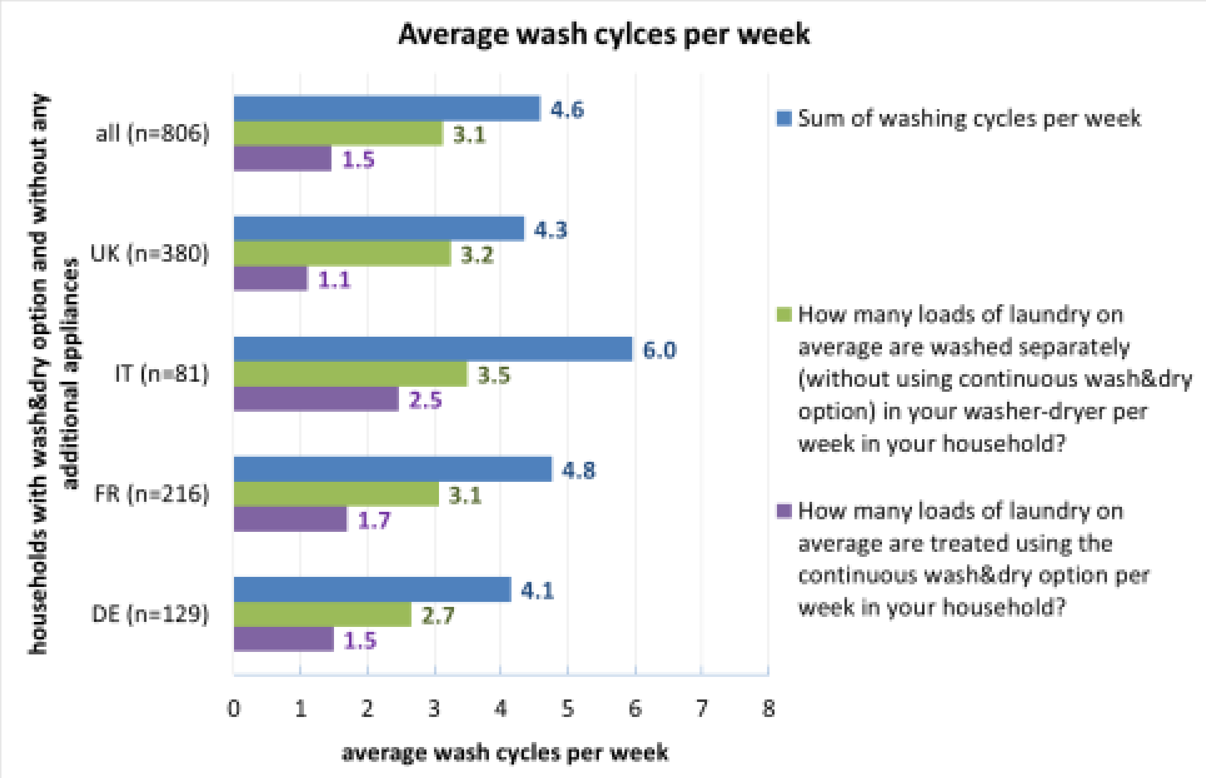


Figure 3.71: Average number of wash cycles per week; source: (Stamminger et al. 2015)

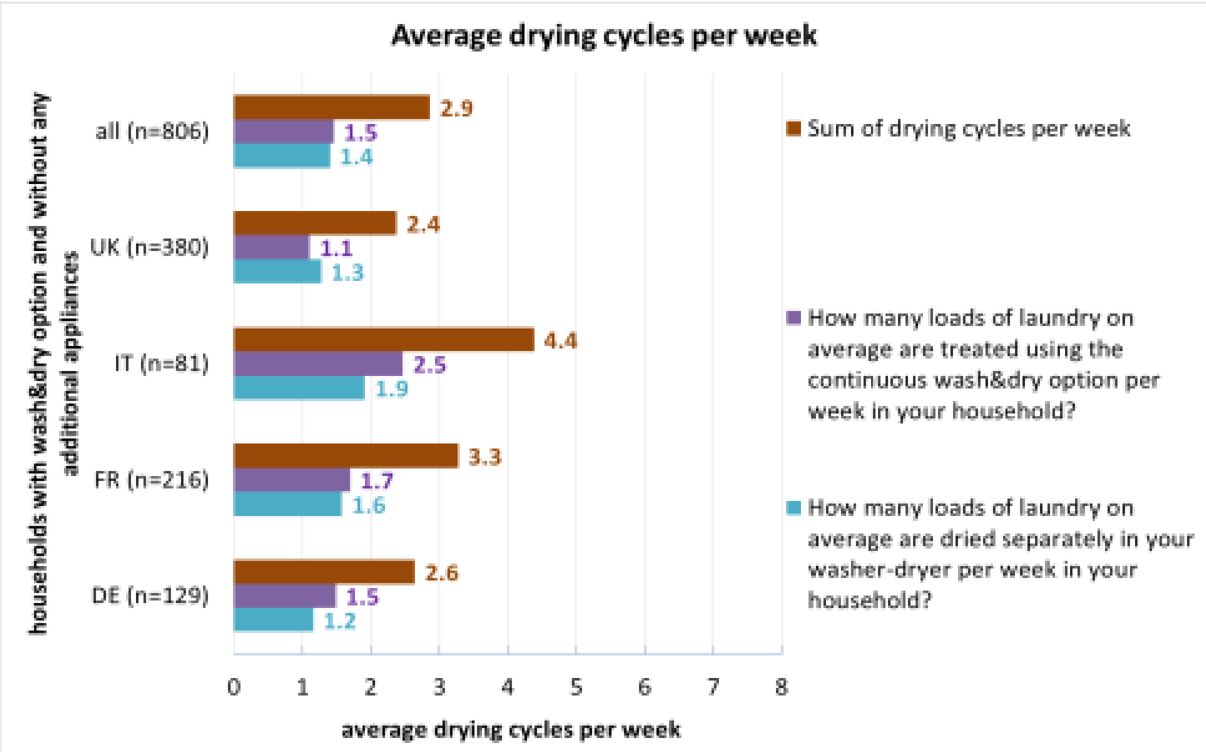


Figure 3.72: Average number of drying cycles per week; source: (Stamminger et al. 2015)

The average number of drying cycles per week is 2.9 (Figure 3.72). Italy has the highest average of drying cycles per week (around 4.4) and the UK has the lowest average of drying cycles per week (2.4), which is well explained by different household sizes.

Delay start function

Respondents were asked, ‘Does your washer-dryer have a “delay start” function?’ This function was defined as follows: the delay start function allows you to set the programme to automatically start later. As Figure 3.73 shows, 72% of respondents claimed that they have a ‘delay start’ function on their washer-dryer and about 46% of them use it often or sometimes.

Moreover, the group of respondents using the ‘delay start’ function were asked about the ‘Reasons for using the delay start function’. The reasons are mostly related to ‘To let the machine run when it’s more convenient for me’, ‘To let the machine finish its cycle shortly before I get home’ and ‘To let the machine run when the electricity tariff is cheaper’.

Respondents, who have the ‘delay start’ function but do not use it, were also asked about the ‘Reasons for not using the delay start function’. Over half of the respondents admitted that there is no need to shift the start time of the cycle.

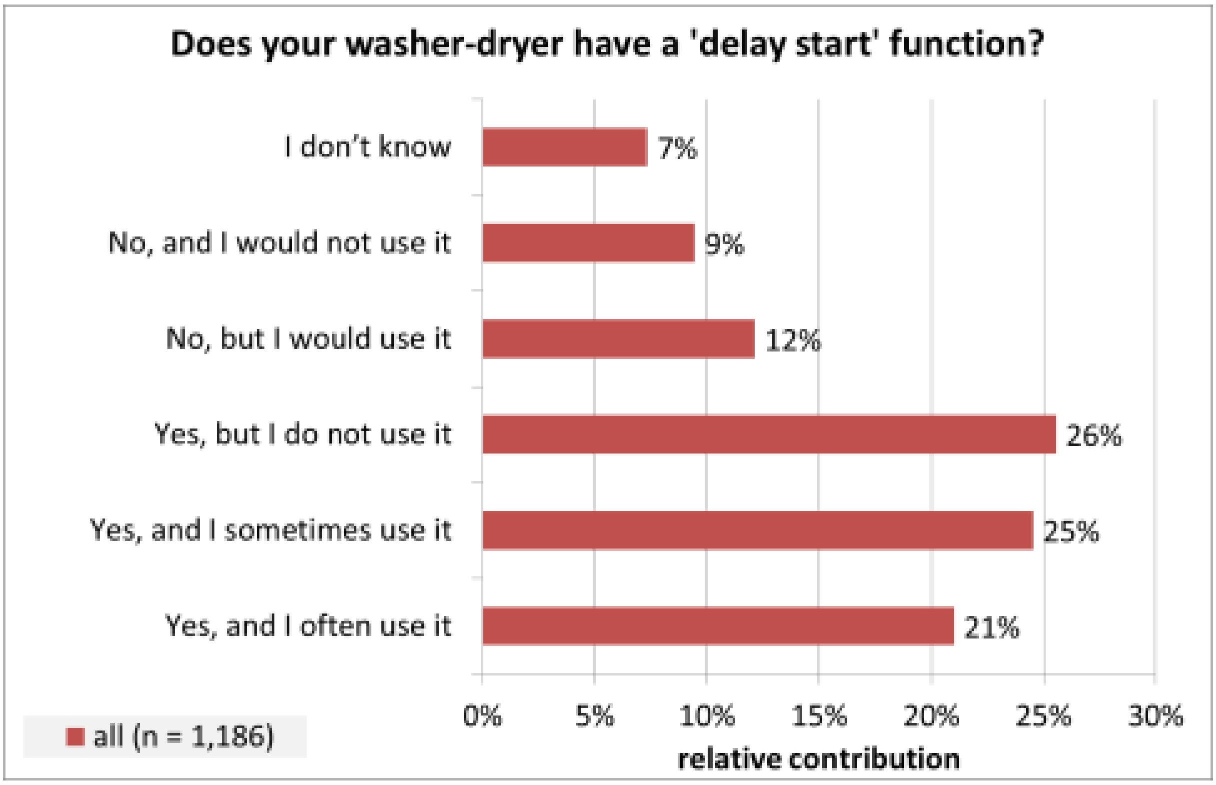


Figure 3.73: Delay start function and its usage; source: (Stamminger et al. 2015)

Programme options to save energy

The respondents were asked the question, ‘Which of the following options would you use if doing so would enable you to save energy/or money?’ Around 64% of respondents indicated that they would use the ‘energy-saving programme offered by machine’ while only 31% of respondents admitted that they would accept longer programme cycles (Figure 3.74). There seems to be some misunderstandings regarding the necessity of longer programme times and the saving of energy in energy-saving programmes. In addition, when respondents answered accepting longer programme cycles, it is not clear how long they meant exactly.

The second and third option most chosen was to ‘Avoid over-drying of the clothes’ (57%) and ‘Using lower temperature programmes (56%), respectively. ‘Changing drying habits’ and ‘Using more of the washer-dryer’s capacity and/or washing full loads appear to be the fourth (51%) joint preferred options for the respondents.

The results of 'Using an external hot water supply from renewable sources' (38%) and 'Accepting longer programme cycles' (31%) were the least popular options selected by the respondents (Figure 3.74).

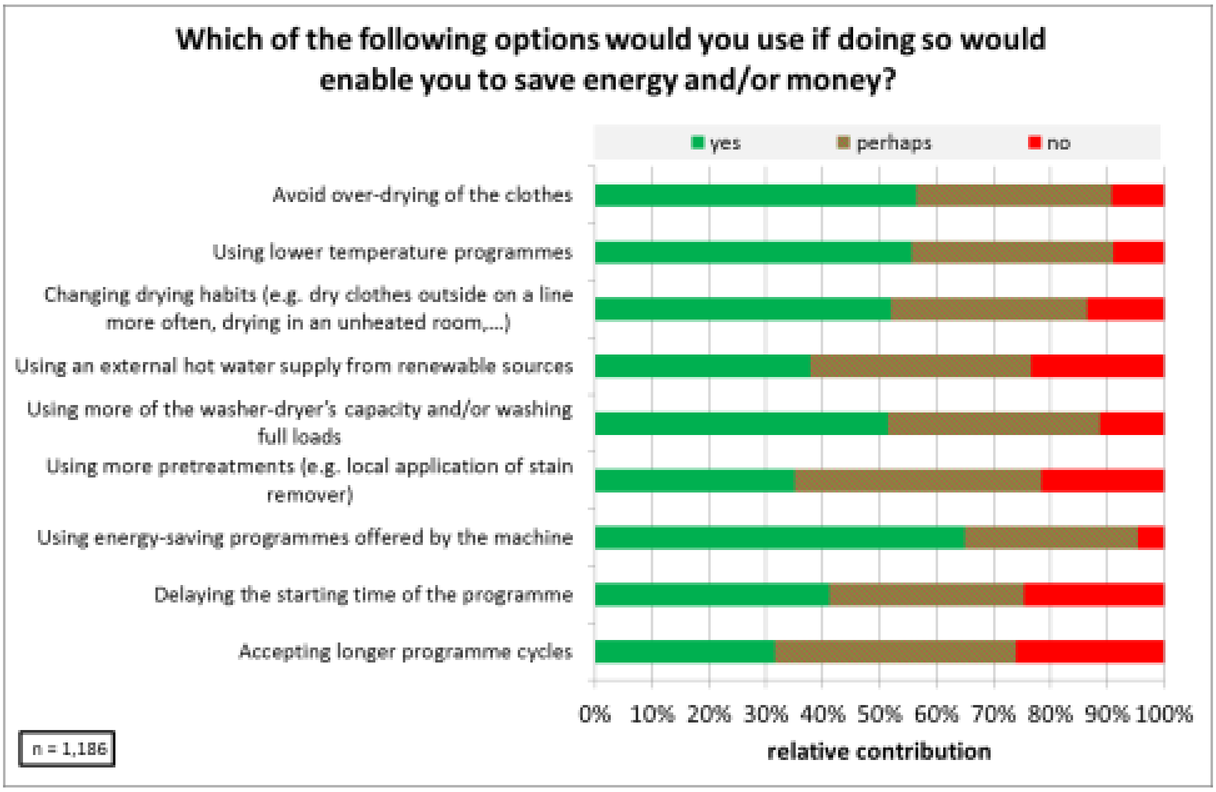


Figure 3.74: Usage of possible options to save energy and/or money; source: (Stamminger et al. 2015)

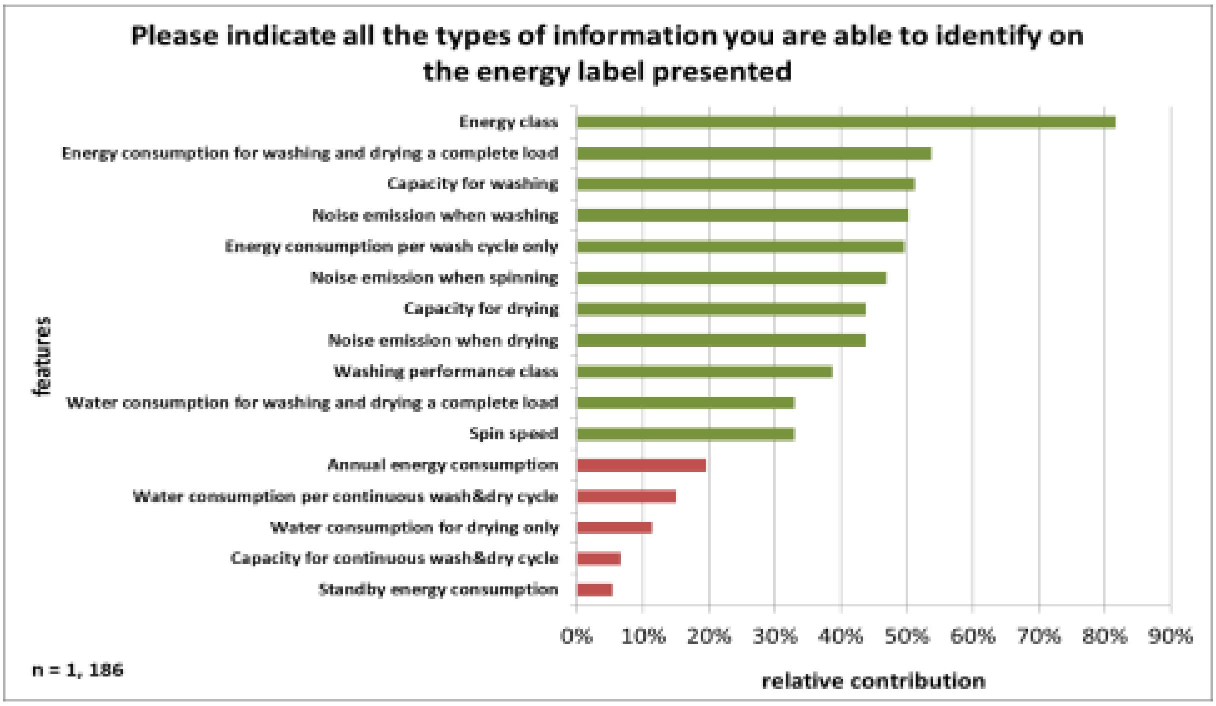


Figure 3.75: Information on the energy label; source: (Stamminger et al. 2015)

Information on the Energy label

When respondents were asked to indicate ‘All types of information that you are able to identify on the Energy label presented’ (in the specific version of their language), over 80% of them were able to find ‘Energy class’, followed by ‘Energy consumption for washing and drying a complete load’ (about 53%). ‘Capacity for washing’, ‘Noise emission when washing’ and ‘Energy consumption per wash cycle only’ were identified by about 50% of respondents (Figure 3.75).

The items which are not listed on a washer-dryer label, including ‘Annual energy consumption’ (19%), ‘Water consumption per continuous wash&dry cycle’ (15%), ‘Water consumption for drying only’ (11%), ‘Capacity for continuous wash&dry cycle’ (6%) and ‘Standby energy consumption’ (5%), were identified by some of the respondents as well. These answers were used as one of the criteria to exclude participants from the evaluation.

Future energy label expectations

The participants were also asked to indicate ‘Which of the following pieces of information concerning a washing cycle of a washer-dryer are important to show on the future energy label?’ (multiple answers were allowed).

- Regarding the **continuous wash&dry cycle**: ‘Energy efficiency’ (55%), ‘Capacity (in kilograms)’ (54%), ‘Programme duration (in minutes) per cycle’ (51%) and ‘Energy consumption per cycle’ (50%) are the pieces of information on the future energy label that are most important to show (Figure 3.76).
- Regarding the **wash cycle**: The information on the energy label that is most important to show includes ‘Capacity (in kilograms)’ (71%), ‘Energy efficiency’ (65%), ‘Water consumption per cycle’ (61%), ‘Programme duration (in minutes) per cycle’ (58%), ‘Energy consumption per cycle’ and ‘Spin speed’ (both 57%).
- Regarding the **drying cycle**: ‘Energy efficiency’ (61%), ‘Capacity (in kilograms)’ (56%), ‘Programme duration (in minutes) per cycle’ (56%) and ‘Energy consumption per cycle’ (55%) are the pieces of information on a future energy label that are most important to show.

In general, referring to water and energy consumption, participants seem to prefer getting this information per wash cycle rather than the annual consumption levels or per kilogram laundry.

Comparability of energy label values

When respondents were asked ‘How important is the comparability of the energy label values of a combined washer-dryer with the values of a …‘washing-machine’?’ around 78% of respondents admitted that the comparability of energy label values is very important or important for them (Figure 3.77). It is important to note that for over 90% of Italian respondents the comparability of the energy label values of a combined washer-dryer with the values of a washing-machine is very important or important, while the level of importance is the lowest for the UK respondents (around 72%).

Respondents were also asked of the same question regarding a tumble-dryer. Results were almost identical to those presented for the comparability with a washing-machine (Figure 3.77).

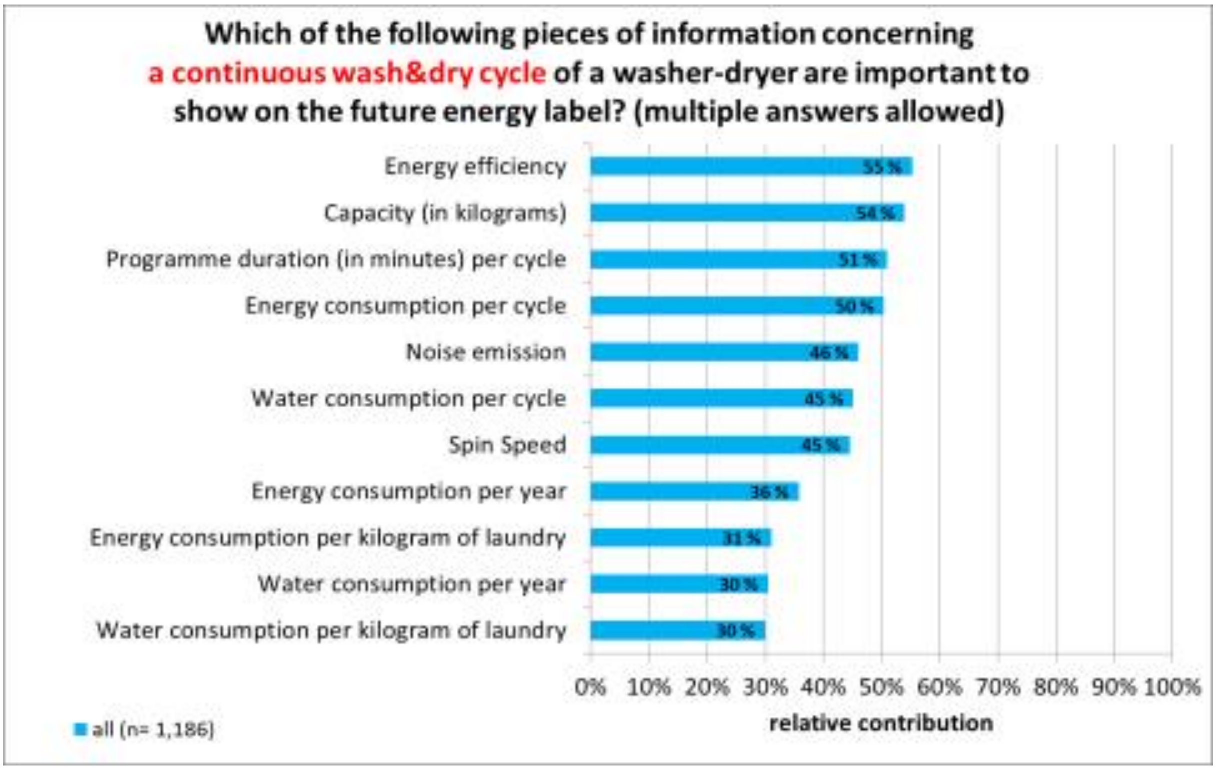


Figure 3.76: Information most important to show on a future energy label concerning a continuous wash&dry cycle; source: (Stamminger et al. 2015)

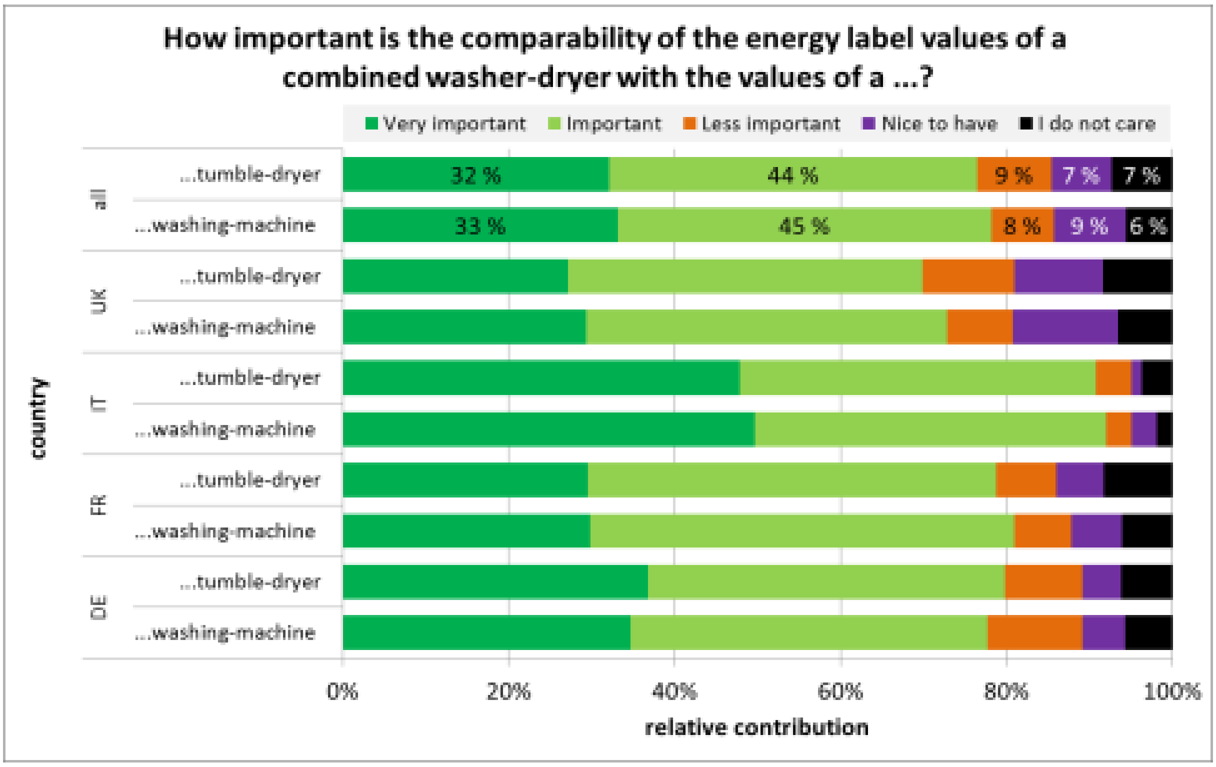


Figure 3.77: Comparability of the energy label values of a combined washer-dryer with the values of a washing-machine and a tumble-dryer; source: (Stamminger et al. 2015)

Summary of the 2015 consumer survey on washer-dryers

To sum up, the main outcomes of the 2015 consumer survey on washer-dryers are:

- The consumer survey has shown clearly that the dominant use of a washer-dryer is as a washing machine.
- The most important purchase features of a washer-dryer based on priority were, in descending order, 'Purchase price', 'Low energy and water consumption and associated bills', 'Simple and easy to use', 'Expected washing performance', 'Availability of short programmes' and 'Load capacity closer to my needs'.
- Around 90% of all washer-dryers in the survey have a continuous wash&dry option.
- Average rated capacity of a washer-dryer is as follows:
  - Washing: 6.9 kg
  - Drying: 5 kg
  - Wash&dry: 5.3 kg
- Average number of washing and drying cycles in a washer-dryer for households only owning a washer-dryer with continuous wash&dry function is as follows:
  - 4.6 wash cycles per week, whereof 1.5 wash cycles are done in the continuous wash&dry process
  - 2.9 drying cycles per week, including 1.5 continuous wash&dry cycles
- The most important option that consumers are willing to do for saving energy and money is using the energy saving programme offered by their appliances. Accepting longer programme cycles was the least popular option selected by the respondents. There seems to be some misunderstandings regarding the necessity of longer programme times and the saving of energy in energy-saving programmes. In addition, when respondents answered accepting longer programme cycles, it is not clear how long they meant exactly.
- Maximum acceptable time for a continuous wash&dry cycle for about 70% of respondents is less than three hours. These results confirm the fact that saving water and energy is important for people but not at the expense of time.
- Important information to show on the future energy label (continuous wash&dry cycle) were, in descending order,
  - Energy efficiency
  - Capacity in kg
  - Programme duration (in minute) per cycle
  - Energy consumption per cycle
- Referring to water and energy consumption, participants seem to prefer getting this information per wash cycle rather than the annual consumption levels or per kilogram laundry.

3.1.2.2. User survey on washer-dryers 2011 by University of Bonn

A user survey was designed in 2011 by the University of Bonn to collect information on the use of washer-dryers in Europe. European consumers were asked about their household equipment, the frequency of use of washing and drying cycles, the chosen washing temperature, the typical practices of drying depending on weather and the availability and use of the 'wash&dry' option (continuous washing and drying in a row). The results of this consumer behaviour study were published in 2012 (Schmitz & Stamminger 2012).

For this study, answers from 1,000 consumers of 10 European countries were collected via internet with the support of a market research institute. Pre-requisite was that participants of the study owned a washer-dryer and were mainly involved in the household activities; additionally half of all participants had to be female.

On average, more than a half of respondents lived in family households (Figure 3.78). The share of family households was very high especially for Italy, Czech Republic, Hungary and Poland (60 to 80%). Family households were followed by couples households (about 30%) and single-person households (about 16%). Just a minor share of respondents (2%) said that they live in a multi-person non-family household. The average number of individuals living in a household resulted to be equal to 2.8 people.

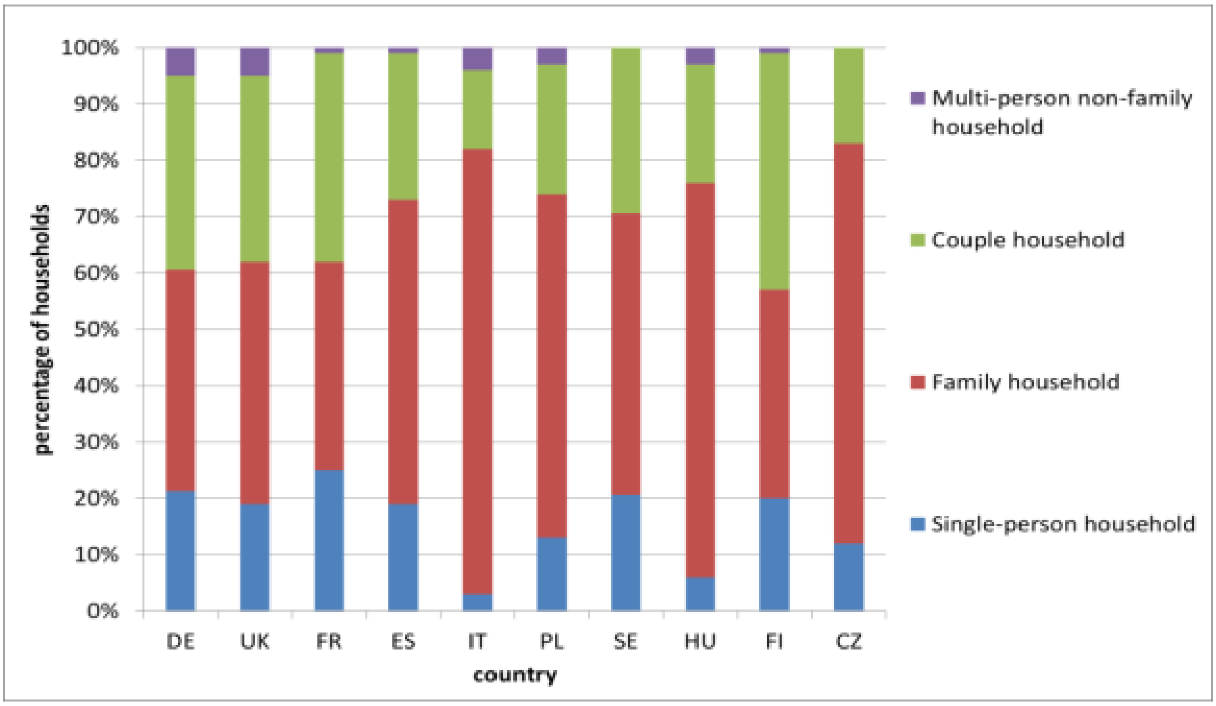


Figure 3.78: Family size of households with a washer-dryer per country (Schmitz & Stamminger 2012)

Purchase reasons for a washer-dryer

For more than a half of respondents, the main reason for purchasing a washer-dryer is in the lack of space for both a washing machine and a tumble dryer (Figure 3.79). Nearly 40% of the participants to the survey answered that the additional drying function was considered an important option when buying a washer-dryer. Also the price of one appliance in comparison to two separate appliances was a frequently mentioned argument (34%). About one quarter of the respondents indicated that they need the possibility of choosing a 'continuous wash and dry' option.

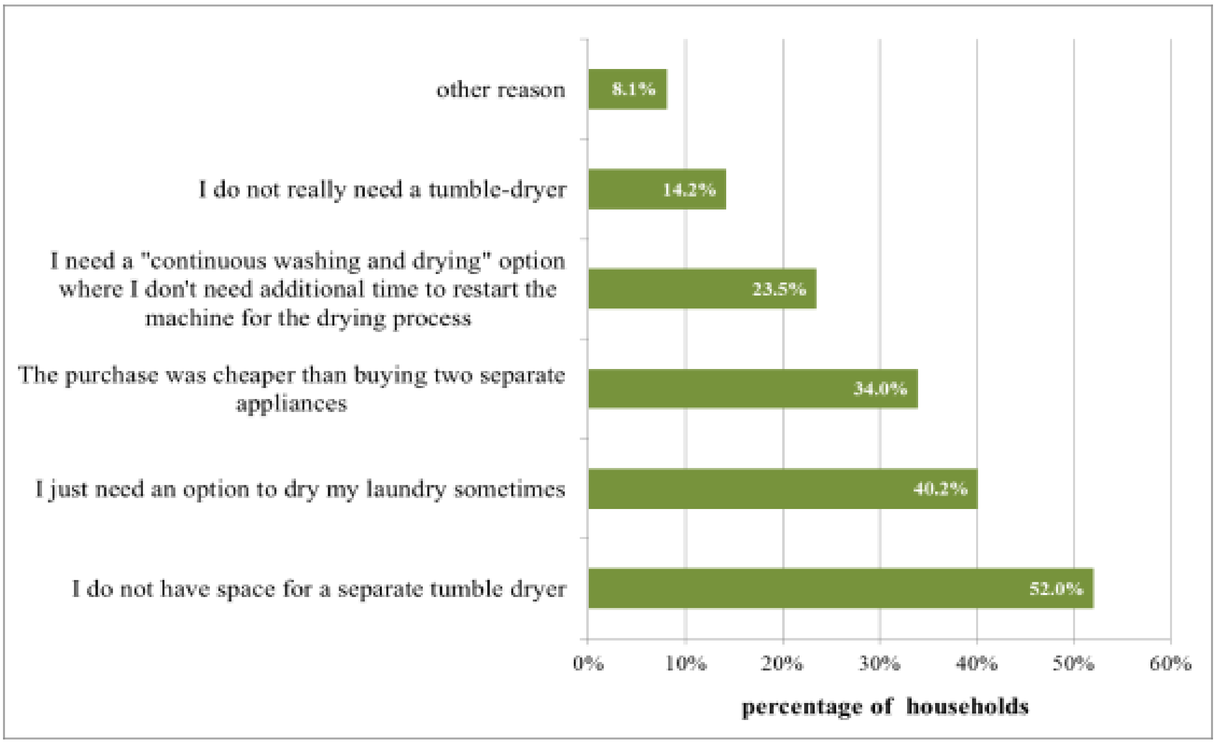


Figure 3.79: Reasons for buying a washer-dryer instead of a washing machine and dryer, or just a washing machine (Mult answers allowed) (n = 1,001 households) (Schmitz & Stamminger 2012)

According to the information gathered through this survey, a washer-dryer seems to be an appliance that is often owned in addition to a washing machine or tumble dryer, especially in Italy, Spain, or Poland (Table 3.15). A washer-dryer and a washing machine were jointly present in nearly 37% of the households while 18% of the households seemed to have a tumble-dryer and a washer-dryer.

Table 3.15: Share of additional appliances next to a washer-dryer in several EU Member States (Schmitz & Stamminger 2012)

	country									
	DE *% of hh*	UK *% of hh*	FR *% of hh*	ES *% of hh*	IT *% of hh*	PL *% of hh*	SE *% of hh*	HU *% of hh*	FI *% of hh*	CZ *% of hh*
Washing machine	42%	27%	27%	48%	54%	46%	25%	40%	38%	26%
Tumble dryer	18%	22%	20%	30%	25%	19%	7%	14%	18%	9%

Frequency of operation

The results of the analysis show that the average number of washing cycles per household is 4.3 times per week. This is 13% higher than the results out of the consumer survey 2011 for washing machines only by the University of Bonn (average number of wash cycles in washing machines being 3.8 times per week, cf. Figure 3.37), again highlighting the uncertainty behind this parameter.

The frequency of washing cycles per week in a washer-dryer is high especially in Italy, Spain and Hungary (Table 3.16). There seems to be an apparent correlation between the household size and the number of wash cycles (Figure 3.80).

Table 3.16: Relative frequency of wash temperatures used 2011 (according to (Schmitz & Stamminger 2014))

	country									
	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
number of households	99	100	100	100	100	100	102	100	100	100
total number of people	225	264	259	334	321	316	227	317	244	292
total number of wash cycles per week	367	458	362	484	627	440	337	478	347	441
wash cyles per week per household	**3.7**	**4.6**	**3.6**	**4.8**	**6.3**	**4.4**	**3.3**	**4.8**	**3.5**	**4.4**
wash cyles per week per person	**1.6**	**1.7**	**1.4**	**1.4**	**2.0**	**1.4**	**1.5**	**1.5**	**1.4**	**1.5**

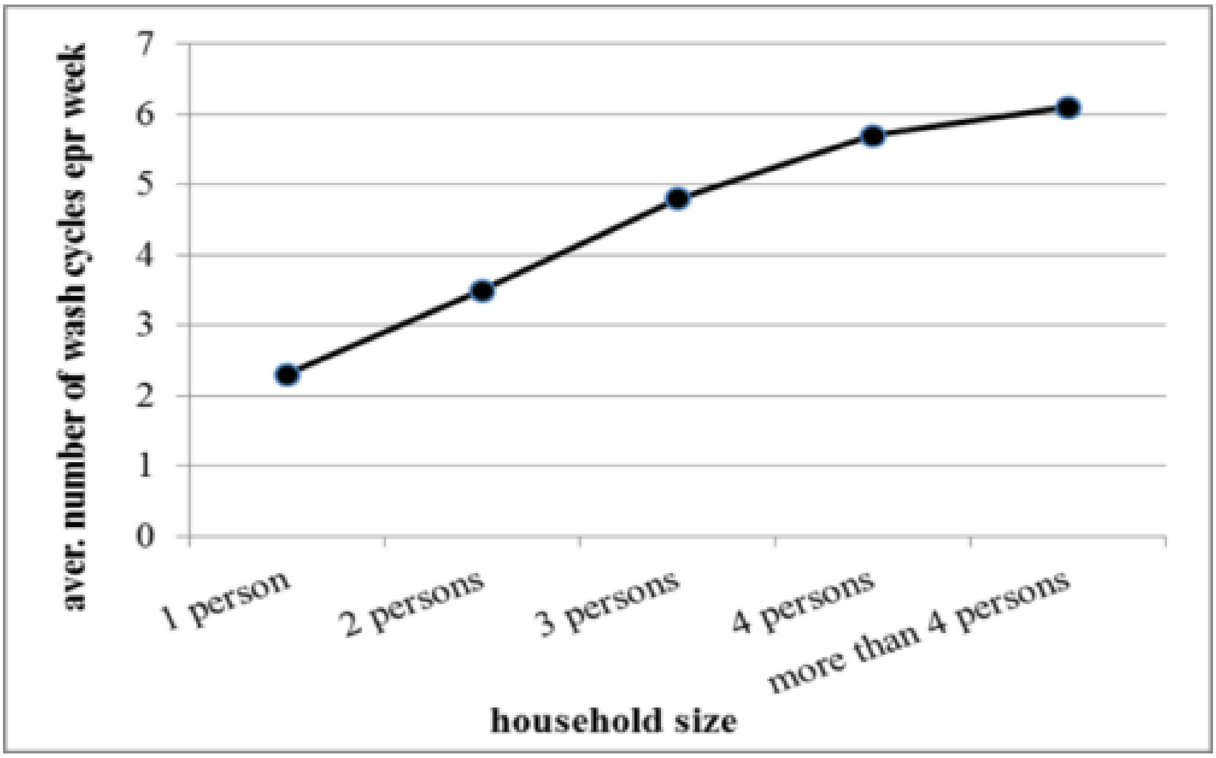


Figure 3.80: Correlation between the size of household and the number of wash cycles (Schmitz & Stamminger 2012)

Programme temperature (washing)

In a range from 20 °C up to 90 °C, the most frequently used washing temperature was the 40 °C washing programme (32.3%), followed by the 30 °C and the 60 °C programme in similar percentages (20.4% and 18.2%, respectively), cf. Figure 3.81. Results appear in general consistent with those obtained in the user survey 2011 for washing machines (cf. Figure 3.39).

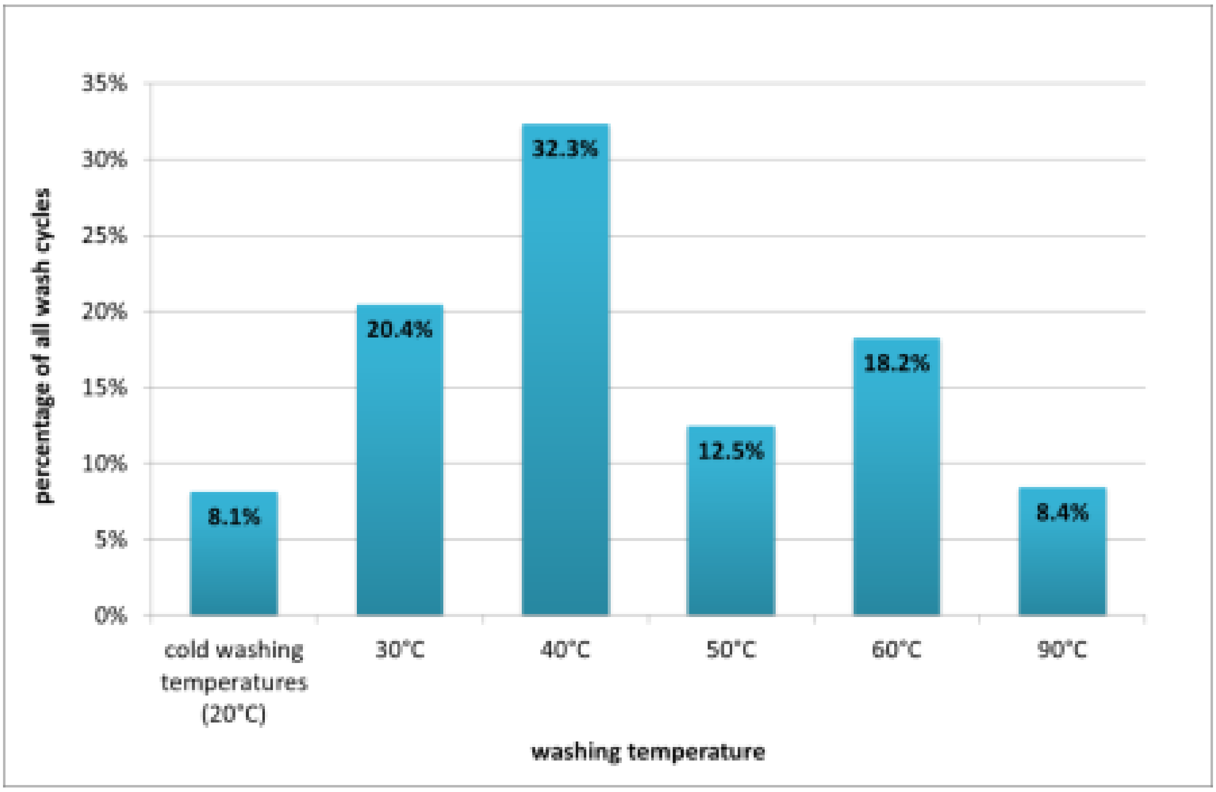


Figure 3.81: Distribution of used washing temperature per week of a washer-dryer (n=4,341 wash cycles) (Schmitz & Stamminger 2012)

Drying behaviour

The participants of the study were asked which practices of drying they use for their laundry. Difference was made between drying of clothes in summer (under conditions of fine weather) and winter (under conditions of foul weather) (Figure 3.81).

Visible differences in drying behaviours were registered depending on the season. In summer nearly 70% of respondents mentioned to dry their laundry outside on the clothes line. In comparison, only 16% answered to choose this option in winter (Figure 3.82). Results also suggest that the laundry is often/always dried in a heated room of the house when the outdoor temperature is lower. This was answered by approximately 60% of the participants to the survey. Comparing these figures to the results of the consumer survey 2011 done by University of Bonn for washing machines only, the trends are similar (cf. Figure 3.46): in summer around 55% drying their laundry outside on a clothes line; in winter around 51% drying their laundry inside in a heated room.

The drying option of the washer-dryer is used rather sometimes, rarely or never. In winter the drying option is used of nearly 43% of all households often or always. In summer these results are minor with 23%.

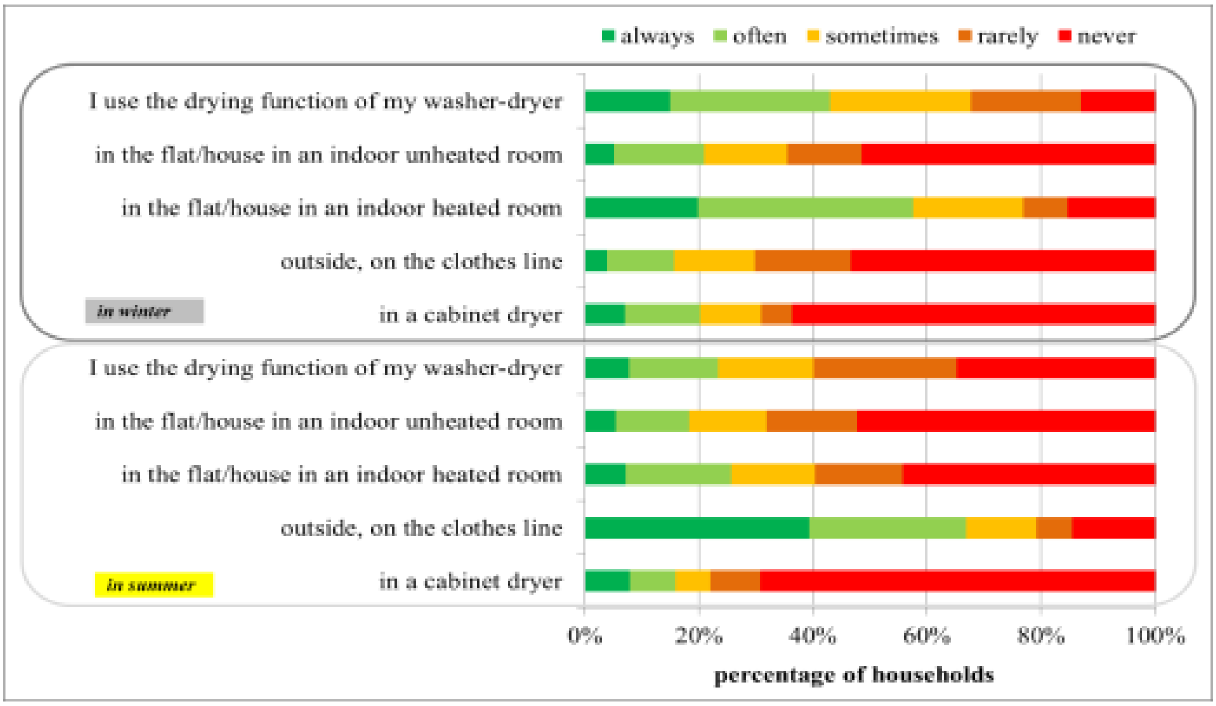


Figure 3.82: **Drying behaviour in winter (at foul weather) and in summer (at fine weather) valid n = 963 households (Schmitz & Stamminger 2012)**

The 'wash&dry' option, i.e. the possibility of washing and drying the clothes in one row, was mentioned by consumers to be an important purchase factor for washer-dryers. Nearly 71% of the owned washer-dryers had this option implemented. This was especially the case for Italy and Spain (Table 3.17).

Table 3.17: **Percentage of washer-dryers having the option of continuous 'wash&dry' (Schmitz & Stamminger 2012)**

	country									
	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
Yes	73 %	74%	74%	79%	82%	60%	59%	72%	62%	71%

On the other hand, it is interesting to observe that, although nearly one quarter of respondents indicated that this is an important option to consider for buying a washer-dryer, 20% of participants answered that they never used this option (Figure 3.83), although it is not clear if they do not use it because being unavailable or because not being interested in it.

This behaviour is visible especially in British and Swedish households, where the 'wash&dry' option was reported to have been never used in 40% of households (Figure 3.84). In comparison, the continuous washing and drying option is used more in Italy, Poland, Spain and Hungary, with an average of 1.4 wash cycles per week and household (Table 3.18). The average for all countries was calculated to be 1.1 wash cycles per week and household using the continuous wash&dry option.

Thus, the 'wash&dry' function was approximately utilised only in 24% of all weekly wash cycles. Again, a small positive correlation between the average number of washing cycles using the 'wash&dry' option and number of individuals per household (r=0,218, p <0,001) is also visible. However, the frequency of using the 'wash&dry' option grows when the household size increases (Figure 3.85)

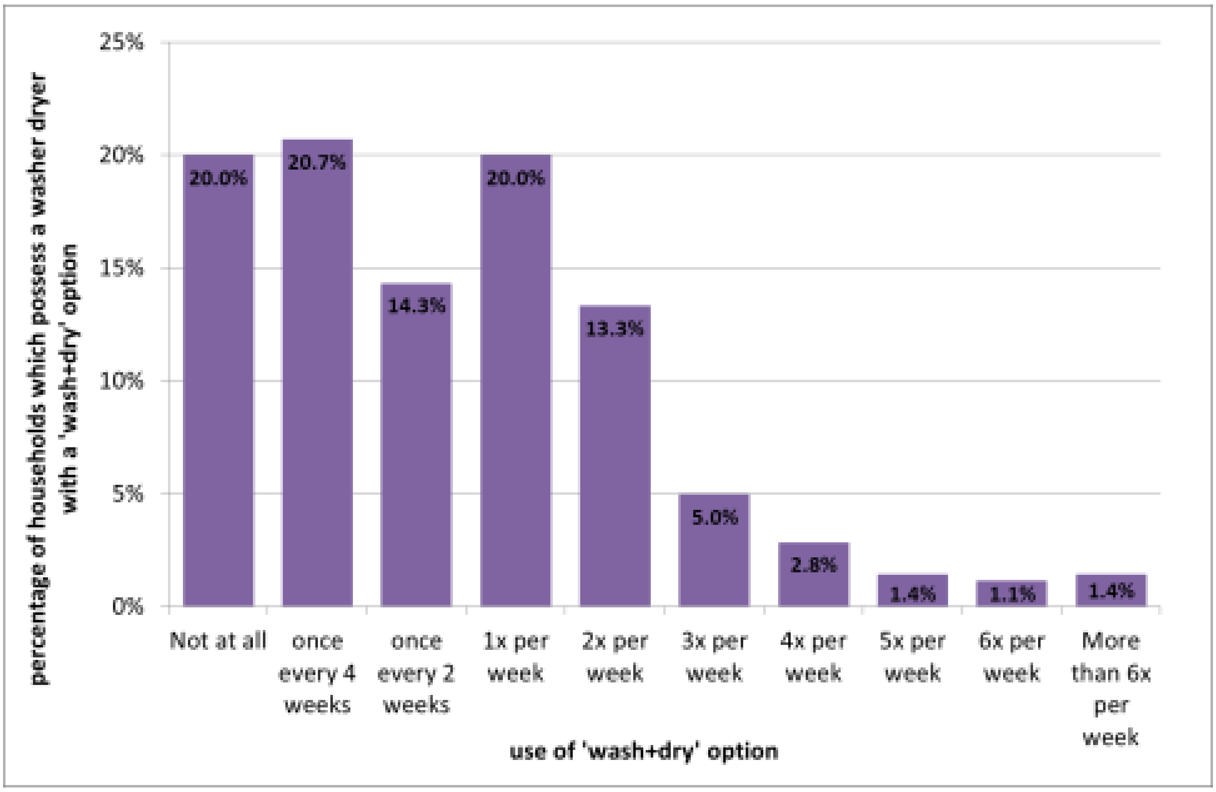


Figure 3.83 **Use of 'wash&dry' option (n= 706 hh) (Schmitz & Stamminger 2012)**

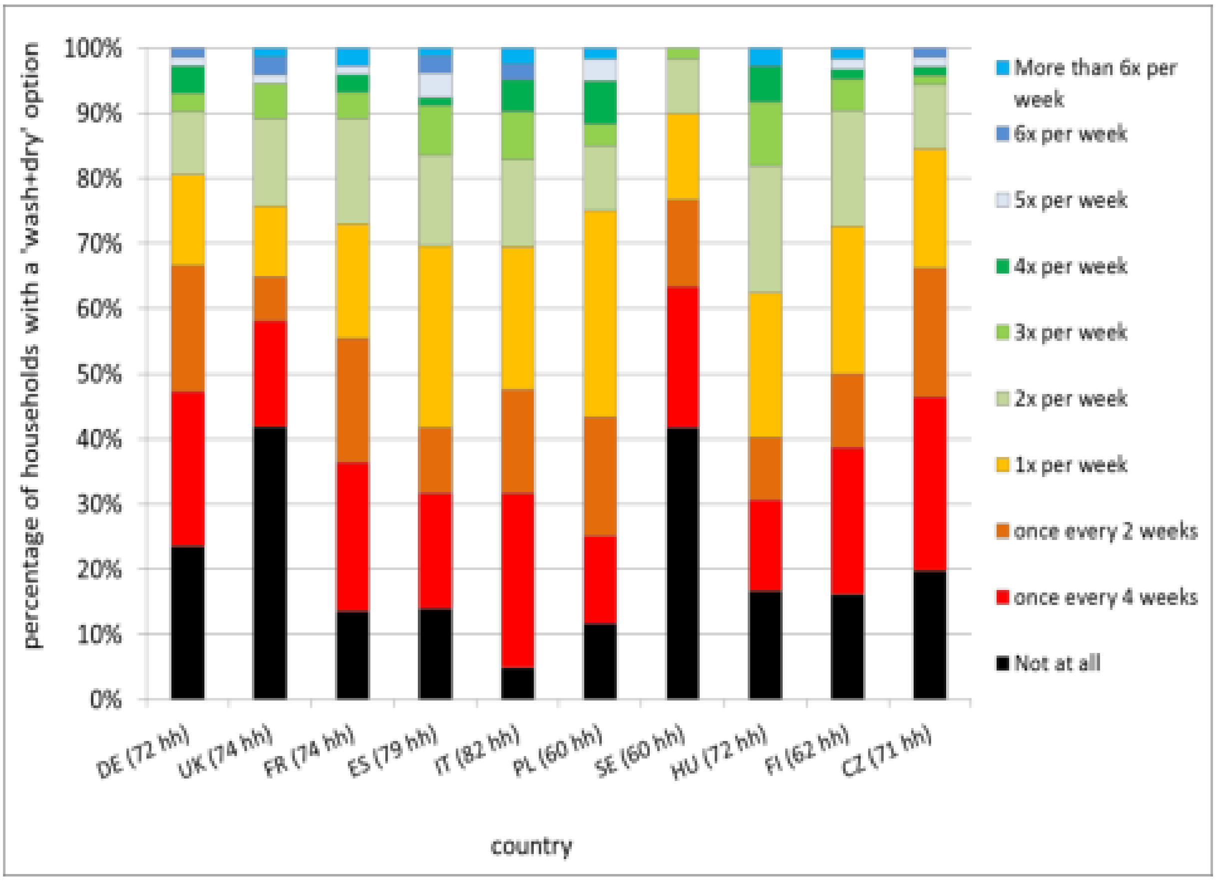


Figure 3.84: **Use of 'wash&dry' option per country (Schmitz & Stamminger 2012)**

Table 3.18: Wash cycles with the use of 'wash&dry' option per country (Schmitz & Stamminger 2012)

	country									
	DE	UK	FR	ES	IT	PL	SE	HU	FI	CZ
number of households with washer dryer with "wash & dry" option	72	74	74	79	82	60	60	72	62	71
total number wash cycles per week	270	355	259	405	501	299	194	345	224	343
total number of wash cycles per week with "wash & dry" option	64	70	84	108	112	78	28	101	68	57
percentage of wash cycles with "wash & dry" option	24 %	20 %	33 %	27 %	22 %	26 %	15 %	29 %	30 %	17 %
wash cycles per week with "wash & dry" option per household	0.9	0.9	1.1	1.4	1.4	1.3	0.5	1.4	1.1	0.8
wash cycles per week per household	3.75	4.79	3.50	5.12	6.11	4.98	3.23	4.80	3.62	4.82

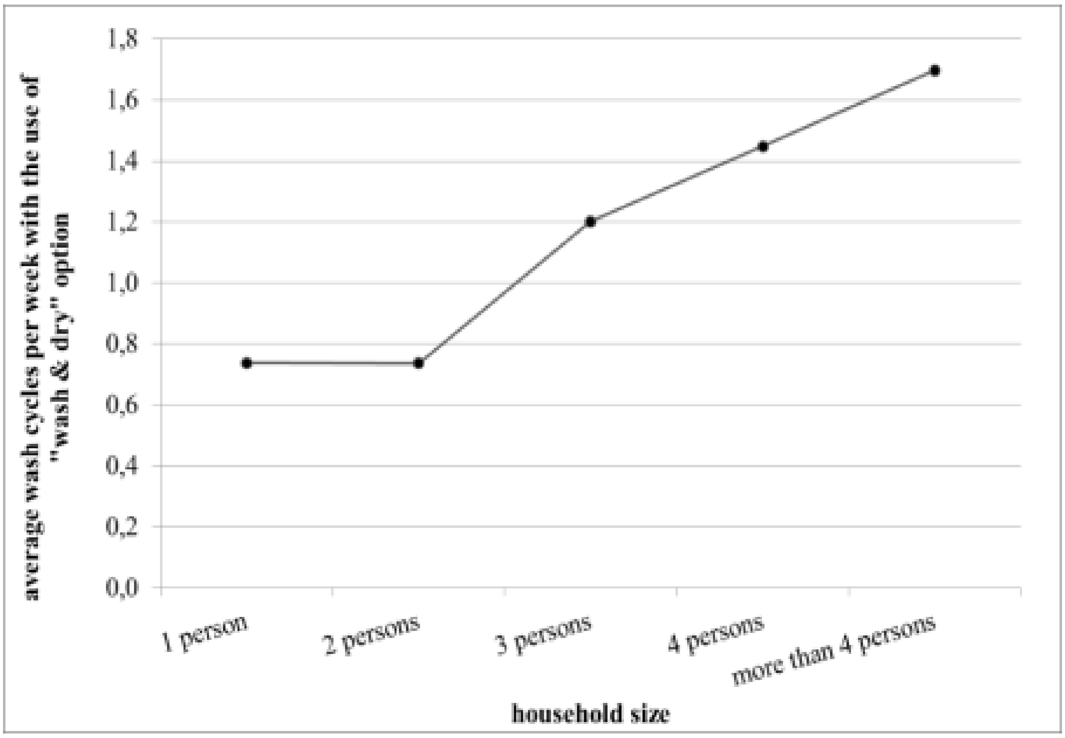


Figure 3.85: Average wash cycles per week with the use of 'wash&dry' option depending on household size (Schmitz & Stamminger 2012)

The reason why consumers don't use the 'wash&dry' option (number of answers = 141 households) can be explained by the practices of drying preferred by consumers (Figure 3.82).

The 'wash&dry' option will not be used at all in households where it is preferred to dry laundry on the clothes line (Figure 3.86). Further, 25% of users reported that they do not use such option to get better drying results or because of the need to separate delicate clothes. Other reasons are the long duration of the cycle and the need to split the load to prevent wrinkles.

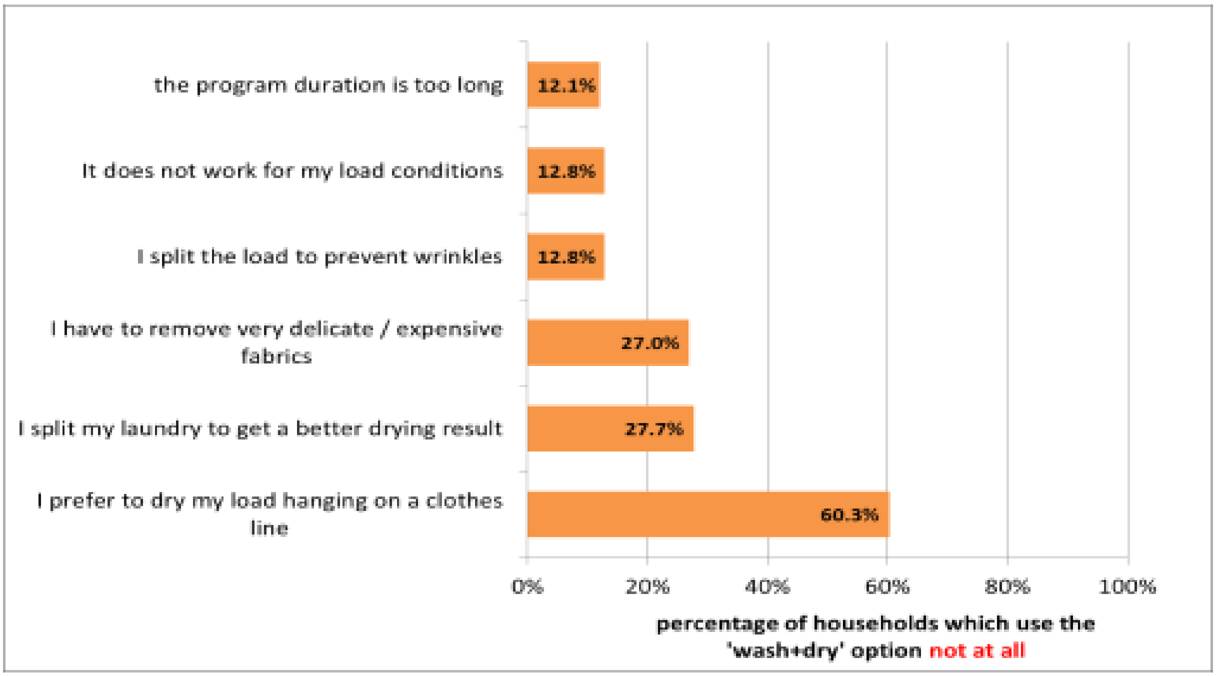


Figure 3.86: Reason for 'not at all' using the 'wash&dry' option (n=141 households) (multiple answers allowed) (Schmitz & Stamminger 2012))

The result of the drying behaviour depending on weather or season indicated that the drying (only) option of the washer-dryer is not frequently used (Figure 3.82). The answers showed that only in 29% of all wash cycles the drying (only) function of the washer-dryer was used by the consumers. With an average of 1.3 drying cycles per week, the frequency of use of the drying only cycle was minimally higher than the average number of continuous 'wash+dry' cycles (1.1). Only minor percentage of consumers indicated they never chose this option (Figure 3.87) but rely on other ways of drying.

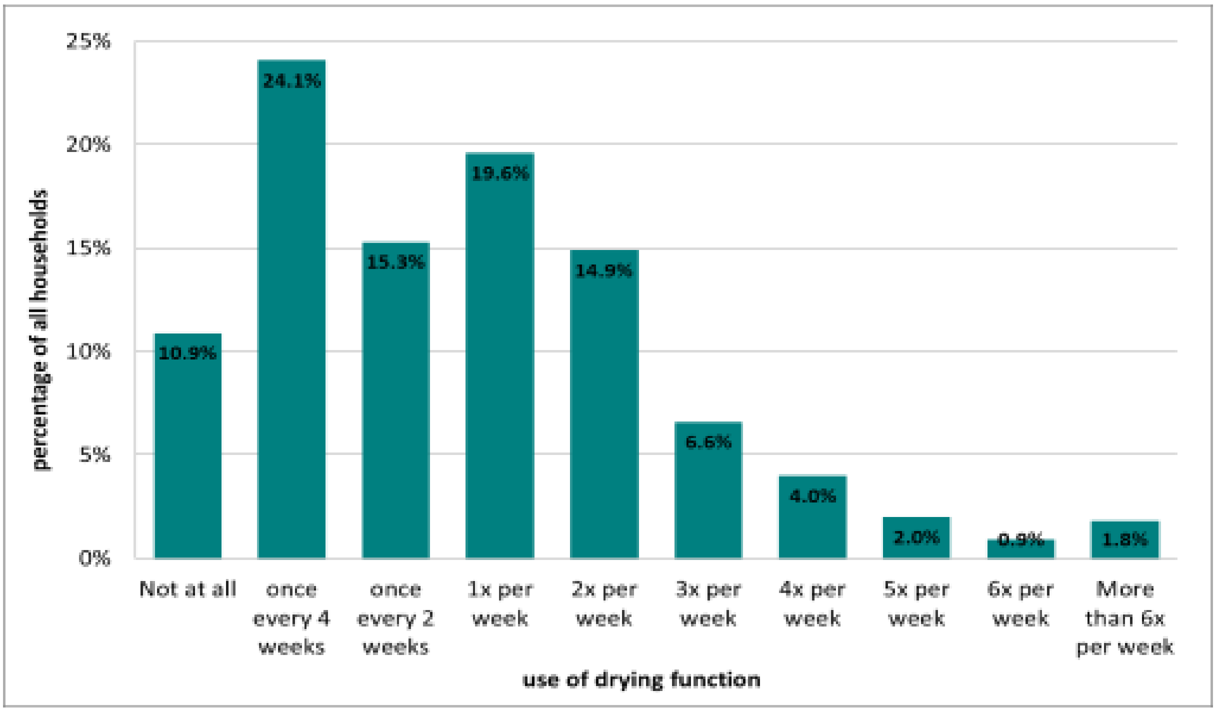


Figure 3.87: **Use of drying only function per week (n = 1.001 households) (Schmitz & Stamminger 2012)**

3.2. Results of the 2015 consumer study on clothes washing and drying

3.2.1. Frequency of operation

Washing machines

According to a user survey carried out throughout Europe by the University of Bonn in 2011, the average number of washing cycles in Europe has decreased from 4.0 to 3.8 cycles per week, in 2011 the average number of wash cycle per week ranged from 3.5 (France, Czech Republic and Sweden) to 4.1 (Italy, Poland and the UK). Furthermore, the average of wash cycles per person per week is 1.3 for the year 2011.

Based on the survey of AISE in 2011, the average number of wash cycles per household resulted to be 3.2 times per week. Data from the Water Energy Calculator reports that households use the washing machine on average 4.7 times each week, lower than previously used data (5.5 times per week).

In summary, although there are differences in the data gathering methodologies, these surveys confirm that there are about 4 wash cycles done per household per week in Europe.

Washer-dryers

Based on the survey of University of Bonn in 2015, the average number of wash-only cycles per household is 3.1 times per week, the average use of 'wash+dry' cycle is 1.5 wash cycles per week, and the average numer of dry-only cycles is 1.4 cycles per week and household.

3.2.2. Selected programme temperature

Washing machine

Based on the survey of University of Bonn, on average, around 40% of washes are done at 40 °C. However, the washing temperatures are quite variable in different countries. The second most used temperature is 60 °C (19%). About 5% of the washes are done at 90 °C programme. The weighted average of these nominal washing temperatures is 43.3 °C (actual temperatures may be lower).

The analysis of selected temperature classes by AISE shows that on average the laundry is washed with a temperature of 41.0 °C.

Results of IKW illustrate that the average washing temperatures (calculated using the nominal washing temperatures) have dropped from 63 °C to 46 °C in almost 40 years (1972 to 2010).

These results show that the average temperature of the wash cycle has decreased and that lower temperatures are getting more important. The average lies probably at about 40-45 °C. Programmes at higher temperature have higher energy consumptions.

Washer-dryers

Based on the survey of University of Bonn of 2011, the most frequently used washing temperature is 40 °C (32.3%), followed by 30 °C and 60 °C in similar percentages (20.4% and 18.2%, respectively).

3.2.3. Loading

Results of the survey carried out by the University of Bonn in 2011 shows that almost 60% of respondents claimed to use the full capacity of their washing machine.

Results of AISE in 2011 illustrate that the majority of consumers in various countries load their washing machines 75 up to 100% full.

3.2.4. Spin speed and drying behaviour

Washing machine

The 2011 survey from the University of Bonn shows that on average, European consumers spin dry their laundries at a spin speed of 941 rpm.

According to the responses obtained, on average, 55% of drying in the summer takes place outside, on a clothes line. This drying method decreases in winter to about 40%. In winter time, the preferred option seems to be the drying of clothes in a heated room inside the house (51%).

Washer-dryers

In line with the results of washing machines presented above, there is a tangible difference in drying behaviours depending on the season. In summer, nearly 70% of respondents mentioned to dry their laundry outside on the clothes line. In comparison, only 16% choose this option in winter. Results also suggest that the laundry is often/always dried in a heated room of the house when the outdoor temperature is low (66%). The drying option of the washer-dryer is used only sometimes, rarely or never. In winter, the drying option of the washer-dryer is used often or always in nearly 43% of all households. The frequency of use of this option is lower in summer (23%).

3.2.5. Further results

Further key results are summarised in the followings:

- Laundry processes in private homes do not involve only the use of washing machines or washer-dryers. For calculating the overall resources consumed during the laundry process, pre-treatments, drying and ironing of clothes are also relevant processes to take into consideration (IKW 2009).
- According to (IKW 2009), the highest amount of energy (52%) is used for tumble drying through a laundry process.

- The optimal detergent dosing volume depends on numerous factors such as water hardness, degree of soiling, type of textile, load volume and machine dimension. According to (Sanner 2011), approximately 90% of customers do not consider all these dosing factors relevant, and thus likely dose detergents incorrectly.
- Based on these GfK data, Prakash et al. (2015) show that the average first useful service-life of large household appliances (covering washing machines, dryers, dishwashers, ovens, refrigerators and freezers) in Germany has declined slightly from 14.1 to 13 years between 2004 and 2012/2013. On average, the product replacement of large household appliances due to a defect slightly decreased from 57.6% in 2004 to 55.6% in 2012.
- WRAP (2011a) identified that typically, a washing machine donated to a preparation for reuse organisation is 4-5 years old in the UK. This is likely to be the point at which the item has reached the end of its economic life for the first owner (e.g. it requires a repair the owner has decided not to undertake). With a technical life of 12 years, this suggests that a reused item may last up to 8 years in its second life. The technical lifetime can typically be extended by refurbishment. Data describing refurbishment periods are limited, but the WRAP study assumed that refurbishment occurs once and extends the lifetime of a washing machine by 6 years (1500 cycles). The share of consumers replacing still functioning appliances to get a better device is increasing. For washing machines, 14% of the replaced appliances were less than 5 years old in 2012 (10% in 2004).

3.3. Consumer behaviour with regard to end-of-life

3.3.1. Consumer attitudes and perceptions regarding the lifetimes of electrical products

In a study commissioned by WRAP, current British consumers' views, attitudes and perceptions of the lifetimes of electrical products were explored. Inter alia, the study covered washing machines as large household appliances, "workhorse products", being heavily and prolonged used. The findings are based on desk research, interviews to focus groups and a nationally representative survey carried out in England and Wales. (WRAP 2013b)

- <u>Consumers' knowledge about the product lifetimes</u>: According to the results of the study, consumers were not knowledgeable about how long washing machines can last. Evaluation of the lifetimes of products was based on a combination of 'general knowledge', sources of knowledge available during the purchase process, and proxies to make assessments about the lifetimes of comparative products. Younger respondents were less likely to have personal experience about how long these products can last, and some consumers also had doubts about whether the lifetime of products can be accurately measured. The main sources of information consumers thought they can access during the purchase process to evaluate and compare the lifetimes of different products are online reviews made by other consumers. However, consumers primarily relied on brand and to a lesser extent on price as proxies for the lifetime, expecting that well-known brands and more expensive products will last longer. Manufacturer warranties were also considered positively as indicating trust of producers on the durability of their products. The participants of the study were interested in long guarantee/warranty periods because these would ensure that products can be quickly repaired or replaced if they break down. (WRAP 2013b)
- <u>Importance of product lifetimes for consumers</u>: The WRAP study revealed that product lifetimes are not primary aspects considered by consumers when buying products, although acknowledged to be important. Typically, product lifetimes are not expressed directly but are inferred through other elements as quality, reliability and durability. When asked, consumers said they do consider product lifetimes of washing machines important, and this is common to different socio-demographic groups. Lifetime was considered an aspect of quality to avoid inconvenience and costs due to repair or replacement of broken appliances. Older consumers and persons with lower

income or with a savings-driven mind-set appeared to give particular importance to the product lifetimes. (WRAP 2013b)

- Consumers' expectations on product lifetimes: On average, consumers of the British WRAP survey expected washing machines to last for six years. Older consumers and consumers living alone or without children, expected products to last longer than other consumers, which may reflect the lesser frequency and intensity with which they use these products in comparison to consumers living in larger households and with children. Consumers were not oriented to replace domestic appliances, inter alia washing machines, before the end of their functional life and wanted them to last as long as possible. Equally, the majority said they were satisfied with how long current products last, although the level of satisfaction was lower for washing machines. Satisfaction with lifetimes of current products was linked to how long consumers expected these products to last. Those with high expectations were also generally those who were most satisfied, suggesting previous experiences have shaped both expectations and satisfaction. (WRAP 2013b)
- Consumers' pull for longer product lifetimes: According to the findings of the WRAP study, the key barriers to the uptake of products with longer lifetimes are the secondary attention given in general to this issue by consumers, the current lack of information and advertising on product lifetimes, and consumers' distrust on manufacturers. The key opportunities for increasing the pull for longer lifetimes are the underlying importance of lifetime for consumers, their appetite for more information about product lifetimes, and the malleability of consumers' priorities during the purchase process. Examples of clearly communicated product lifetimes were identified by participants (Kia cars 7 year guarantee and Ikea in-store product testing demonstrations). Interest in products with longer lifetimes is not confined to a small subgroup of consumers: around half of consumers indicated they would be willing to pay more for products that are advertised to last longer (on average, they would be willing to pay 10% more). More than eight out of ten consumers also indicated they would be willing to pay more for products that are advertised to last longer and have a longer standard guarantee or warranty. The future uptake of more durable products could be maximised if these are accompanied by longer standard guarantees or warranties – both as element of trust for consumers and as advertisement hook. Consumers were also receptive to advertisements emphasising the benefits of longer lasting products, and to the provision of sound information on product lifetimes through mainstream channels. (WRAP 2013b)

In the current European consumer survey by University of Bonn on washing machines in 2015 (cf. section 3.1.1.1), the participants were asked to indicate 'which information they would expect to see on the future Energy label' (multiple answers were allowed). Inter alia, participants appreciated an additional indication of information which is not listed on the current Energy label, including 'Expected lifetime of machine' (42%) being on a future Energy label. This result backs the consumer attitudes of the WRAP study regarding importance and information need about product lifetimes.

3.3.2. Product use & stock life

Whereas this section describes the *consumer behaviour* with regard to the duration of the product use, in section 0 the product lifetime is analysed from a *technical* point of view (i.e. time to failure of critical parts).

(Prakash et al. 2015) analysed data of the Society for Consumer Research (GfK) for large household appliances in Germany with regard to the developments of the average "first useful service-life". This indicator is the timespan in which the product is *used* only by the *first* consumer; it is – however – not to be confused with the technical product lifetime. The technical product lifetime might be longer compared to the first useful service-life if the appliance is still functioning and is for example passed on within family members and/or to friends or resold to third persons. The GfK data is based on a consumer survey asking for the reasons in case of purchasing a new product (desire for such a product (because no such product was possessed until that moment); wish for an additional product; defect of the old appliance;

desire for a better appliance despite functioning of the existing one). In case of replacing existing products, GfK asked for the first useful service-life of the existing product; the GfK data did not provide information about potential second-hand use of products still functioning, i.e. the overall technical lifetime. This can only be derived for those products that were replaced due to a defect (cf. section 4.5.5.1).

The results of the study show that **the average first useful service-life of large household appliances at all (covering washing machines, dryers, dishwashers, ovens, refrigerators and freezers) in Germany has declined slightly from 14.1 to 13.0 years between 2004 and 2012/2013** (Prakash et al. 2016).

On average, the product replacement of large household appliances due to a defect slightly decreased from 57.6% in 2004 to 55.6% in 2012. This means that a defect still is the main cause of the replacement; on the other hand, it is important to realise that almost **one third of the replaced large household appliance was still functional**. In 2012/2013, the proportion of devices that were **replaced because of a desire for a better device, although the old device still worked, was 30.5% of the total product replacements**.

Extracting the data specific for dishwashers, the results show that the average first useful service-life of dishwashers in Germany nearly stayed the same with 12.1 years in 2004 and 12.4 years in 2012/2013. Considering only those appliances still functioning but being replaced due to a wish for a better appliance, the average first useful service-life was 11.7 years in 2004 and 11.4 years in 2012/2013.

Attention has to be drawn to the aspect that the share of consumers replacing still functioning appliances *rather early* to get a better device, increases. For dishwashers, 18% of all appliances being replaced on the basis of the wish for a better one were **less than 5 years old** in 2012 (while in 2004 this was around 13%).

3.3.3. Installation, maintenance and repair practices

In April 2014, University of Bonn has conducted an internet-based consumer survey in Germany "An empirical survey on obsolescence of appliances in households" (Hennies & Stamminger 2015) aiming at identifying reasons for obsolescence of different household appliances, inter alia washing machines; the results are published within the research project "Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence" (Prakash et al. 2016).

In this survey, 308 out of totally 734 appliances (42%) were repaired once in their lifetime. Half of the machines (50%) were not repaired at all. 13% of the 299 respondents answered that the repair has been done during the legal warranty period, whereas 82% of the repairs occurred after the warranty period.

In 2013, RReuse has conducted an investigation into some of the main obstacles its members encounter when repairing products, inter alia for washing machines, to provide part of the basis for setting requirements within implementing measures to improve the reparability of products, and thus their material and resource efficiency. Based on a questionnaire sent out through their network, the findings are answers from 9 individual reuse and repair centres from four national networks of social enterprises namely AERESS (Spain), Repanet (Austria), Réseau Envie (France) and the Furniture Reuse Network (UK).

The study revealed the following common obstacles in repairing household washing machines (RReuse 2013):

- Lack of access and cost of spare parts
    - Respondents noted a lack of access to spare parts both from the point of view of their availability and price. For example, when ball bearings are pressed into the plastic casing

of the drum, in order to replace them, not only do these have to be replaced but also at least part of the casing. However, in many cases reuse and repair centres are forced to purchase the complete casing including the drum which is very expensive, which makes it often uneconomic to repair the machine.

  - Replacement costs of the electronic card and timer are very expensive as one needs exactly the same component from the original manufacturer in order to repair a washing machine. Whilst reuse centres can repair the appliance using tested salvaged components from obsolete machines, stocking up key used spare parts such electronic boards, timers and pumps is very difficult due to the sheer volume of different types of makes and models of products on the market.

- Lack of access to service manuals, software and hardware
  - The exact documentation, service manuals and relevant software and hardware to diagnose the faults of the product are difficult to access for reuse and repair operators that are not official after sales service providers of the manufacturers.
  - Today's increasing use of electronic instead of mechanical components means that one can often only identify the problem with the appliance by attaching it to a laptop using special hardware and using fault diagnosis software. Use of these tools requires training and are often only available to the after sales service providers of the manufacturers which makes repair of washing machines for reuse centres often impossible due to a simple lack of information.
- Examples of design that hinders disassembly for repair:
  - Control board: Finding the defect in the electronic board is becoming increasingly difficult, especially if some boards are sealed with resin. This means that electronic board components which are most known to fail the quickest can often be very difficult to access and replace.
  - Door Hinges: Door hinges that are fused to the washing machine are extremely difficult and time consuming to replace due to accessibility
  - Repairing the drum spider, seals, bearings and drum casing is often impossible, especially if the bearings are forced into the 'plastic' outer casing of the drum. This is especially because of the price needed to replace these components and also because there are some instances where the drum casing is impossible to open as it is physically sealed.

According to stakeholder feedback obtained during this study, maintenance and repair are very important, and more important with more efficient machines. Products are provided with extensive installation instructions to ensure that maintenance and durability are not impacted. For washing machines, for example, filter cleaning on a monthly basis is relevant for maintenance. General cleaning of surfaces including door gasket is recommended. Hot washes are also recommended every couple of months for avoiding build-up of detergent. One stakeholder assumes if products are installed in a kitchen that is used by more than one household (e.g. in student dormitory buildings), it can be expected, that product maintenance is on average not as good as for a product used by only one household. This will then also reduce the durability.

A stakeholder has provided examples of typical maintenance and repair instructions given in user manuals (cleaning of the washing machine, cleaning of the detergent dispenser drawer, cleaning the pump, use of descaling agents in case of very hard water). To facilitate repairs, certain tools are provided: technical assistance service; fault code in the user interface indicating the suspected cause of breakdown; PC diagnostic tool to detect faults by the technical assistance and to update the software.

According to feedback from one stakeholder, spare parts usually cost too much (cf. also section 2.3.2), leading consumers to buy new products instead of repairing the old one. High spare part costs are often combined with high labour costs and design options that impede repair. Another stakeholder points out that for essential household appliances such as dishwashers and washing machines consumers can usually not manage without them for a longer time. Offering a similar product as a loan to cover the repair time would make repair more attractive.

Regarding repairs, in September 2014, Portuguese consumer organization DECO Proteste published a study on washing machine repair services. In the context of the study, DECO contacted 29 different repair shops/services for a small repair of a specific washing machine. Many of the services made an incorrect diagnosis of the malfunction, others charged for pieces that were not replaced and others didn't present a correct invoice for the service. Such situations can create a feeling of mistrust from consumers regarding the repair services. For small repairs, consumers could even avoid a repair service. However, the lack of information on how they can repair the appliance themselves is an impediment to that.

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used following generic input data for the category "Maintenance, repairs, service" of washing machine models in 2007 (Table 3.19).

Table 3.19: Average input data for maintenance, repairs and service of a 5 kg washing machine model used by Lot 14 in 2007; source: (ENEA/ISIS 2007c)

Maintenance and repairs needs for a 5 kg washing machine	Amount
Number of km over the product life for the maintenance and repairs service	160 km / product life time
Spare parts (fixed value: 1% of product materials and manufacture)	723 g
(ISIS 2007c)	

The total amount of spare parts was estimated to be 1% out of the total weight of the appliance. As spare parts for washing machines might be sometimes lighter (e.g. keys, seals, sensors, electronics) and other times heavier (motor, suds container, shock absorber), and there is no clear indication which components fail more often (cf. section 4.5.5.2) this approach seems to be a good approximation.

160 kilometres over the product life for maintenance and repair service seems high. As the results of the German consumer survey from University of Bonn (see above) indicates, less than 50% of appliances are repaired at all during their lifetime. Further, it can be assumed that at least in cities, the distance of a repair service is not that far, otherwise, as consumers often have to pay costs for the distance travelling of the repair service, the repair would not be done at all if the distance costs sum up too much.

3.3.4. Collection rates, by fraction (consumer perspective)

(Huisman et al. 2012) describe the following possibilities for consumers to get rid of no longer used (waste) electric and electronic equipment (WEEE), inter alia large household appliances like washing machines and washer-dryers.

- <u>Municipal collection point</u>: Also called 'waste transfer station' or 'container park'. Households discard bulky household waste like furniture, hazardous waste and also WEEE at these container parks. By law, municipalities are obligated to have at least one location where households can discard waste like furniture, chemical waste and also WEEE. From these collection points, most WEEE is handed over to the system of the compliance schemes (treatment plants being in compliance with at least the minimum standards required for accreditation). Another possibility is that municipalities sell WEEE or dismantled fractions like copper cables to metal scrap processors to receive more money than the reimbursement per ton collected from the compliance schemes.

- Retailers: When households buy new equipment, they can hand in the old item ('old for new'). Retailers having a contract with the compliance schemes will hand over the received equipment to recyclers that are under contract of the compliance schemes. Some of the contracted retailers, however still deliver such equipment outside the compliance scheme. Retailers without a contract can still legally sell WEEE to local or regional metal scrap processors.
- Door-to-door collection: Households can also choose to give or sell WEEE to door-to-door collection which mainly happens in cities or being announced by local collectors collecting metals and used EEE. Driven by high metal prizes informal collection pathways exist and obviously the collected WEEE will never be handed over to the system of the compliance schemes.
- Charity initiatives: Charity initiatives often work in close cooperation with municipalities and businesses. Their main function is to sell 2nd hand appliances, if still functioning, to other consumers.
- 2nd hand/internet market: Usable equipment will be sent from one household to another. Strictly speaking, this is not WEEE but it affects the amounts of WEEE since the equipment can be used for a longer period. In order to prevent double counting of equipment, it is necessary to exclude the 2nd hand market from the WEEE prediction model.

Due to the large size of devices, disposal via the municipal household waste is believed not to be relevant in terms of quantities. For Italy, (Magalani et al. 2012) state that for large household appliances the two main disposal paths are through municipal collection points and retailers. Regarding retailers, large household appliances are mostly picked up at consumers' homes 75-95% of the time, often in conjunction with the delivery of new equipment. See Table 3.20.

Table 3.20: Disposal channels for large household appliances used by consumers in Italy in 2012; source: (Magalani et al. 2012)

	Average disposal channel of large household appliances*
Municipal collection points	39.1%
Retailers	37.1%
Reuse (sold or given away)	8.0%
Bad habits (e.g. waste bin, plastic waste, other wrong streams)	5.8%
Life extension (old house...)	5.3%
Do not know, do not remember	4.1%
Warranty replacement	0.6%

* Note: In this study large household appliances subsume: dishwashers, washing machines, wash dryers and centrifuges, furnaces and ovens, and microwave ovens. The rates within these waste streams might vary, e.g. the re-use rate is 1.5% for boilers and 20% for microwave ovens. Further, the likelihood of improper disposal practices appears negatively correlated with the size of the equipment, i.e. for washing machines and washer-dryers the values might be smaller.

According to stakeholder feedback via questionnaire, about two-thirds of e-waste is managed by commercial actors without the involvement of producer responsibility schemes.

3.3.5. Estimated second hand use, fraction of total and second product life

According to (WRAP 2011a), washing machines are thought to pass through a wide range of pathways once they have reached the end of their first life. This may be via direct reuse (e.g. passed on to friends and family, sold in online networks, or given to a charity), retailer „take-back" schemes, bulky waste collections and drop off at Household Waste Recycling Centres. Owing to their bulk, washing machines are not thought to be disposed of through regular household waste collections. In their case study on benefits of reuse, WRAP indicates that 97% of the washing machines are sent to either recycling (43%) or landfill (54%), meaning that 3% might be reused.

In section 3.3.4 above, (Magalani et al. 2012) estimate the re-use rate (appliances sold or given away), of large household appliances in Italy 2012 to be 8%. However, this data covers dishwashers, washing machines, wash dryers and centrifuges, furnaces and ovens, and microwave ovens. Especially for re-use, the rates vary, e.g. the re-use rate is 1.5% for boilers (fix installed) and 20% for microwave ovens (smaller appliances). This leads to the assumption that the rate for large household appliances such as washing machines and washer-dryers might be lower than 8%.

Refurbishment for reuse only takes place in cases where it is economically viable. According to (WRAP 2011a), on average, of the machines received by reuse organisations, 25% are sent to recycling immediately, with another 10% sent to recycling after initial testing. The result is a low level of reuse of washing machines. In the UK approximately 100,000 washing machines (6,700 tonnes) are reused in some form every year. This represents 3% of all washing machines reaching the end of their life each year. Preparation for reuse by charitable and private organisations currently accounts for just 1.5% of discarded washing machines in the UK, while 1.3% are reused directly via online exchanges or otherwise.

(WRAP 2011a) identified that typically, **a washing machine donated to a preparation for reuse organisation is 4-5 years old.** This is likely to be the point at which the item has reached the end of its economic life for the first owner (e.g. it requires a repair the owner has decided not to undertake). With a life of 12 years, this suggests that a reused item may last up to 8 years in its second life. The technical lifetime can typically be extended by refurbishment. Data describing refurbishment periods are limited, but the WRAP study assumed that refurbishment occurs once and extends the lifetime of a washing machine by 6 years (1500 cycles).

For washing machines, stakeholders describe that the market for re-used and remanufactured products or components has the character of a “grey market”, which is not well-organized; some retailers offer this “service”. It has been also reported that re-used washing machines and washer-dryers are mainly reconditioned in charity like operations and offered for sale to target customers with lower incomes. However, for example an outlet selling 2nd hand household appliance has been found in Italy (Omar Degoli 2015).

4. Task 4: Technologies

This section aims at collecting information on technologies and preliminarily identifying the main product options for which it could be relevant to perform an environmental and economic assessment in the following Tasks 5 and 6, as for instance:

- Typical reference products available on the market (for building Base Cases),
- Product (design) options with improved performance,
- Best available technologies on the market (BAT),
- Technologies for improving energy/resource efficiency not yet available on the market (BNAT).

Before going into details of the product specific technologies (cf. section 4.3 ff.), first in section 4.1 the general principles of the laundry process in private homes will be explained, as it does not only involve the use of washing machines or washer-dryers. For calculating the overall resources consumed during the laundry process, pre-treatments, drying and ironing of clothes are also relevant processes to take into consideration (IKW 2009). Figure 4.1 shows the share of energy demand of a laundry process. According to (IKW 2009) the highest amount of energy (52%) is required for drying.

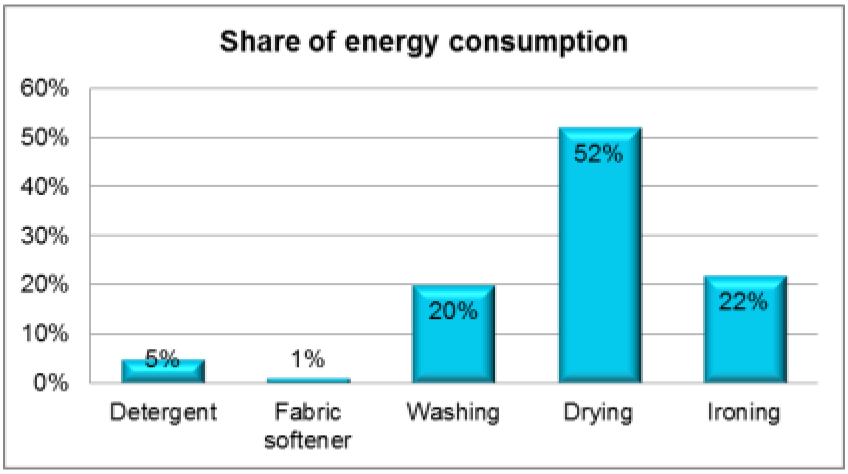


Figure 4.1: Share of energy deamand for a laundry washing process; (according to (IKW 2009))

In the following, each factors of the laundry process are explained separately, but also the interlinkages and mutual interferences between the single steps. Additionally, in section 4.2, aspects of the local infrastructure influencing the laundry process are shortly described.

4.1. System aspects of the laundry process – General principles of washing, drying and ironing

4.1.1. Laundry washing

Laundry washing, in the sense of cleaning textiles in aqueous liquor, is a complex process involving the cooperative interaction of numerous physical and chemical influences. In the broadest sense, . washing can be defined as both removal by water or by an aqueous detergent solution of poorly soluble residues, as well as the dissolution of water-soluble impurities (Jakobi & Löhr 1987), (Smulders et al. 2002)). Terpstra defines the primary objective of cleaning as "…restoration of the fitness for use and the esthetical properties of the textiles, e.g. removal of soil, stains, odours and creases and regaining surface smoothness and thermal isolation" (Terpstra 2001).

4.1.1.1. Sinner's Circle

The washing process is described as a function of four different factors: washing temperature, chemistry (types, ingredients and amounts of detergent), time (length of washing cycles), and applied mechanical work. It is best described by using a circle, which many researchers today refer to as Sinner's Circle (Sinner 1960), as presented in Figure 4.2.

The mechanical work depends on several factors: the speed of the outer drum side, the dropping height of the laundry, reversing rhythm of the drum, loading ration (laundry amount to drum volume); liquor ratio (laundry amount to water amount); construction of the drum casing shield.

Temperature is influencing the washing result as higher temperatures dissolve the soil easier and faster; certain detergent substances are effective at higher temperatures (bleaching) or in a temperature optimum (enzymes); high temperatures have a germicidal effect.

The washing liquor further needs a certain time for a sufficient contact with the textiles and the soiling; and the necessary energy in a laundry process often is compensated by a longer programme duration.

(Stamminger 2010) even adds a further fifth parameter, water (inner circle), which represents the combining element of all factors.

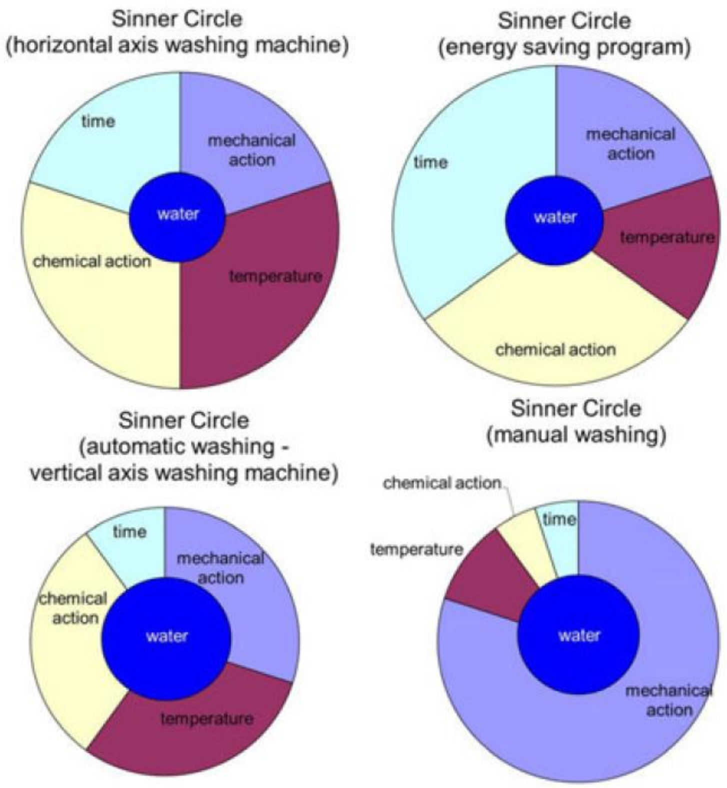


Figure 4.2: Sinner's Circle; source: (Sinner 1960) cited in (A.I.S.E 2013)

If one is to get the same target washing result (washing performance), these factors depend on each other, i.e. one factor cannot be reduced without increasing one of the others. For example, a decrease of the temperature can be partially compensated by increasing either one or more of the other factors, i.e. chemistry, washing time or mechanical agitation (Wagner 2011), (Kutsch et al. 1997).

The combination of different factors depends on the washing technique employed. In the case of washing laundry by hand, the portion of the mechanics is much higher than the portion of the washing time. Laundry washing in a washing machine at a higher temperature results in a higher contribution of the temperature in the washing process.

4.1.1.2. The typical phases and programme types of a washing cycle

The typical phases of a washing cycle are:

- Pre-rinse: offered as additional option; a pre-rinse is carried out without detergents, for taking out all kinds of loosely bound soils.
- Main wash: depending of the chosen programme , it is carried out with different water levels and wash rhythms (from sensitive or hand-wash to intensive)
- Main Rinses: 2 to 4 rinse phases and different water levels; an additional rinse is carried out when for example a temperature below 60 °C is selected, if there is too much foam in the drum, a spin speed lower than 700 rpm has been selected or no spin has been selected.
- Spinning: final spinning in all programmes for water extraction; depending on the chosen programme additionally an interim spinning phase
- Anti-crease: At the end of every programme, with exceptions like e.g. the Wool programme, the drum continues to turn at intervals for up to 30 minutes to help prevent creasing. The door can be opened to remove the laundry at any time during the anti-crease phase.

The different programme types of the main wash cycle mainly differ in the reached temperatures, the levels of water consumption, the intensity of wash rhythms, the number of rinses, the length of different phases, and the number of spinning and their speed. The panorama of washing programmes is broad and various. Examples of typical washing programmes are provided in the following:

- Cotton 20 °C/ Cold wash
- Cotton 30 °C
- Cotton 40 °C
- Cotton 60 °C
- Cotton 90 °C
- Synthetic / Easy care 30 °C
- Synthetic / Easy care 40 °C
- Standard cotton 40 °C (Eco)
- Standard cotton 60 °C (Eco)
- Quick wash / Short
- Wool / Hand wash
- Mix / automatic (all fabrics)
- Other wash programmes

4.1.1.3. Detergents

Dosing detergent seems to be an easy process. However, the optimal dosing load depends on numerous factors such as water hardness, degree of soiling, type of textile, textile load and machine dimension. According to (Sanner 2011) approximately 90% of customers do not consider all these relevant dosing factors and therefore dose detergents incorrectly. The consequences are manifold.

Both, over and under-dosage, result in lower washing performance and a negative impact on the environment. In case of over-dosage both water and detergent are wasted, if under-dosage, one would need to repeat the laundry. The waste of detergent is obvious and analysis shows that in average 4.8 kg of detergent is wasted per household and year (Sanner 2011).

In contrast, the waste of water is not as obvious, but it is a result of the excess use of detergent. Extra detergent leads to the foam creation inside the drum. The majority of washing machines on the market are able to detect foam and take counteractions. In order to get rid of excess foam, rinse cycles are added, rinse duration is prolonged and the water level in the tub is raised. When using a powder detergent, which includes a fraction of insoluble components (e.g. zeolites), it is also necessary to rinse out not only loaded soil but also detergent residues. Therefore, there is a need for an easier and more precise detergent dosing process, which allows the consumer to consider all relevant dosing parameters to achieve continuously perfect washing results and furthermore actively practice sustainability.

In this regard, for example, automatic detergent dosage technologies have been recently introduced on the market, cf. section 4.4.2.7.

4.1.1.4. Low washing temperatures and hygiene

The temperatures indicated in care labels of clothes are maximum temperatures the garment allows to be washed at, according to the assessment of the garment producer. However, it is not necessary that these temperatures given on the care label are necessary to remove soiling, and there is no additional indication of where the temperatures shall be reached: inside the clothes or in the wash water, or for how long.

As a matter of transparency, one may think that consumers expect some relation between the temperature indicated with the programme name, and the one actually reached on the washing machine. The consumer survey conducted by University of Bonn in 2015 indicates a degree of tolerance to this, and it has shown (Figure 3.21) that only 21.8% of the consumers would expect no deviation or a deviation of <5 °C between the real and the nominal temperature (of an energy-saving programme). Some 40% of consumers would accept a deviation of 5 to 10%, and 24.1% of consumers a deviation of 10 to 20% or more.

The UK consumers' magazine Which? published in September 2013 experts' views on this matter (Adrian Porter 2013):

1. Professor Bill Grant, emeritus professor of environmental microbiology at the University of Leicester, explained that 'bacterial spores and some viruses are quite resistant to 60 °C. The major sanitizing effect of the domestic wash is the removal – rather than destruction –of bacteria and viruses. Modern detergents contain an aggressive mix of surfactants which dissolve fats, bleaches that target stains, and, in biological detergents, enzymes designed to dissolve fat, protein and starch glue that binds microbes to the fabrics. These work much better at low temperatures than years ago, when higher temperatures were necessary to achieve the same results.'
2. On the other hand, Lindsey McManus from Allergy UK said that 'to denature house mites, a washing machine needs to maintain a temperature of at least 60 °C for 20 minutes and then rinse thoroughly.'

However, tests results published by Which? in November 2013 (Adrian Porter 2013) showed that none of the tested appliances maintained 60 °C for more than very few minutes (for details see section 2.2.6.2).

(Stiftung Warentest 2013) presents similar findings concerning the temperature reached during the 60 °C energy saving cotton programme.

According to feedback received by a stakeholder, reduced washing temperatures would not generally cause any hygiene problem. It was reported that even washing at low temperatures (30 °C) is leading to a high germ reduction on textiles (Honisch et al. 2014). The increased use of low temperature programmes would however demand high temperature maintenance cycles from time to time to avoid contamination of appliances with biofilms causing malodours, e.g. 60 °C washes using a general-purpose powder detergent every month (A.I.S.E 2013).

Hygiene would be a special issue for the treatment of clothes which could come into contact with elderly people and persons with a vulnerable health condition or for clothes soiled with faeces, vomit, blood, body fluids (including babie's nappies), or soiled by pets. In this case application of high washing temperatures for a certain minimum time e.g. according to (A.I.S.E 2013) 60 °C for 40 minutes and the use of a heavy duty powder detergent with bleach would be recommendable.

(Riley et al. 2015) indicated that 'a ten-minute wash at 60 °C is sufficient to remove most microorganisms, while a 30 °C wash is sufficient to eliminate most Gram-positive organisms'. For the destruction of spores higher temperatures up to 90 °C are required. However, according to (A.I.S.E 2013) full disinfection is outside of the scope of the normal household laundry process.

According to (Patel et al. 2006), temperature control would be easier in industrial laundering machines than in domestic washing machines. However, there is little evidence suggesting that domestic laundering is inferior to industrial laundering (Loveday et al. 2007), although fewer bacteria were detected on hospital uniforms laundered in hospitals than at home (Nordstrom et al. 2012). (Tano & Melhus 2014) found out that also tumble drying can significantly reduce the bacterial numbers (by about the same order of magnitude than washing at 60 °C). Without tumble drying, there could be the risk of promoting the proliferation of non-fermenting gram-negative bacteria, originated from the washing cycle, at least for hospital textiles.

Programmes handling hygienic aspects

Already in the preparatory study of the first revision of the ecodesign and energy label regulations (ENER Lot 14, 2007) increased attention was registered to hygiene problems and the possibilities of micro-organism reduction, like high temperatures or silver ions release. The latter was rather seen as a marketing tool than as an effective means to reduce micro-organisms.

Today, this topic becomes more important to consumers, both to ensure a clean washing machine and for certain types of laundry (towels, underwear) or specific situations (vulnerable people, contagious diseases). Thus, some manufacturers already offer special programmes (e.g. anti-mite option, anti-allergy options, and hygiene or machine cleaning programmes) that promise to effectively reduce microbes and allergens in the laundry and/or biofilms in the machine. Such programmes/options obviously increase the energy and water consumption as higher wash temperatures are necessary which also have to be maintained for a longer period of time and/or the laundry is rinsed more often.

4.1.1.5. Mechanical action – avoidance of damage to textiles

According to (WRAP 2013a), the lifespan of clothing is influenced by how it is used and maintained. Garments are generally susceptible to abrasion, stains and soiling to varying degrees depending on the circumstances of use, and certain types of clothing will need to be cleaned more frequently than others. Regarding the washing process, the frequency with which a garment is washed will affect its lifetime, and laundering at the wrong temperature is liable to shorten its life. Recent evidence suggests that many people do not sort their laundry – hence increase the risk of colours running, or of washing more delicate fabrics at the wrong temperature. People also wash their clothes frequently, out of habit rather than necessity. Many consumers are unaware of material properties, and therefore do not care for their clothes as effectively as they could: for example, they don't know whether the best way to care for a garment is to hang it up or fold it, dry it flat or on a hanger, use the loops provided or hang it by the shoulders. (WRAP 2013a)

In general, washing has a mechanical impact on the textile fibres, and it damages it with time. The longer the washing cycles, the more damage occurs. As stated above, energy saving cycles often achieve reduced energy consumption by increasing their programme duration. When a 60 °C cotton programme achieves 60 °C, it is possible to achieve the desired level of cleaning within 60 to 90 minutes. When the wash temperature is lowered to 25 to 35 °C it can take three times longer to achieve the same cleaning performance. The higher the mechanical action on the laundry, e.g. through this longer programme duration, the better will generally be the washing performance on the one hand. However, on the other hand, the length of the washing process also impacts the lifetime of fibre quality. Manufacturers can control this damage not only by shortening the washing time, but also by other actions, like using more water, less spinning, etc.

However, stakeholders remarked that textiles are damaged in a washing process not only by mechanical action but also by temperature and chemistry. For example, (Laitala et al. 2011) analysed that using lower washing temperatures can reduce wear and tear, potentially increasing clothes' lifespan. Thus, longer cycles at lower temperature are not necessarily worse than shorter cycles at higher temperatures with high detergent concentration. According to manufacturers' feedback there is no clear evidence that programme length is causing damages. Further, manufacturers highlighted the fact that they already take care of mechanical actions and textiles protection, as the machines are designed to take care of textiles. For example, drum washing machines are very gentle in comparison to tub washing machines (Asian style or US-style) because of the more even distribution of mechanical action, and the better use of gravity for mechanical action.

Different methods for measuring the mechanical action of washing machines are available at international level (IEC/PAS document which is currently expired but planned to be included into the 6th edition IEC 60456, cf. section 1.2.5.1). Manufacturers claim to use them, but according to their feedback, repeatability and reproducibility are low and the overall test effort is high.

In a recently published study (Scheid et al. 2016) the effectiveness in assessing the mechanical action and their reaction to different washing conditions, like load size, temperature and duration of the washing programme was investigated. It was the task of this study to verify this relationship and confirm that the thread removal fabric, as specified in IEC PAS 62473:2007, adds additional information to the assessment of a washing process. As a result of a wide variation of washing parameters, it could be shown that this test fabric is almost independent of the washing temperature, but shows a clear correlation with the load size and the length of the washing process. This is illustrated by the observation that the total effect of mechanical action in case of a full load wash at the maximum washing time of 5 h is almost the same as that in case of a half-load wash with only 1 hour washing time. Authors conclude, that the thread removal specimens add valuable additional information concerning a relevant parameter of the washing process.

4.1.2. Laundry drying

After the washing process, the clothes have to be dried. The washing process in a washing machine already includes the spin drying process, which mechanically reduces the residual moisture content. Depending on the spin-drying efficiency, different levels of residual moisture content remain in the clothes which afterwards have to be removed, essentially by evaporation. The energy needed to evaporate 1 kg of water from the laundry is 2260 kJ/kg.

There are different possibilities to dry clothes (see (Rüdenauer et al. 2008a; Rüdenauer & Gensch 2004)). Clothes can either be dried on a clothes line or in a dryer (tumble dryer, washer-dryer).

Drying on a clothes line

- Drying outside: No additional energy is needed if clothes are dried outside.
- Drying inside rooms:
    - Non-heated rooms: No additional energy is needed if clothes are dried inside a non-heated room.
- Heated rooms: If clothes are dried inside heated rooms, this has effects on space heating. During the evaporation process, moisture is transferred from clothes to the surrounding environment. Since the evaporation process absorbs energy, evaporation tends to cool down the laundry. The room would need to be ventilated to remove the moisture and avoid the risk of mould formation. This is done by replacing the warm and humid air of the room with drier air. As a consequence, the temperature of the room would need to be adjusted and in the winter season, this would require additional thermal energy (Gensch & Rüdenauer 2004; Rüdenauer et al. 2008a; Rüdenauer et al. 2008b).

Drying in a tumble dryer or a washer-dryer

In the following, the general principle of tumble dryers is shortly explained. The drying part of a washer-dryers is working similarly; details of the specific drying technology of washer-dryers are provided separately in section 4.3.2.2.

Tumble dryers remove moisture by blowing warm air among the freshly washed laundry. Warm air can hold more moisture than cold air. Tumble dryers mainly consist of a steel tub that spins, as well as an electric motor, a heating element, and a control device. The motor both spins the tub and turns the fan that draws air into and pushes it out of the dryer. The motor drives the tub with a long belt.

There are two basic types of tumble dryers: air vented dryers, and condensation dryers.

- Air vented dryers:
    - <u>Conventional air vented dryers</u>: In air vented dryers air is pulled into the appliance from the room, passes the heating element, and goes into the tub. There it picks up moisture in the form of water vapour. The air is pulled out by the fan through holes in the inside of the front door and passes into a lint filter and a long flexible tube (Sobey, E. J. C. 2007). The energy content of the warm humid air leaving the dryer is lost to the outside. Besides the electricity demand needed for circulating and heating the process air, air vented dryers might require room ventilation and additional energy to balance humidity and temperature (see above).
    - <u>Gas dryers</u>: Gas dryers are air vented dryers that use gas instead of electricity as heat source to dry the laundry. As with electric vented tumble dryers, warm humid air is expelled from the machine through a hose. Electricity is used to turn the drum and power the control panel, but this is less than 10% of the total electricity used by an electric dryer. Gas dryers have to be installed by a Gas Safe registered engineer. (Porter [n.d.])
- Condenser dryer:
    - <u>Conventional condenser dryers</u> also take cold, dry ambient air into the appliance, heat it and pass it through the wet laundry. They condense the moisture of the warm humid air from inside the drum with an air-air heat exchanger. Water is deposited into a container which has to be emptied regularly by the user. The heat exchanger needs to be cleaned

regularly to remain effective. Some models have a self-cleaning technology or a drain, thus manual cleaning is not necessary. As the condensing process takes place within the appliance, condenser dryers without a drain can be installed anywhere in the property (Porter [n.d.]). Energy is released in the condensation process. The energy used to heat up the air and run the appliance is kept within the room where the condenser dryer stands. Moreover, the vent air is less humid than in air vented dryers. These factors can possibly contribute to reduce the heating needs in the winter season.

– Heat-pump dryers:
  - Working principle: These appliances heat air that is pulled into the drum with the energy released by the condensation of the moisture contained in the warm humid outlet air. To do so, a heat-pump is built into the tumble dryer, including two heat exchangers, one compressor and a throttle. Condensed water is collected in the machine or drained as with a conventional condenser tumble dryer. Heat-pump dryers are more expensive but consume much less energy. Heat-pump tumble dryers save approximately 50% compared to a conventional condensation dryer, and dissipate less energy to the ambient air since the heat produced from cooling down the warm humid air and from condensing the contained moisture is reused to heat up cold dry air.
  - Refrigerant: Typically, heat-pump tumble dryers (HP TD) use approximately 270 g of R134a (tetrafluoroethane) as refrigerant for a drying process. There are also other heat-pump tumble dryers on the market which use either R407c (a blend of three different refrigerants: R32, R125, and R134a; R32 serves to provide the heat capacity, R125 decreases flammability, and R134a reduces pressure); or R290 (propane). For R134a and R407c, the amount of refrigerant in the heat-pump is between 220 g and 430g depending on different TD models; for R290, the maximum amount is 150g which is mandatory for cooling appliances where propane is usually used as refrigerant. (BSH, personal communication 2015)

All dryers can be humidity-controlled or time-controlled. Time controlled dryers stop after a certain time that is set by the user. Automatic dryers, also called sensor dryers, have humidity sensors that detect the moisture level of the laundry and stop the machine when it has reached the level of dryness selected by the consumer. Levels of dryness are defined in the standard IEC 61121, as reported in Table 4.1 Additional dryness levels are defined by each manufacturer individually, like ‘super-dry’ or textile specific programmes.

Table 4.1: Levels of dryness according to the standard IEC 61121

Programme or user requirements	Target final moisture content value μ_{f0}	Range for final moisture content for a test run μ_{fj}
Dry cotton	0%	–3% to +3%
Iron dry cotton	+12%	+8% to +16%
Synthetic/blends textile	+2%	–1% to +5%

The lower the target residual moisture content of the laundry, the higher is the effort for drying (energy, time). Generally speaking, one can say that the higher the spinning efficiency of the washing machine, the lower is the residual moisture content. The spinning efficiency is influenced by several factors: the spin speed of the washing machine, the diameter of the drum or the specific spin speed profile of the machine.

The spinning efficiency should be as high as possible (i.e. low remaining moisture content) if the laundry is dried

- in a tumble dryer, as (mechanical) spin drying is more efficient than (thermal) tumble drying in terms of energy consumption; or
- on a clothes line inside heated rooms. For households not equipped with a separate laundry room with external ventilation, spinning is essential to prevent excess humidity and consequently formation of mould.

A drawback of high spinning speeds is that this also has higher wrinkling effects, and is thus counterproductive if one intends to iron clothes (increase energy consumption when ironing), or dry on an outdoor line

4.1.3. Laundry ironing

Not all the washed garments are typically ironed. Depending on the drying process and type of cloth, the load needs different levels of flattening. In order to reduce the effort (both energy and time) for ironing, it has to be ensured that the wrinkling of the laundry is minimal. There are several factors that influence the wrinkling of the laundry and thus the potential effort for ironing:

- Spin speed: the higher the spin speed, the higher is the wrinkling of the clothes. Especially in case of subsequent line drying, higher spin speeds reduce drying time, but increase the need for ironing. This can lead consumers to reduce the spinning speed.
- Drying method: Drying in tumble dryers reduces the wrinkling and thus the effort for ironing, although need and intensity of ironing depends on the selected drying programme (with the dry cotton programme clothes can be ready for cupboard storing; clothes dried with the iron dry cotton programme have higher residual humidity that is meant to ease ironing but needs also ironing to be removed . A similar effect can be achieved if the laundry is hung up outside on a windy day.
- Final moisture content after drying: The effort for ironing is less if the textile is humid and not over-dried. In case of automatic tumble dryers different levels of residual moisture content can be selected to avoid over-drying (cf. Table 4.1). The usage of time controlled tumble dryers increases the risk of over-dry the laundry.
- The prolonged storage of laundry before ironing increases wrinkling. The laundry should be ironed immediately after the drying (when the laundry is taken off the line or taken out of the dryer).

For tumble drying EN61121:2013 (cf. section 1.2.2.3), which is also used in the EN50229 standard for washer-dryers (cf. section 1.2.2.2), defines final moisture contents for cotton loads for (cupboard) dry and iron dry programmes.

Table 4.2: Specification for final moisture content of test load after drying

Programme or user requirements	Target final moisture content value μ_{f0}	Range for final moisture content for a test run μ_{fj}	Allowable range for average final moisture content μ of a test series
Dry cotton	0 %	–3 % to +3 %	Less than +1,5 %
Iron dry cotton	+12 %	+8 % to +16 %	Less than +14 %
Synthetic/blends textile	+2 %	–1 % to +5 %	Less than +3,5 %

While the first programme 'cotton dry' is targeting to a final moisture content which will allow to store the clothes after drying immediately in a cupboard, the second programme 'iron dry' reaches a final humidity which is fit for a consecutive iron dry process. By ironing, additional energy for ironing may be consumed. But not all textiles which are dried to iron dry level are subject to a consecutive ironing process. Many textiles, especially shirts and blouses, are declared as 'iron free'. For these textiles it is recommended to dry them to iron dry status and then to hang them on a hanger and let them dry by themselves. So no additional electrical energy is used.

But also many textiles dried to cupboard dry level are subject to a consecutive ironing process. In that case, for ironing it is necessary to wet the textiles again to be able to iron out the wrinkles. Thus the ironing process does not only use the energy to heat the iron, but must also evaporate the water which is added. No information is found in the public domain about the frequency of using either the cupboard dry or iron dry process, neither on the way how ironing is done after a drying process in a tumble dryer.

Following an investigation by Braun und Stamminger for Germany (Braun & Stamminger 2011), ironing can be considered as one of the most time-consuming processes of laundry treatment, as the average time spent per week on ironing is calculated as two hours.

Ironing is not only a time-consuming but also an energy-consuming process when laundry treatment is considered. Depending on what kind of flat iron is used, energy consumption per year ranges from more than 50 kWh up to more than 90 kWh. Ironing stations need even more than 100 kWh per year. This approximation is based on the assumption that the flat iron or the ironing station is used for three hours a week [(Stiftung Warentest 2009) cited according to (Braun & Stamminger 2011)]. Detergent industry association reports that 22% of energy used for the whole process of laundry treatment is used for ironing (IKW 2009).

4.1.4. Dependencies between washing, drying and ironing

Besides the dependencies between washing / spinning, drying and ironing already described in sections 4.1.1.5 and 4.1.3 above, the overall environmental impacts of the laundry process depends on the individual consumer behaviour, e.g. the choice of the drying alternative or the frequency of ironing.

University of Bonn has elaborated a model of predicting energy and water consumption of single households for completing the laundry process (Stamminger 2011). This model is taking into account the established factors influencing the consumption of resources for laundry treatments and combining this with possible consumer behaviours. To simplify the number of combinations, six artificially created consumer segments (Table 4.3) are created and used to show the range of consumption values (cf. Table 4.3).

Table 4.3: Characterisation of consumer segments (according to (Stamminger 2011))

Consumer segment synonym	Characterisation of consumer behaviour
Modern	Average laundry behaviour
	Uses tumble dryer intensively
	Normal ironing behaviour
Do it yourself	Average laundry behaviour
	Line drying only
	Normal ironing behaviour
Careless	More than average laundry washing at higher temperatures
	Inefficient spinning process
	Uses tumble dryer
	More than average gets ironed
	Uses old and inefficient appliances
Wish-wash	More than average laundry washing at higher temperatures
	Line drying only
	Less than average ironing
	Uses old and inefficient appliances
Sustainable	Less than average laundry washing at lower temperatures
	Good spin drying
	Use of efficient tumble dryer (heat-pump technology)
	Less than average ironing
Pseudo-Eco	Less than average laundry washing at lower temperatures
	Line drying only
	Normal ironing behaviour

The applied model is able to provide relevant and plausible values for estimating the real life consumption of energy (Figure 4.1) and water (Figure 4.3) for a total laundry process in a private household in Germany. The calculations allow learning more about the influence that different consumer behaviours and installed appliances may have on energy and water consumption. Differences of a factor 4 to 6 are much larger than results of other studies where a factor 2 to 3 was found for CO_2 emissions values between different life-style groups (Baiocchi, et al. 2010). Although in (Stamminger 2011) CO_2 values were not calculated, these are related to the energy usage (primary energy, but without any conversion factors), which is one of driving factors for the laundry care process.

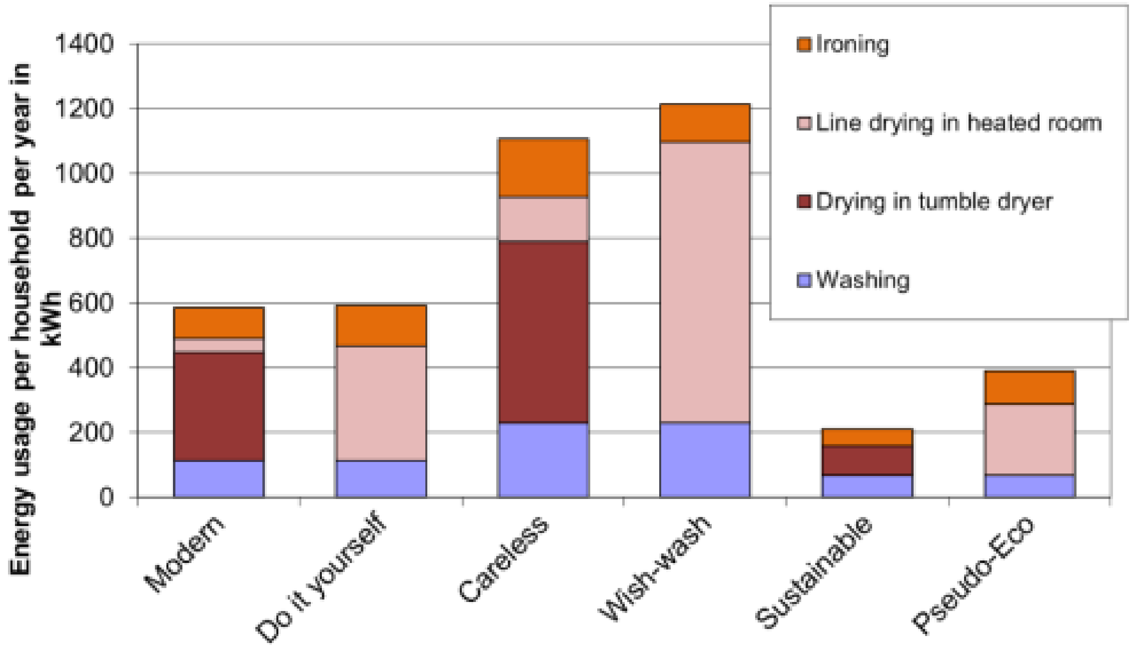


Figure 4.3: **Estimated energy usage per year for six consumer segments for laundry process; (according to (Stamminger 2011))**

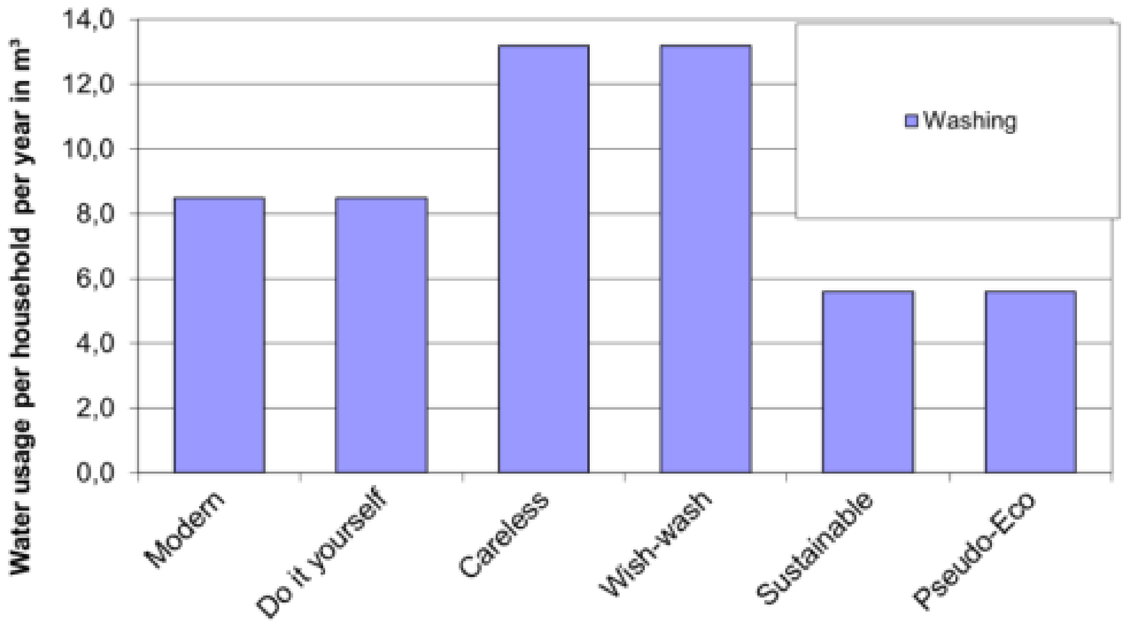


Figure 4.4: **Estimated water usage per year for six consumer segments for laundry process; (according to (Stamminger 2011))**

The results show that ironing and washing are almost using the same amount of energy, around 20 percent of the total impacts of a complete laundry process; also the energy use for ironing and for washing is typically much lower than that needed in the drying process (cf. Figure 4.3). The share of detergent and fabric softener in energy consumption is around 6%.

4.2. Local infrastructure

4.2.1. Energy

Around 70 to 90 percent of the electrical energy consumed by washing machines is used for heating the water, the laundry and the machine itself. This could be replaced by heat from other sources than electricity.

Use of hot water supply

Technical options such as heating by hot water circulation loop ("heat-fed machines") or hot fill, i.e. connecting the machines to the domestic hot water pipe, are described in detail in Chapter 4.4.2.4. Today, most household washing machines and washer-dryers can be connected to a hot water supply. Overall energy efficiency of such options, however, depends on system conditions as source of energy used (renewable water heating sources) and design and characteristics of the hot water supply network (optimal length and insulation of the hot water pipe, efficiency and control characteristics of circulation pump). For hot fill, studies show that solar hot water combined with gas heating is the option resulting in the lowest GHG emissions (Saker et al. 2015). However, according to information provided by stakeholders of this study, the diffusion of additional hot water supply connections in the EU households is limited at the moment.This is in contrast to e.g. US households, where hot and cold water connections in washrooms are commonplace.

This option is expected to achieve higher market shares in the near future as the installations of renewable energy technologies in the residential sector are supported by the Art.13 (4) of Directive 2009/28/EC on the promotion of the use of energy from renewable sources (European Parliament 2009b). According to this Directive, Member States shall introduce in their building regulations and codes appropriate measures in order to increase the share of all kinds of energy from renewable sources in the building sector.

Demand-response enabled appliances

As the energy system of the future is getting more and more variable to fluctuating energy production by wind and solar PV stations, it is necessary and helpful to have some flexibility on the demand side as well. This can be realised by appliances which offer a demand-response possibility. It is therefore useful for a more renewable energy sourced system (and a better match between generation and consumption of the energy) to support the introduction of demand-enabled appliances. Further details of this technical improvement option for washing machines and washer-dryers are provided in section 4.4.2.9.

4.2.2. Water

The following measures for a more sustainable use of water are to be mentioned with regard to infrastructure and system aspects:

- Change of use patterns: avoiding extra-rinse programmes would be a possible option to reduce the overall water consumption connected to clothes washing (except for consumers having very sensitive skin, who might use the extra-rinse function on their washing machine for better removing detergent from laundry).
- Use of grey water and rainwater: reuse of domestic greywater and rainwater has a significant role to play in water efficiency. A rainwater harvesting system can be attached to a tank where the water is finally stored until needed and using a pump the water can then be recycled through the water supply for washing machines. This is very useful as rainwater is

what is known as soft water and therefore causes no limescale which can often cause problems with filters and elements in such appliances (Claridge 2015). Rainwater harvesting systems can provide either a direct or indirect supply from the main storage tank to the appliances. In a direct system the pump sends the rainwater on demand straight to the appliance. In an indirect system, the rainwater is pumped up to a rainwater header tank, where it is gravity-fed to where it is needed. The advantage of an indirect system that pump wear and tear is reduced and 8 to 10 times less electrical power is used because the pump is activated only when the header tank is empty rather than every time an appliance is used (RainWaterHarvesting [n.d.]).

4.2.3. Telecommunication – smart appliances

Companies are racing to offer Wi-Fi connected multi-featured washing machines. These connected appliances provide the opportunity to consumers to control them remotely. Consumers could have control over almost all operations of their machines including monitoring the washing process remotely, trouble shooting, setting the cycles and several other features, to be operated and controlled via smartphones, tablets and PCs.

LG, Samsung and Whirlpool have all announced smart washing machines in the International Consumer Electronics Show (CES) 2015 with special smart features (Griffin 2015). Whirlpool's announced machines that can connect with the consumer's thermostat. Moreover, other companies have several innovations in this area.

- Whirlpool's new washing machine was revealed alongside Nest's announcement that its thermostats and smoke detectors can hook up to yet more home appliances. The Whirlpool appliance can be controlled by a thermostat, asking it to launch when it thinks that the consumer has left the house, for example and will text or email him when the clothes are ready to dry. That is part of a range of smart features built into the Whirlpool, which can also be monitored remotely using its Wi-Fi connection. The washing machine can also time itself to turn on at the most cost-efficient times of day, using electricity during cheaper off peak hours (Griffin 2015); (Doll, P., Kaspar, F. & Lehner 2003); (Kates 2000).
- Samsung's innovation is called "Active Wash", and tied together a top-loading washing machine with a built-in sink where delicate and pre-treat stains can be washed. Smart Control let the consumer remotely control and monitor the washing from anywhere by using a smartphone App. It can be instantly started or paused and cycle selections, remaining time and finishing alerts are monitored (Griffin 2015). Furthermore, easy troubleshooting is another feature of new Samsung washing machines. The Smart Check automatic error-monitoring system detects and diagnoses problems and provides easy troubleshooting solutions using a smartphone App. (Samsung).
- Siemens washing machines are equipped with an "isensoric" control unit. The isensoric control unit can precisely identify the volume of the load, its characteristics, and even the degree of soiling on the clothes. One new feature of these machines is stain removal. Each stain is different and therefore has to be treated in a special way. Once attain was manually selected on the washing machine's display, the isensoric control unit collects data from each of the sensors and determines the ideal amount of water, temperature and drum speed. In this way, 16 of the most stubborn stains are automatically and reliably removed. Another feature is i-Dos. By this feature, the amount of laundry detergent is precisely adapted to the individual load of laundry (Siemens [n.d.]).
- German appliance manufacturer Miele announced a new Miele@Home brand that will take the company's connectivity even further when it launches in 2015 by allowing users control of compatible machines even outside of their home Wi-Fi network. According to Miele, the app

will give users full control over all three machines, allowing almost all operation to happen remotely (Miele [n.d.]b).

According to (European Commission 2013c), increased frequency of internet usage, coupled with faster speeds and the growth of mobile access are accelerating recent trends in internet use and inducing new and different behaviour patterns by users. Mobile data traffic is driving an exponential increase in data transmission through the internet. Mobile devices like smartphones and tablets are increasingly moving away from being purely "utility" devices, with entertainment occupying more and more of a central role in the usage of internet on the go.

Smartphones were expected to account for more than half of all handset shipments in 2013, and the percentage was expected to continue to grow, mainly due to decreasing prices and the perceived value and greater integration of mobile apps into everyday life. However, adoption levels are not homogeneous across Europe: While in France, the UK and Ireland the penetration rate of smartphones already exceeded 60% in 2013, Greece, Portugal and Poland have adoption rates below 40% (30% in the case of Poland), all starting from below 10% in 2005. (European Commission 2013c)

In general, the increasing trend to mobile access to internet via smartphone, tablet etc. might also drive the trend towards connected household appliances in future.

4.2.4. Shared washing machines and services

Community washing centres are a well-known phenomenon. For instance, in Sweden and other Nordic countries they are practiced since 1920s, and therefore historical data are available, which will provide possibility to track evolution of these services at regulatory and normative levels. In other countries, majority of the laundry is washed in laundromats or by professional washing service companies. No community-based washing centres are usually available (Plepys & Mont [n.d.]). According to feedback from stakeholders, professional use of household appliances is covered by the machinery directive and cannot be addressed to regulations handling conventional household uses (cf. section 1.1.2.3).

In Sweden the establishment of washing services was primarily initiated in a governmental programme as a consequence of equality policies aiming at freeing time for housewives. From the middle of the 20th century a trend towards the so-called self-service economy could be seen. Following the chosen course towards integrating women into the work market, the question of assisting the washing activities got regulatory support. A number of studies followed this servicing strategy advocating collective way of doing laundry at the beginning of 60-ies, the countryside households started using private washing machines (Plepys & Mont [n.d.]). However, communal washing centres were rapidly spreading in cities and commercial washing facilities became more and more common. Later, different national authorities provided recommendations on how these centres should be equipped and designed. The regulation was so overwhelming that it gradually encompassed even standardising and guiding the design of washing centres and choice of equipment. In a few decades, communal washing centres became a standard feature in urban communities and at some point in time was even considered as an issue raising the prestige of the real estate (Plepys & Mont [n.d.]).

Today communal laundries are spread all over Sweden, where typically 50-400 households share one washing facility with one or more machines. Studies have indicated high customer acceptance in terms of the distance to the washing centre (70%), availability of washing time (50%) and quality of equipment (75%). There are also some drawbacks associated with washing centres, such as low cleanliness in the premises (60% dissatisfied) and the increased use of electrical drum-dryers. Even though the long historic record and pervasiveness of laundry services make them interesting to study in more details, surprisingly few studies on the environmental implications of these services have been made with the focus of product lifetime, energy consumption and other direct environmental impacts (Plepys & Mont [n.d.]).

New business models such as washing machines rental or a supermarket of second-hand washing machines have been also developed more recently. Leasing or renting are possible future options, based on the examples of models which already exists for cars and mobile phones (see for instance (Omar Degoli 2015). According to stakeholder feedback, however, several hurdles have been detected, mainly due to the relatively low price of household appliances, which invites consumers to buy their own appliance. The major issue is the financing model, since solutions are either very expensive or require considerable effort which entails considerable costs. Also the destination of the appliance at the end of the leasing contract is an open issue: either it remains in possession of the end-user until the end of its technical lifetime, or is taken back by the manufacturer. In the latter case, the issue of refurbishment (and the following destination of the appliance) is critical. Examples in which household appliances are sent to recycling do not exist for the moment.

4.3. Technical product description

4.3.1. Washing machines

The general principle of washing laundry in washing machines has already been described in section 4.1.1., as well as in the previous revision preparatory study (ENER Lot 14, 2007). The basic technological principles of washing machines have not changed since then.

However, neither the former preparatory studies on washing machines (ENER Lot 14) nor on tumble dryers (ENER Lot 16) have included washer-dryers in their scopes. As these appliances have specific characteristics differing from washing machines and tumble dryers, the following section will focus on the technical product description of washer-dryers.

4.3.2. Washer-Dryers

Washer-dryers are appliances that combine the washing function of a washing machine with the drying function of a tumble dryer. This means that it is possible to wash and tumble-dry the clothes in one single appliance. The washing and drying processes can be used separately or combined in a continuous wash and dry cycle.

The washer-dryer construction is based on the washing machine concept (motor, drum, water inlet, drain pump, detergent box, etc.). Additionally there are components integrated which are necessary for the drying process. A washer-dryer can thus be considered as washing machine with the additional function of drying.

Space is a critical factor in the design of washer-dryers since in Europe the outer dimensions are usually the same as customarily for washing machines or tumble dryers (typical width and depth: 60 cm). This helps to understand the characteristics of this appliance. Washer-dryers have the typical components of tumble dryers like a fan, a heater and a heat exchanger; however the details and the location are different due to the space and drum construction constraints (see also the following sections). It is also more difficult to integrate the counter weights which are necessary in washing machines to balance the appliance during the spinning phase. Therefore, the spinning profile of washer-dryers has to be adapted, which might result in longer spinning phases compared to washing machines. The construction of a washer-dryer is quite complex.

The main advantages of washer-dryers are

- Space saving compared to a separate washing machine and tumble dryer as it is one appliance with two functions, and

- Possibility of a continuous washing and drying process, that can be convenient for consumers as no action is needed between washing and drying.

The disadvantages are

- The capacity of the drying process is smaller than the capacity of the washing process. If a full load is washed it has to be separated in between and dried in two goes,
- In general the drying process is slower than that of a tumble dryer (however this also depends on the used drying technology),
- Stronger creasing is produced as the drum is smaller than that of a tumble dryer.

One main reason for consumers to buy a washer-dryer instead of two separate appliances is the space limitation in their homes. However the consumer survey 2015 on washer-dryers (see section 3.1.2) shows that there is a substantial share of owners of washer-dryers that additionally own a washing machine and/or a tumble dryer (around 8% of the respondents of the consumer survey possessed an additional washing-machine, 2% an additional tumble-dryer, and around 13% a washing-machine and a tumble-dryer additional to the washer-dryer; i.e. in total 23% of owners of washer-dryers also own a washing machine, a tumble dryer or both). For these consumers the washer-dryer is a second appliance that allows washing and drying laundry in shorter time. Current developments (e.g. higher capacities, especially for the drying process, which make the continuous washing and drying process more attractive, air condenser or heat pump drying processes) are generally making these appliances more attractive. Some manufacturers therefore foresee that washer-dryers will gain more and more market shares (cf. also section 2.2.2).

The following sections describe the different functions of washer-dryers in detail.

4.3.2.1. The washing process in washer-dryers

The washing process of a washer-dryer is almost identical to that in a washing machine. Due to the space restrictions the capacity is sometimes limited to smaller values. Currently the typical washing capacity of washer-dryers on the market is 7.5 kg (7.2 kg for washing machines) while the reported largest washing capacity is 12 kg (14 kg for washing machines) (CECED 2014).

4.3.2.2. The drying process in washer-dryers

Currently, all washer-dryers on the market are condenser dryers, this means as in tumble dryers (cf. section 4.1.1.5) the cold dry ambient air is pulled by a fan inside the appliance, heated by an electric heating element and passed through the laundry where it takes up moisture. The warm and humid air then has to be cooled down to condense the water which is collected in a container that has to be emptied regularly by the user.

There are no air vented washer-dryers on the market and it is not to be expected that they will appear in the future. The reason for this is that a vented dryer needs an additional flexible tube to blow the warm and humid air to the outside. This is a strong restriction with regard to possible installation locations. As washer-dryers are rather expensive appliances, consumers seem not to accept such inconveniences. Also for tumble dryers, the market share of air vented appliances is decreasing.

In current washer-dryers there are three possibilities to condense the water:

- Water condenser drying: originally all washer-dryers had this type of drying process as only few additional components have to be added (which is advantageous due to the space restrictions). Both water inlet and a pump for draining the water are already installed due to the washing machine function. The steam is condensed by cooling the warm, humid air with cold water (which is sprayed). The water runs to the sump, where it is drained by the drain pump. The advantage of this technology is that it does not need much extra space and is cheap to realise. However, fresh water is needed not only for the washing process but also for the water-condensed drying process (between 5 and 10 litres/kilogram of laundry, additionally to the washing process). Still this is the most common drying process in washer-dryers. (see also Figure 4.5 and Figure 4.6)

- Air condenser drying: this is a rather new development and was introduced in 2011. Is only used by few manufacturers. As in condenser tumble dryers, the cooling of the warm and humid air is done by the surrounding cold air which is led through a cross flow heat exchanger by a second fan. This technology needs more space for the additional components (heat exchanger, fan, tubes for cooling air) and is therefore more complex to realise and thus more costly than the water condenser drying. The advantage is that it has much lower water consumption than a water condenser dryer, as only about 3 litres of water per drying cycle are needed to automatically clean the lint trap. Regarding the energy consumption there is no difference. The capacity of such dryers is smaller (around 7 kg for washing, 4 kg for drying) due to the larger space needed for the additional drying components. A possible drawback is that the condensation efficiency seems to be slightly lower compared to water condensing washer-dryers.
- Heat pump drying: this is the latest innovation for washer-dryers and it was introduced onto the market in 2013. The drying process is in principle the same as in heat pump condenser tumble dryers (cf. section 4.1.1.5). The warm and humid air is cooled down by a heat pump. The recovered energy is then used to reheat the cool air which is pulled into the drum. Such a washer-dryer needs a compressor as additional component and pipes leading the refrigerant to the condenser (cools down the warm humid air) and the evaporator (heats up the cool dry air). R134a (tetrafluoroethane) is currently used as refrigerant, which is also used in heat pumps of tumble dryers, washing machines and dishwashers. The use of a heat pump significantly reduces the electricity needed for the drying process. However the refrigerant has a certain global warming potential and hazardous properties which require proper design and handling of the appliance during its entire lifecycle. This technology is quite complex and costly to realise and the drying process is often slower due to lower process temperatures. Due to space limitations of the appliance, only one single heat pump fits into washer-dryers and this is designed and used currently for the drying process only, as this is far more energy intensive than the washing process.

Figure 4.5 shows the schematic water condensing process of a condenser dryer. The fan (1) generates an air stream which is heated by the heating element (2) and led into the drum where it takes up moisture from the laundry and cools down slightly. Afterwards it leaves the drum (4) and is led to the water condenser (5, 6). Both the cooling and condensed water (7) is drained (8, 9).

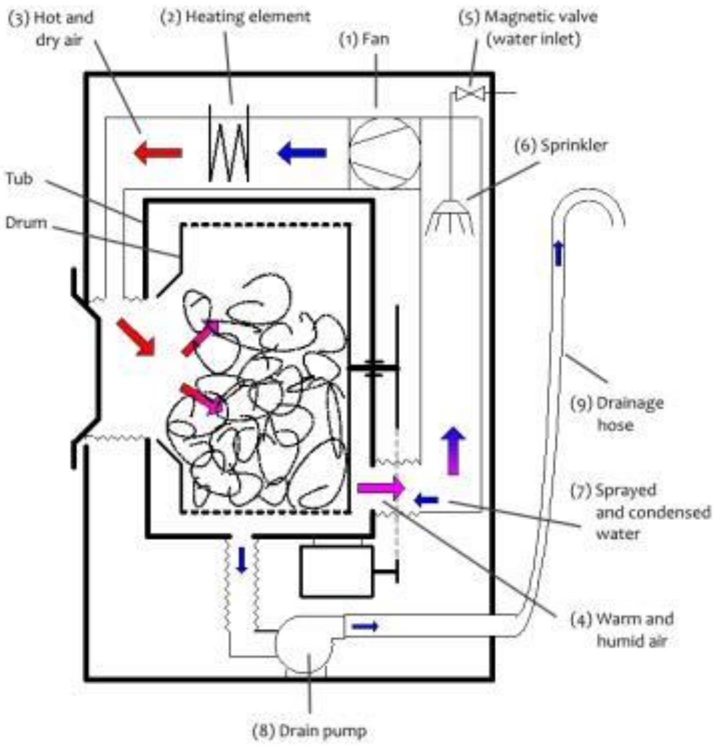


Figure 4.5: **Schematic water condenser drying process in washer-dryers (source: BSH)**

Figure 4.6 shows a three-dimensional figure of a water condenser washer-dryer.

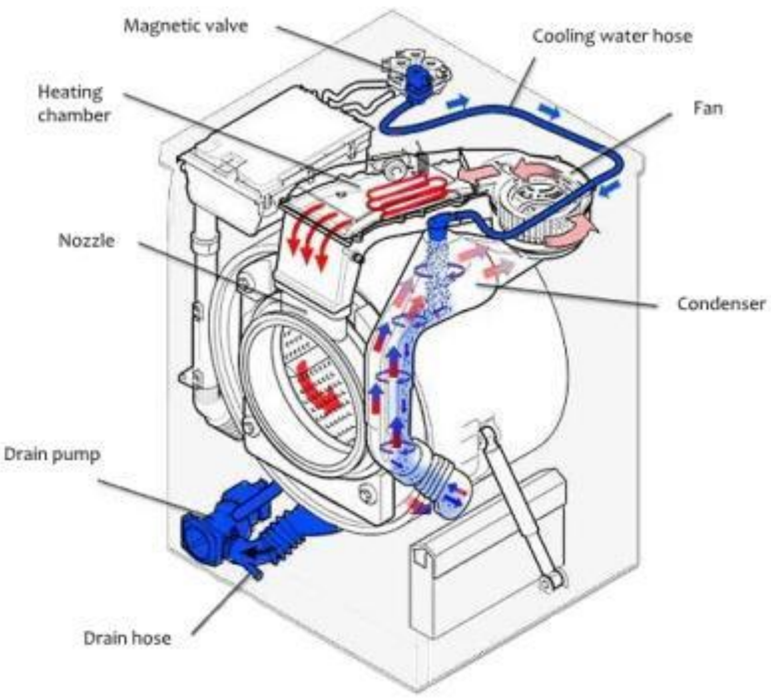


Figure 4.6: **Water condenser washer-dryer (source: BSH)**

As described, the drying process is very similar to that of a tumble dryer, although there are some differences:

- One aspect is that the drum is smaller than that of a tumble dryer: In tumble dryers the drum volume usually is between approximately 100 and 120 litres, in washer-dryers the drum volume is much smaller (between approximately 50 and 70 litres, as in washing machines). The laundry therefore does not have as much space as in a tumble dryer. Due to the space restrictions other components are smaller as well (e.g. the fan, diameters of hoses and tubes) resulting in a smaller process air stream (around 100 m^3/h compared to 200 m^3/h in tumble dryers). These aspects lead to usually longer drying times compared to tumble dryers.
- Another special aspect of the drying process is that for washer-dryers there is an additional spinning phase directly after the laundry heating up. Spinning warm laundry leads to a lower residual moisture content and therefore, compared a tumble dryer, more humidity is removed mechanically, which is more energy efficient than thermal removal by heat/evaporation (see also section 4.4.2.6). Typically at the beginning of the drying process the spin dried laundry out of the washing process is heated up to a certain temperature (e.g. 90 °C) and then spun again. Afterwards the regular drying process continues. Through this “thermal spinning” the residual moisture content of the laundry can be reduced by approximately 4%.

As with tumble dryers, there are time-controlled and automatic washer-dryers (also called sensor washer-dryers). The additional construction effort is rather small but sensors and controlling devices need to be added. There are different types of sensors available (e.g. measuring the conductivity of the laundry or measuring the temperature difference between the air stream before and after the laundry in relation to heat supply). Manufacturers see a trend to automatic washer-dryers. All automatic washer-dryers also have time controlled programmes.

4.3.2.3. Continuous wash&dry and other drying modes of washer-dryers

Washer-dryers also allow users to wash and/or dry their laundry. Drying can generally take place in different forms:

- Drying only, i.e. for drying laundry washed earlier / somewhere else, therefore using the appliance as it were a tumble dryer;
- Interrupted wash&dry, i.e. drying the laundry shortly after the wash cycle, with an intermediate interruption for the potential unloading of (part of) the laundry;
- Continuous wash&dry, i.e. drying the laundry immediately after the wash cycle, without an intermediate interruption.

The continuous wash&dry function, in particular, allows wash and dry laundry “in one go” without any intermediate intervention by the consumer. The capacity for continuous washing and drying is limited to the maximum drying capacity, which is always lower than the rated capacity for washing. Today the rated drying capacity is between 50-75% of the rated washing capacity (e.g. 8 kg washing capacity, 6 kg drying capacity), 65% on average. That means in case of using the washer-dryer “in one go” the total washing capacity of the machine cannot be used completely (as if used as a washing machine only), which might result in higher specific consumption (per kg laundry) compared to usage up to full capacity.

The wash&dry function is not offered in all the washer-dryers, although present in about 90% of the appliances according to the results of the 2015 user survey from UniBonn (Alborzi et al. 2015). Most new machines offer this function, while the function may not be present in older machines.

Some appliances have a warm final rinse phase in the washing process to increase the efficiency of the spinning (same effect as the thermal spinning, cf. section 4.3.2.2 above) and thus reduce the energy demand in the subsequent drying phase.

One challenge in case of continuous washing and drying is avoiding the formation of a “laundry-ring” inside the drum after the spinning, as it usually occurs in washing machines. This laundry-ring has to be avoided as the laundry cannot be dried properly if it sticks together in form of a solid ring. Thus, usually the spinning profiles are different to those in case of washing only. These profiles put more mechanical stress on the system and take longer.

Heat transfer from the washing to the drying process is a theoretical consideration but it has not been yet investigated and may have some challenges, as the rinsing at the end of the washing process is customarily done with cold water. There might be options like heat storage units (using another fluid) or when a warm final rinse is used. Additional options for optimising the washing and drying process lay in the digital sharing of information within the machine, e.g. information about load size or load type (textile composition), as detected in the washing process, may be used for optimising the drying process.

4.3.3. Existing products

4.3.3.1. Basic product types

According to the definition given by Commission delegated regulation No. 1061/2010 (European Commission 2010a) and Commission regulation No. 1015/2010 (European Commission 2010b), a “‘household washing machine’ means an automatic washing machine which cleans and rinses textiles using water which also has a spin extraction function and which is designed to be used principally for non-professional purposes.” Besides this general definition, both regulations further use various sub-categories of washing machines (built-in appliances; different requirements related to capacity of the machines, cf. section1.1.1.1).

The same regulations define ‘household combined washer-dryer’ as “a washing machine which includes both a spin extraction function and also a means for drying the textiles, usually by heating and tumbling”.

In the following, these basic types of washing machines and washer-dryers shall be introduced systematically.

Basic differentiation of washing machines and washer-dryers by the way of installation

The appliances on the market can be divided in the following sub-categories according to the type of construction and the way they are installed. (HEA [n.d.])

- *Freestanding front loaders* have a preinstalled countertop and are loaded from the front. Depending on the capacity their dimensions are: height 85-96.5 cm, width 59.5-60 cm, depth 55.5-64.5 cm. All front loaders are horizontal axis appliances (cf. section 1.1.1.4).
- *Freestanding top loaders* are loaded from the top; this means they cannot be put under the countertop. Their lid can partly be used as work surface. The typical dimensions of top loaders in Europe are: height 85-91 cm, width 40-45.6 cm, depth 60-65 cm, i.e. they are usually smaller than front loaders. They can be either vertical or horizontal axis appliances (cf. section 1.1.1.4). Most top loaders in the world are vertical axis appliances, but in Europe these tend to have horizontal axis, and are designed to fit small households with limited space. Top loaders are not common for washer-dryers.
- *Under counter*: Usually the preinstalled countertop of the freestanding front loaders can be removed to put the device below the general countertop (e.g. if it is installed in the kitchen).
- *Integrated*: Besides the freestanding machines, there are machines that are capable of being integrated in the kitchen cabinets. In these cases the front door of the appliance is hidden behind a kitchen cabinet front. Either are they semi-integrated, which means that the control panel is still visible, or they are fully integrated, which means that the control panel is hidden

behind the door and thus invisible from the front. The front looks identical as any other kitchen cabinet. The dimensions of integrated washing appliances are: height 82-87 cm, depth 54-58 cm, width 60 cm.

In general, vertical axis top loading machines are less efficient than front loading machines. This is partially a result of specialisation of the market on (horizontal axis) front loaders, and technological development has focused on such type of appliances, In Europe, top loaders are rather niche products. All washing machines and washer-dryers on the European market are horizontal axis appliances and most of them are front loaders. According to stakeholder feedback, top loaders with horizontal axis are as efficient as front loaders.

Basic differentiation of washing machines and washer-dryers by capacity

With regard to capacity, there is a wide variety of household washing machines and washer-dryers on the market (from 3.5 to 15 kg). An overview of capacities is provided in section 2.2.4.1 for washing machine models and in section 2.2.4.2 for washer-dryer models.

4.3.3.2. Evolution of the product and preliminary environmental considerations

Nowadays, main innovations take typically place every 8-10 years, but this depends on market conditions and technological evolution.

New developments are introduced on the market after extensive environmental impact assessments, market relevance studies, and consumer acceptance studies.

In terms of environmental impacts, it can be generally agreed that the use phase is the main source of environmental impacts. Manufacturers have reported that they constantly investigate on possible improvements which may lead to lowering the environmental impact of their appliances. However, some stakeholders consider that the improvement potential for washing may be close to its technical limit, and further improvements would mainly be possibility by changes in user behaviour. With respect to water saving, it has been pointed out that in some regions further reduction of the water consumption of washing machines and washer-dryers might lead to additional water consumption for cleaning the public drainage systems.

Noise has been indicated also as a source of concern by some stakeholders, as well as material resource efficiency (e.g. detergents and other material use, durability, reparability and recyclability). Some of these aspects are already regulated through other legislation (e.g. RoHS, REACH, WEEE, F-gases, cf. section 1.3.1).

4.4. Improvement options

The following sections describe different areas of technological progress which have an influence on energy, water and/or other resources consumption (e.g. materials, detergents). Main sources of the description of the development were the WASH II study (Novem 2001), the preparatory study on domestic dishwashers and washing machines ("ENER Lot 14") of 2007 (ISIS 2007a) (ISIS 2007c) and new information based on stakeholder feedback, scientific publications and other web sources (e.g. www.topten.eu). The general approaches to reduce the energy and water consumption of washing machines and washer-dryers, as well as the specific design options identified in the course of the study are presented in the following.

4.4.1. General approaches to reduce the energy (and water) consumption of washing machines and washer-dryers

The energy breakdown in a washing cycle can be split into 3 main contributions:

1. Heating: By far the most energy consuming component for both washing machines and washer dryers is the electrical heating system. The energy for heating can be divided into energy for heating water (based on heat capacity of water) and energy for heating the laundry and machine parts (estimation: about 50% of the energy for heating water; specific heat of laundry is about 1/3 of that of water). Therefore reducing water consumption and washing at low temperatures has a high energy saving potential.
2. Motion: With much lower energy consumption per cycle, the motor is the second contributor. The exact share mainly depends on the motor efficiency and programme type. The absolute consumption may vary between 0.1 and 0.4 kWh per cycle. Spinning uses much less energy compared to the thermal energy consumption that is needed by using a subsequent tumble dryer when the laundry is insufficiently spun (e.g. with an spinning efficiency B instead of A).
3. Other aspects: energy consumption from other components (e.g. low-power modes, displays) can be instead considered marginal.

According to one stakeholder, in a cycle where the total energy consumption is 1.5 kWh, 55% is used for the heating phase, 25% for the mechanical action in the main wash phase and 20% for the rinsing and spinning phase. Another stakeholder splits the total energy of a 60 °C washing programme into around 68% for heating, around 30% for motion and pumping, and around 2% for controls. The exact shares depend on many factors that vary depending on the design and specific characteristics of the considered model and washing programme (e.g. motor efficiency, reached temperature, length of the cycle).

The general approaches to reduce the energy and water consumption of washing machines and washer-dryers can be described as follows:

Reducing temperature

Due to the interrelation of the four factors of the Sinner's Circle (see section 4.1.1.1) one possibility to reduce the energy consumption of a washing machine or washer-dryer is to reduce the temperature, and compensate it by extending the duration of the washing cycle. Therefore today's most energy efficient programmes have very long cycle duration. Special low-temperature detergents have been developed which can ensure good washing performance (see section 2.2.7). However, this comes with some consequences:

- It is important to consider hygiene aspects, especially with regard to lowering the temperatures reached during the washing cycle (see section 4.1.1.4). The clothes may be free of soiling, but odours or bacteria may still remain.
- Long washing programmes increase the mechanical action on the textile (see section 4.1.1.5).
- Waiting time may be not satisfactory for consumers (see section 2.2.6).

Improving the heating system

Energy demand can be reduced by recovering part of the heat which otherwise would escape as waste heat (e.g. through heat-pumps and heat exchangers) or by using alternative heating systems (e.g. hot-fills).

Reducing water consumption

Also reducing the amount of water can help to reduce the energy consumption, as less water has to be heated. There are various technical possibilities that contribute to lowering the amount of water which were utilised during the last decades, e.g.:

- Optimised machine construction (e.g. tub-drum geometry or increased rated capacity which lead to lower water consumption per kilogram laundry (if fully loaded)).
- Sensors adapting the water consumption to partial loads.
- Improved drenching of the laundry.
- Reduction of the number of rinse cycles or improved rinsing.

According to market research, the water consumption already has decreased to a large extent during the past years; while in 1997 water consumption of the majority of machines was 66.8 litres per cycle in 2013 this value reached 45.1 litres per cycle (see Figure 2.33) (compared to around 50 litres taken as standard Base Case for washing machines in the EuP Preparatory Study ENER Lot 14 in 2007). A further reduction of water consumption is partly seen critical and should only be achieved in combination with a good rinsing performance to avoid residues of detergents on the laundry, especially for people with sensitive skin.

Optimising the drying process

The drying process can be for instance optimised through:

- Higher water extraction by spinning at the end of the washing cycle, which reduces the residual moisture content of the laundry resulting in lower drying effort.
- Use of heat pumps in washer-dryers to reuse heat during the drying process.

Optimising mechanical action

If the mechanical action is improved, one of the other factors of the Sinner Circle can be reduced while maintaining the same wash performance (e.g. temperature, programme duration). The mechanical action can be for instance improved by acting on the tub-drum geometry (increasing the volume-to-load ratio) and/or by enhancing the process of detergent dissolution, distribution and penetration in the fabrics.

Increasing motor efficiency

A more efficient motor directly reduces the input of energy needed for the drum motion (less waste heat is generated).

4.4.2. Specific improvement options

In this section, specific design options for improving the environmental impacts of washing machines and washer-dryers are presented in detail, and will serve as basis for Task 6.

Table 4.4 provides an overview of the design options for household washing machines and washer-dryers.

Table 4.4: Overview of design options for household washing machines and washer-dryers

Design options with regard to improving the environmental impacts of WM and WD	Sub-options
Option 1: Machine / drum construction	• Increasing the drum volume without increasing the rated capacity • Increasing the rated capacity

Design options with regard to improving the environmental impacts of WM and WD	Sub-options
	• Multi-drum washing machines
Option 2: Increased motor efficiency	• Brushless, inverter-driven asynchronous DC motors • Brushless, permanent magnet synchronous motors (PMSM)
Option 3: Temperature – time trade off	• Moderate extension of the programme duration • Extreme extension of the programme duration
Option 4: Alternative heating systems	• Heat pump technology for the washing function • Heat-fed machines • Hot-fill
Option 5: Improved drenching systems / improved detergent dissolution	• Different systems on the market, mostly based on different water spraying location in the drum, and sequence
Option 6: Higher water extraction by spinning	• Increased spinning perfomance
Option 7: Sensors and automatic controls	• Automatic load detection • Automatic detergent dosage systems
Option 8: Consumer feedback mechanisms	• Displaying the actual loading • Displaying a detergent dosage recommendation • Displaying the different energy and water demands of the chosen programmes
Option 9: Improved interconnectivity between appliance, user and technical system	• Internet connectivity (smart appliances) • Electronic update of programmes / diagnostics in case of failures • Smart-grid ready products
Option 10: Material selection	• Use of recycled materials (e.g. plastics) • Increased durability of appliance / components, including improved repairability
Option 11: Alternative washing systems	• Ultrasonic cleaning technologies • Polymer bead technology • Steam care / steam finishing

4.4.2.1. Option 1: Machine / drum construction

Increasing the volume-to-load ratio

As described in the WASH II study (Novem 2001), this option means increasing the drum volume without increasing the declared load. Between 1993 and 1998, the volume-to-load ratio of the average washing machine has increased by around 10 to 15% (from 42-44 litres drum to 48 litre drum without changing the rated capacity of 5 kg).

Increasing the drum volume was possible without changing the outer dimensions of the appliances by reducing the tub-drum clearances significantly with values found as low as 10 mm. Prerequisite for this was an optimised unbalance control of the drum. Unbalance control is achieved by the use of sensors for the motor, shock absorbers and machine mechanical construction. Shock absorbers can be mechanical (frictional) or high pressure (filled with gas or oil). In Lot 14, it was supposed that some sort of simple unbalance controls were implemented in 90% of the models, and that a more sophisticated unbalance control was in 5% of the models. It can be assumed that today a quite high share of washing machines is equipped with a more sophisticated unbalance control as most appliances have larger capacities at the same outer dimensions.

Benefits by reducing the clearance and increasing the drum volume versus load capacity are expected to be an improved washing performance, as the same load is exposed to better mechanical action due to more space within the larger drum; according to the principles of the Sinner's Circle (cf. section 4.1.1.1).

This effect also enables either decreasing time or less energy input. Further, the increasing drum volume results in a reduction of the suds volume, which is directly leading to lower energy demand.

In the Ecodesign preparatory study ENER Lot 14 it was considered that the tub drum geometry had been fully optimised in the machines on the market. Today the rated capacity has increased even further. The average capacity has increased from about 4.8 kg in 1997 to 7.04 kg in 2013, with capacities up to 15 kg (see section 2.2.4.1, Figure 2.21) without increasing the outer dimensions of the appliances. This means that, although the drums have increased and the tub-drum clearance is very low, the volume-to-load ratio of the tub has even decreased.

Further optimisation with regard to tub-drum geometry to reduce the suds volume seems hardly possible. This is also reflected by the fact that manufacturers try to reduce the suds volume while maintaining the drenching of the load by other means, see section 4.4.2.5).

Increasing the rated capacity

In Lot 14 an increase of the capacity of 1 kg (from 5 kg to 6 kg washing machines) was considered as improvement option. Meanwhile the average capacity has grown even further with 7 kg machines being the average, but also models with larger capacities (from 8 to 15 kg) are available on the market (cf. section 2.2.4.1).

The Energy Label requirements in place in 2007 allowed larger washing machines (i.e. those with a higher rated capacity) to consume more energy per cycle since thresholds between different energy efficiency classes were set on a “per kilogram” basis. However, the increase of water and energy needed for washing additional kilograms of laundry is less than proportional to the increased rated capacity. Thus, larger machines have lower consumption values per kilogram than smaller machines and were able to reach certain energy efficiency classes more easily. One of the reasons for this is that a certain amount of water to be heated always stays in the suds and hose system, and this is approximately the same independent from the drum capacity.

The method for calculating the Energy Efficiency Index (EEI) has been adapted to follow the evolution of the market. According to the requirements set in the Energy Label Regulation No 1061/2010, larger machines are allowed to have a higher absolute energy demand than smaller machines to be in the same energy efficiency class. However, the allowed energy demand per kilogram of laundry is slightly lower, i.e. larger machines have to be slightly more efficient on a per kg basis. For instance, a washing machine with a rated capacity of 9 kg can consume up to 42% more energy than a machine with a rated capacity of 6 kg. However, considering that the rated capacity increased by 50% from 6 kg to 9 kg, the allowed specific energy consumption per kilogram has to be 5% lower. This trend is reflected also in the benchmarks for best-performing household washing machines provided in Annex IV of the Ecodesign Regulation No 1015/2010.

It is however seldom that people would use regularly the bigger machines up to their full capacity. Especially with the decrease of household size and the increase of special programmes offered by the machines (and the respective detergents offered by the detergent industry), like “black”, “jeans” or “outdoor”, the amount of specific types of laundry washed per cycle has not changed much, and is for cotton loads about 3.5 kgs on average over the last 5-10 years). Larger machines might invite users to increase the total amount of laundry that is put into the machine, but this is apparently only done occasionally. The user surveys by University of Bonn and A.I.S.E described in section 3.1.1 show that the number of washing cycles per person and week are stable over the years, and thus not follow the market trend of larger appliances. If the load per wash had increased, the number of washes per week would have decreased, but this is not the case. This is an indication that the load per wash is stable.

The results of the studies carried out by University of Bonn show that the average number of washing cycles in Europe has indeed slightly decreased from 4.0 in 2006 to 3.8 cycles per week in 2011, whereas in the latest survey of 2015 the EU average was reported to be higher again with 4.4 wash cycles per week. However, considering the uncertainty related to the exact quantification of such parameter, it can be considered that the average number of wash cycles per week has not changed appreciably.

All in all, there is a drawback for high rated capacities: even if larger machines can wash (slightly) more efficiently per kg of rated capacity, it is foreseeable that more and more partial load washing occurs, as loading size remains stable. Ideally, when the washing machine is only half loaded, the water and electricity consumption per cycle should be reduced proportionally, (e.g. 50% compared to a full load in the same programme). However, the values reported in product fiches of washing machines currently marketed in the EU (See also results from ATLETE II project on section 2.2.5) indicate reduction ranges from 0% to 41%, and rarely over 20% for half loads. This means in practice an increase of the energy consumption per kilogram of laundry. Thus, the savings per kilogram of nominal load are not achieved under real-life conditions of use, unless the machines are very efficient in load adaptation.

Energy consumption of partial loads depends on good load-size-sensing and well-designed adaptive programmes. High capacity machines should be accompanied by sophisticated programme design (cf. improvement option 7, section 4.4.2.7). This may be triggered by testing methods that reward load adaptation by appropriate weighting of load cycles for the calculation of the EEI.

Multi-drum washing machine

"Multi-drum washing machines" have two washing drums, placed side-by-side or above each other, which can either work simultaneously or separately to complete the washing process. They have existed for some years in some Asian countries, and are being introduced in the EU by manufacturers such as Haier and LG (cf. Figure 4.7). Multi-drum washing machines could be used to wash at a time different cloth types which need to be washed separately, using different programmes. Consumers can select the proper washing drum according to the weight or type of the laundry (e.g. small loads or special care / delicate laundry).

Two different principles are so far detected:

- Multi tub in one machine (housing). This type has different tubs in one housing. The tubs may use the same connections to power, tap water and sewage water and may share the use of some internal components. They may also have means to share resources, like using rinse water of one tub for pre- or main-wash in one of the other tubs. Example of this machine are currently available in some markets (China, US) and may come to Europe soon.
- Multi tub in separate units. This type is characterized by having at least two separate units where at least one can operate also without the other. This means the other unit is an optional extension of the first machine. Components may be shared but this additional unit may also have its own connection to power and water. It may or may not be operated only when connected to the main machine. These machines are currently on the market in Korea and US and may come to Europe soon.

Figure 4.7: Multi-drum washing machines presented at the IFA 2015 fair in Berlin; left: Haier; right: LG (source: own pictures)

For example, in case of the LG Twin drum, a so called SideKick™ pedestal washer is installed beneath the regular front load washer, just like a regular pedestal. It has its own power cord that plugs into a standard household socket, so there's no need for special wiring. No separate water or drain lines are needed as the SideKick™ washer includes two Y-connectors for the hot and cold water lines, a third Y-connector for the drain and the necessary hoses to install the SideKick™ to the front load washer. (LG 2015)

In the Haier dual-drum machine, the upper drum is smaller than the lower drum. Both drums work independently of each other. The machine is provided with independent detergent drawers and instruction panels; each drum also hast its own set of specified programmes. (Kashiv 2015)

4.4.2.2. Option 2: Increased motor efficiency

For washing machines and washer-dryers, the main motor is responsible for driving the washing drum. According to (Stekl 2006), the drive has to be designed to run a very wide range of drum speeds from 0 to 2,000 rpm, depending on the modes of operation:

(a) Tumble wash (typical low drum speeds reversing the direction of the drum rotation every few turns); the speed of the drum for a tumble wash is typically 30-45 rpm depending on the type of clothes and determined by the washing programme.

(b) The out-of-balance detection and load displacement being performed until an equal distribution of the drum load is achieved before starting spin drying.

(c) The spin drying phase with up to 2,000 rpm of the drum depending on the machine and chosen programme.

According to stakeholder information, motors of washing machines and washer-dryers have a rated power input of up to 950 W during spin-drying peaks, whereas their typical operational power input is usually lower (around 100 W). Further, the water circulation pumps in washing machines and washer-dryers are operated by separate, mainly synchronous motors, however with a comparatively low rated power input of around 15 to 30 W. In household appliances such as washing machines and washer-dryers, different types of motors are applied.

In the Ecodesign preparatory study of 2007, ENER Lot 14, three different motor options were described, which were seen as alternative systems (i.e. not additive), see the following table.

Table 4.5: Possible motor efficiency improvements in 2005; source: (ISIS 2007a)

Motor options	Market share in 2005	Motor efficiency (compared to AC phase motor)
Brushless DC (+control)	0,5%	+6%
Brushless DC direct drive (+ control)	0,5%	+6%
Three-phase (+control)	5%	+6%

Universal motors

Initially, universal motors (commutator motors) with brushes were common. They can be operated at direct current (DC) as well as alternating current (AC); driven through pulse width modulation, they are also called PWM motors. According to stakeholder information (personal communication), their efficiency is low, (up to 50%, i.e. only 50% of the power input is effectively used for moving the drum, the rest is dissipated), they are prone to wear, and noisier compared to other motors. They are still used, especially in the low-price segment.

Brushless, inverter driven asynchronous DC motors

In the medium to upper price segments of household appliances, brushless, inverter-driven asynchronous DC motors are often applied. Their efficiency is 50-60%, thus higher compared to universal motors; also, they are more reliable and more silent due to absence of brushes and commutator.

Brushless, permanent magnet synchronous DC motor (PMSM)

Brushless, permanent magnet synchronous DC motor (PMSM) have found application where compactness (lower volume and weight compared to the above motors), high torque per unit volume, better dynamic response (due to the low inertia of the rotor), reliability (no brushes), low-noise machinery and high efficiency are primary requirements. The lifetime of both brushless asynchronous inverter driven motors and permanent magnet motors is similar, and higher compared to universal motors with brushes, as only the bearings are prone to wear. According to stakeholder information, the motor efficiency of PM motors is between 65% and 80% depending on the operational mode; also, they are smaller and lighter (around 3.5 kg compared to 6.5 kg for asynchronous inverter driven motors).

According to estimation of one stakeholder (personal communication), around 50% of washing machines might already be equipped with PMSM motors, and 60% for some manufacturers of appliances; for washer-dryers, the implementation of high-efficiency motors is still delayed compared to washing machines.

Some permanent magnets contain rare earth elements (REE), identified as critical raw materials. According to Dalhammar et al. (2014), the employment of REEs is one of the options for achieving better energy efficiency in PM motors. The rare earth elements currently used are Dysprosium (Dy), which is a less abundant heavy rare earth element, and Neodymium (Nd) and Praseodymium (Pr), light rare earths.

Rare earths like Neodymium (used as NdFeB with a rather high share of the rare earths Nd, Pr, and Dy) enhance the magnet field. Neodymium further stabilises magnets against demagnetisation due to mechanical shocks or other magnet fields. Dysprosium, for example, is added to get permanent magnets more heat-resistant. Pr can substitute Nd by up to 6% in these magnets.

For Permanent Magnet motors, if not based on NdFeB, there are further possibilities: SmCo (based on Samarium and Cobalt which is costly and difficult to processing); AlNiCo (Aluminium, Nickel and Cobalt, but there is no mass production for this type, i.e. rather unlikely used for washing machines and washer-dryers) and PM motors based on ferrites (BaO $(Fe_2O_3)_6$ or SrO $(Fe_2O_3)_6$). The two latter ones do not contain critical raw materials, are cheaper, but also weaker compared to PM motors containing rare earths, but this can be compensated by using more active material, i.e. larger magnets which leads to heavier motors.

According to stakeholder feedback, it is frequent in current permanent magnet motors of washing machines and washer-dryers, to not use rare earths, but permanent magnets based on ferrites.

Dalhammar et al. (2014) assume that the potential in terms of the improved energy efficiency level which can be attained by PM motors means that their market share is expected to increase with further commercialization, resulting in increased supply, and a price decrease for such motors. However, it has to be taken into account that the motor efficiency alone does not determine the efficiency of the whole washing machine or washer-dryer.

Regarding the drive construction, belt-driven and direct-drive motors can be distinguished. According to (Freescale Semiconductor 2012) the most common washing machines contain belt-driven motors. This mechanical construction consists of two pulleys with the belt transmitting the power, torque and the speed from the motor to the drum. The smaller pulley is mounted on the motor shaft while the larger pulley is mounted on the drum shaft. Direct drive washing machine construction does not include pulleys and belts, therefore the motor shaft is directly mounted to the drum shaft.

Direct drive simply means that the motor shaft is "directly" connected to the washer / dryer drum instead of "indirectly" via. a belt.

Different pros and cons are mentioned for both constructions. While direct-drive was presented some 10 years ago as a clear improvement, and several models were presented on the market, the cons of this option seem to be substantial, and the use of this construction has not expanded, and most current machines use belts.

Table 4.6.: pros and Cons of belt-drive vs direct-drive motors

	Pros	Cons
Direct Drive	They are usually quieter because there's no squeaking / skidding of the belt Marginally more energy efficient because no energy is lost flexing the belt / with the belt slipping	The direct drive motor is more complex and needs to be as flat as possible to not take drum space in the EU standard front loader They suffer more wear and tear from the drum, some of which is absorbed in belt-driven motors
Belt drive	Vibration Absorption Longer Life	Noisier Loss of Efficiency

4.4.2.3. Option 3: Temperature – time trade-off

Extension of programme duration and lowering of washing temperature

Lower wash temperatures lead to lower energy consumption for heating. However, in accordance to the Sinner's Circle (cf. section 4.1.1.1), this has to be compensated by another factor. The the chemistry cannot be influenced easily, thus the main factor that has been used to compensate lower wash temperatures is the mechanical action, which once the machine's shape is fixed can only be achieved by extending the programme time. As a result of this, washing cycles have become longer during the past decades.

Already the WASH II study (Novem 2001) described an increase of the cycle time of 10 to 20% between 1993 and 1998. In in 1993 the cycle time was 100 to 110 minutes, whereas by 1998 it was 120 to 130 minutes. Manufacturers claimed by that time that there was zero benefit from time-temperature trade-off referring to the situation from 1998 onwards. It was concluded that for the immediate future this would be a saving option only for low-range machines. Also in the Ecodesign preparatory study ENER Lot 14 of 2007, the possible savings due to this option were considered to be implemented in all machines on the market with no further improvement potential.

Nowadays, the common cycle time for the standard 60 °C cotton cycle is at least around 180 minutes, i.e. much longer than the cycle time in 1998. Some machines have even much longer cycle times in the standard programmes, which are the basis for indications on the Energy label. This results from strongly lowered wash temperatures in the standard programmes of as low as 35 °C (in the 60 °C standard programme) and 25 °C (in the 40 °C standard programme), cf. also section 2.2.6.2. Thus only the names of the respective programmes remain.

Manufacturers can guarantee the required washing performance (>1.03) despite these lower wash temperatures. However, in some cases (e.g. in specific situations (vulnerable people, contagious diseases)) this approach might lead to hygiene problems (cf. section 4.1.1.4).

As indicated in this section, there are also other possibilities to reduce the energy demand than just lowering the wash temperature of the standard programmes and increasing the time. However, these are usually connected to certain technologies that are more costly (extending the time or lowering the washing temperature does not have any significant implications on the cost of products). The advantage however is that such technologies not only reduce the energy demand of the standard programmes but also of other programmes.

Low temperature programmes: introduction of 20 °C cycle

During the past decade, new detergents and bleaching agents active at low temperatures have been introduced into the market, allowing washing at lower temperatures. This has led to the mandatory presence in washing machines, by means of Ecodesign Regulation 1015/2010, of a cold wash programme (20 °C programme) for all washing machines coming on the market. Some of these 20 °C cycles are shorter and others longer, some refresh laundry only, others are full washing cycles. Currently, washing at 20 °C is not part of the standard measurement procedure for the calculations of the related washing performance and EEI. Besides hygienic aspects, also the cleaning efficiency of low temperature programmes has to be considered, as it will be lower than the value of 1.03 required under standard conditions for the current 60 °C and 40 °C standard programmes.

Improved thermal efficiency by design optimisation

The WASH II study (Novem 2001) described the improvement of the thermal efficiency. The total energy consumption for machine heat up, heat-up of the glass door, radiation and convection losses had been reduced from 276 Wh/cycle in 1993 to 175 Wh/cycle in 1998. A further reduction of 50 Wh/cycle was seen possible for the future.

In 2007, Lot 14 stated that this total energy consumption for machine-heat up, heat up of the glass door, radiation and convection losses had been optimised, and thus no further reduction was considered possible.

It is assumed that also today further optimisation of the thermal efficiency is possible only at high cost, e.g. by means of complex systems such as heat pumps. Especially with lower wash temperatures (both chosen by consumers and reached in otherwise declared programmes) the energy for heat up of machine, glass door, radiation and convection is lower anyway compared to the situation in 1993, 1998 or even 2007.

4.4.2.4. Option 4: Alternative heating systems

Washing machines with heat pump (HP) technology

Through heat-pumps in washing machines it is possible to (partly) replace the electric energy usually used to heat the washing machine, the laundry and water, using instead the heat of the ambient air. Current HP models also recover heat from the wastewater before it is discharged. Currently, it seems that there is only one washing machine with heat pump technology on the market, the VZUG Adora SLQ-WP, introduced by V-ZUG in 2013. This washing machine is equipped with both a conventional heating element (electric resistence) and a heat pump. The wash water is heated by the heat pump taking the heat from a water-ice tank, which serves as latent heat storage.

The consumer can set heat pump utilisation in three levels: 1) heating only by the heat pump (up to wash temperatures of 45-50 °C) leads to lowest energy demand but longer washing cycles; 2) hybrid heating by the heat pump, with the aid of the resistance, with a shorter wash cycle that with HP only; and 3) heating by the heat pump and conventional heating elements in equal shares, leading to the relative shortest washing cycle and highest electricity demand. The savings in electricity compared to the same model without heat pump is reported as 50-70% (level 1), 40-50% (level 2) and 10-20% (level 3) (V-ZUG 2013; V-ZUG operating instructions 2014b). The energy demand of the model with heat pump (under standard conditions) is 50% lower than the current A+++ threshold.

The following table compares the main characteristics of 2 equivalent washing machine models under standard conditions (Adora SLQ with heat pump and Adora SLQ without heat pump).

Table 4.7: Comparison of heat pump washing machine with equivalent washing machine without heat pump under standard conditions; source: V-ZUG operating instructions (2014a, 2014b)

	Adora SLQ WP	Adora SLQ
Energy Efficiency Class	A+++ (-50% of the current threshold)	A+++ (-30% of the current threshold)
Capacity (in kg)	8	8
Recommended retail price	6,240 CHF (approx. 6,000 EUR)	5,180 CHF (approx. 5,000 EUR)
Per annum (220 cycles)		
Annual energy consumption (in kWh/annum) (threshold A+++: 197)	98	136
Annual water consumption (in L/annum)	9,800	9,900
60 °C cotton cycle (full/half)	(full/half)	(full/half)
Energy demand (kWh/cycle)	0.52/0.41	0.78/0.62
Water demand (litres/cycle)	55/36	55/36
Duration (min/cycle)	190/180	225/220
40 °C cotton cycle (half load)		
Energy demand (kWh /cycle)	0.36	0.37

	Adora SLQ WP	Adora SLQ
Water demand (litres/cycle)	36	36
Duration (min/cycle)	180	215

The use of HP as heating system has a number of drawbacks:

- Heat pump technology does not work for short cycle programmes, because of the slower heat transfer speed, caused by a smaller temperature difference.
- The installation of the heat pump is currently costly: it adds ca. 150€ of material and manufacturing costs, which are reflected in ca. 400€ purchase cost difference.
- End-of-life considerations: HP need the use of a refrigerant: currently, the most used refrigerant in heat pumps in washing machines, washer-dryers and dishwashers is R134a (tetrafluoroethane), which is also used in the heat pump washing machine by V-ZUG. The amount of refrigerant needed for such a heat pump is approximately 150 to 200 g (i.e. similar to that of a dishwasher, but less than heat pump tumble dryers). R134a however has a very high specific global warming potential of 1,430 kg CO_2eq / kg, which could be released during the end-of-life phase if the appliance is not properly collected and/or de-polluted (cf. section 4.5.6.2). The following table shows the global warming potential of the refrigerant per appliance.

Table 4.8: Global warming potential (GWP) of refrigerant used in washing machines with heat pump

	Used amount per washing machine	Specific Global Warming Potential R134a	Total GWP in case of 100% loss per washing machine
R134a (Tetrafluoroethane)	150-200 g	1,430 kg CO_2e / kg	215-286 kg CO_2eq

In principle, as in cold appliances, also the use of other refrigerants is possible (e.g. R290 (propane) or R600a (isobutane)) which have much lower global warming potentials. For example, one manufacturer recently introduced a heat pump tumble dryer with R600a as refrigerant. However this would require different equipment (e.g. compressors) and raises safety concerns, as R600a and other hydrocarbon refrigerants are flammable, and in cocntact with oxygen can generate an explosive mixture. If the content of refrigerant is above a certain threshold, the appliance has to be equipped with additional features and protection to withstand a possible leak of gas and explosion risk.

Washer-dryers with heat pump technology

Compared to the use of HP in washing machines, in washer-dryers the heat pump is used to heat air, and not water. In 2014 Electrolux introduced a washer-dryer with heat pump technology (model name "ÖkoKombi", for both the brands Electrolux and AEG). The heat pump works equivalent to that of a regular heat pump dryer, i.e. a small amount of air is heated and passed through the wet laundry. The hot, humid air is then passed through a heat pump where the moisture is condensed. The heat is reused for heating the dry air which is passed again through the wet laundry, so the condensation heat is used internally from the water condenser to the heated air flow. In comparison to a condenser dryer without heat pump, up to 50% of energy can be saved (Rüdenauer et al. 2008a).

According to the manufacturer the washer dryer model equipped with this technology needs 40% less energy and 15% less water compared to a standard A-class washer-dryer (i.e. compared to the threshold for class A which is 0.68 kWh per kg and full cycle). It has a capacity of 9 kg (for washing only) and 6 kg (for drying or continuous washing and drying) (AEG 2014a).

Table 4.9: Comparison of heat pump washer dryer with equivalent model without heat pump

	Electrolux WTSL6E200 (L99695HWD, with heat pump)		AEG L77695WD (without heat pump)	
Recommended retail price (Germany)*	1,919 Euro (offer: 1,089 Euro)		1,369 Euro** (offer: 969 Euro)	
	Washing only (standard 60 °C cotton)	Washing / drying (standard 60 °C cotton / dry-cotton drying cycle)	Washing only (standard 60 °C cotton)	Washing / drying (standard 60 °C cotton / dry-cotton drying cycle)
Capacity	9 kg	9/6 kg	9 kg	9/6 kg
Per cycle				
Energy consumption (kWh)	1.09	3.67	1.04	5.86
Water consumption (litres)	69	69	59	103
Programme duration (min)	238	580	209	471
Per annum (200 cycles)				
Energy consumption (kWh)	218	734	208	1172
Water consumption (litres)	13,800	13,800	11,800	20,600

* The prices are the recommended retail prices given on the respective websites. The recommended retail price may vary according to the Member State in which the appliances are sold.

** The recommended retail price is that of the very similar model AEG L77685WD

Sources: (AEG 2014b), (AEG 2015a); (AEG 2015b); (Electrolux 2015a); (Electrolux 2015b); price info: (Amazon 2015) (Computeruniverse 2015)

As the table shows, the energy consumption for a full cycle (i.e. washing, spinning and drying) is 3.67 kWh with heat pump and 5.86 kWh without heat pump, which is a reduction of about 38%. The threshold energy consumption for class A for a rated capacity of 9 kg is 6.12 kWh/cycle; i.e. in comparison to this value the reduction is about 40%. The energy and water consumption of the heat pump model of washing only is slightly higher than that of the model without heat pump. As the model without heat pump uses water condensing drying technology the water consumption of the heat pump model in the full cycle is about 35% lower than that of the model without heat pump.

The difference in the recommended retail price is very high (550 Euro), however usually the appliances are offered (and sold) for prices that are often far below the recommended retail price (as illustrated by the offer prices given below the recommended retail prices).

So far, no washer-dryer is equipped with a heat pump for the washing process, which would require a different design of the heat-pump technology. For drying, the refrigerant has to exchange heat with a gas, for washing the heat exchange is done with a liquid. According to manufacturers, the use of a heat pump for the washing process is not convenient for washer-dryers. Indeed, because of space limitations, only one heat pump can fit in this appliance and this is applied to the drying process, because the saving potential achievable is much higher for the drying process compared to the washing process. This is even more in light of the trend towards lower washing temperatures.

With regard to the use of different types of refrigerants, the same considerations apply as for heat pumps used in washing machines, see above.

"Heat-fed machines" (heating by a hot water circulation loop)

This option describes the possibility to replace the electric heating elements with heat from a hot water circulation loop, using a heat exchanger to transfer the heat from the dwelling's circuit of hot water to the machine. In contrast to the "hot fill" option (see below), the appliance itself is connected to cold water which is then heated NOT by an electric resistance heater but by a hot water heat exchanger.

The advantage of this option compared to the hot fill option is that not only the heating of the water can be replaced, but also the heating of the machine itself and the laundry.

The saving potential depends on the temperature of the hot water. According to Persson (2007) with a hot water temperature of 70 °C (or above) the whole electricity demand for heating can be replaced by the heat from the hot water circulation loop, i.e. the electricity demand for a 60 °C standard washing cycle could be reduced to about 0.27 kWh.

It was reported by stakeholders that products implementing this technology would require specific standardization needs for aspects not covered by existing standards. The technical effort for the installation of the hot water circulation loop can also be significant. The installation of such machine would be more difficult as (besides the electricity connection) it has to be additionally connected to the hot water source.

This type of installation is most efficient if the hot water source is renewable (e.g. solar systems).

Hot-fill (connection of the appliance to a hot water supply)

This option is commonplace in some countries, like the USA. However, in the Ecodesign preparatory study ENER Lot 14 this option was described as a declining option in Europe, as several producers in the UK no longer offered it and it was offered in no other country of the European Union. The main reasons for the decline and limited penetration of this technology were seen in the general trends towards reduced water consumption and lower washing temperatures, which results in lower additional energy saving potential. Indeed, if less water is needed per cycle, also the amount of (hot) water is reduced, and if less water has to be heated up to lower temperatures, the energy consumption for heating decreases as well as the possible savings through hot fill, which would be the main reason for replacing electrical devices for heating water with more efficient external heating systems (e.g. based on renewable energy or primary energy resources).

In principle however, it is possible to connect most washing machines and washer-dryers directly to a hot water line, as shown in studies by (Bush & Nipkow 2005), (Gensch et al. 2009), and (Saker et al. 2015).

Hot-fill is a standard technology, but it is currently not widely implemented in Europe as appropriate connections are only rarely available in households. However, this may be an interesting option since in many countries more and more households use solar energy. Hot-fill can potentially allow for electric energy savings, but the real saving depends on the selected cycle, the selected temperature, and site specific conditions, like the temperature of the externally heated water and the source of energy used. Also the hot water supply needs to be well insulated and distance between hot water source and the appliance connection point must be short. It is most efficient when a circulator is installed (which also uses some electricity and results in heat losses).

In contrast to dishwashers, two inlet valves followed by a thermostatic mixing valve, or a separate mixing device outside of the washing machine are needed in case of hot-fill feature. While dishwasher water can in all programmes be above 50 °C, some textiles cannot be washed with high temperatures (delicates, wool), and certain stains need a gradual temperature increase or pre-soaking with cold water to prevent fixing (e.g. protein stains) or to enable cold rinsing. It is therefore not possible to connect a washing machine or a washer-dryer solely to hot water. Therefore specially designed appliances are necessary in case of washing machines (and washer-dryers), which leads to additional costs. In cases where / under the assumption that the hot water delivery of the dwelling is more energy efficient than the heating of water within the machines using electricity, this measure could result in energy savings. However, there are few scientific studies assessing these savings on a quantitative basis.

While (Saker et al. 2015) consider both dishwashers and washing machines equipped with an additional hot-fill connection, (Gensch et al. 2009) focus on several types of dishwashers only, one of them specifically designed for hot-water filling. The authors of both studies conclude that the potential benefits of hot-fill appliances depend on the specific site conditions and parameters, like the length and the insulation of the hot water pipe, efficiency and control characteristics of circulation pump, water heating sources (e.g. gas boiler, off-peak electric, solar combined with gas or electric).

Overall energy efficiency might be worse if hot water is inefficiently heated and/or significant losses take place along the water pipes.

Both studies conclude that under certain conditions the additional connection of washing machines to hot water can provide the possibility to reduce and shift electricity demand. (Saker et al. 2015) recorded a high share (80% of washes) of washing programmes at 30 °or 40 °C, resulting that no electric heating was required for virtually all these washes with hot fill use. (Gensch et al. 2009) and (Saker et al. 2015) agree that solar hot water combined with gas heating for hot water supply is the option resulting in the lowest GHG emissions for hot water generation and consequently for washing machines (and washer-dryers) using the hot fill option (if site conditions and parameters are beneficial).

The option not necessarily results in lower water consumption but can allow saving electrical energy. As drawback, washing machines with two water inlets are more expensive because of the need of additional components and adaptations (e.g. valve, hoses, controls). Additionally, protein stains may be fixed and difficult to remove if the initial water temperature of washing is too high. Wastage of energy would also occur during the rinsing process if a washing machine without warm water inlet is connected to a hot water supply only.

Today some manufacturers still offer washing machines with two water inlet valves enabling to connect them to two types of water (e.g. hot and cold water or tap water and rain/well water, see section 4.2.1) (Gorenje [n.d.]; Miele [n.d.]c).

This option could be in principle applicable also to washer-dryers however so far there is no such model on the market.

4.4.2.5. Option 5: Improved drenching systems / improved detergent dissolution

Different systems are available on the market that mix air, water and detergent for reportedly improving the process of detergent dissolution, distribution and penetration in the fabrics, and ultimately washing performance. However, also costs increase compared to appliances without such technologies implemented. It has to be considered however that some technologies are patented and therefore not available to all manufacturers.

Internal water circulation

Through internal water circulation (e.g. like PowerWash/“spin-and-spray-technology” by Miele) the drenching of the laundry by repeatedly spraying water on it and spinning at the same time is improved. Thus less water is needed which also results in a lower energy demand. According to the manufacturer, machines with this technology need up to 40% less energy than the A+++-threshold, and is realised with washing times below three hours. Usually the water and energy demand per kg laundry is much higher if the washing machine is not fully loaded compared to full load. This technology is supposed to effectively reduce also the water and energy demand with partial loading.

Ecobubble™ technology

Recently washing machines with a so-called "Ecobubble™" technology came on the market. This technology introduces detergent/air/water bubbles in the wash water during the wash cycle to create wet foam, which is claimed to result in a better wash performance at lower temperatures. According to the manufacturer, energy can be saved by this technology as washing with cold water (15 °C) is supposed to be as effective as washing with 40 °C (SAMSUNG UK 2012). Initial tests from consumer organizations reported little difference to washing performance versus conventional machines. Recent test results from consumer organizations (Que choisir 2013; Which? 2013b) have reported Ecobubble™ washing machines delivering strong performance.

Spray-technology

In 2014 Whirlpool introduced this technology that aims at reducing the free water beneath the drum. A hydraulic system allows spraying a mixture of detergent and water directly to the laundry by the help of a specially developed nozzle. The (known) principle behind the Spray technology is to fill in only the water that is needed for the wash process by an improved water distribution system. The reduction of water leads also to energy and possibly detergent savings. According to the Spray project (an EU funded project to demonstrate the feasibility of the new technology) the following savings can be achieved: water saving 27%, energy saving in average 10%, detergent saving 5%, while maintaining the rinsing efficiency; however, the data basis for these indicated reductions have not been disclosed so far. First washing machines should be put on the market (upper market segment) from March 2015 onwards (Spray project 2015a, 2015b).

Pre-dilution chamber for compact detergents

Some producers of detergents have launched very compacted detergent formulations like the super concentrated liquid or gels but also the mono dose capsules (both with a dosage per wash below or equal to 35 ml). However, according to the detergent industry, there are difficulties to dissolve these nowadays highly compacted detergents in reduced quantities of water in current washing machines. To improve the dissolution of compact detergents, a so called pre-dilution chamber for detergents can be equipped, as recently done by some manufacturers of washing machines (cf. for example (AEG n.d.). The system enables the concentrated detergents to be pre-diluted before they are mixed with water from the main water supply and are sprayed onto the laundry.

4.4.2.6. Option 6: Higher water extraction through spinning

The spin-drying efficiency influences the residual moisture content of the laundry which ultimately decreases the energy demand of the subsequent drying process. To remove an equal amount of humidity, indeed, the thermal evaporation process requires more energy than the mechanical process in washing machines (cf. section 0).

According to the German Energy Agency DENA, spin speed profiles with maximum spin speeds above 1,200 rpm require between 5% (at 60 °C) and 10% (at 40 °C) more energy in the washing cycle than lower spin speeds (DENA 2006). However, as the remaining moisture content of the laundry is reduced, the subsequent energy demand for drying is also reduced leading to a higher overall efficiency of the washing-drying system when a dryer is used or the laundry is dried in heated rooms (Rüdenauer et al. 2008a; Rüdenauer & Gensch 2004). It has been also reported that moving from a washing machine with a spin-drying class B to one with a spin-drying class A saves three times more energy (in case that a tumble dryer is used for drying) than moving from a washing machine with energy class A to one with energy class A+. The spin-drying efficiency is of high importance for the overall efficiency of the total laundering process (Josephy et al. 2011).

In the Ecodesign preparatory study ENER Lot 14, an increase from 1,200 to 1,600 rpm was considered as improvement option. There were machines with 1,800-2,000 rpm on the market at the end of nineties but they have disappeared meanwhile. According to stakeholder information there is a practical limit for the maximum spin speed at around 1,600 rpm, since higher spin speeds can hardly achieve any reduction in remaining moisture content but cause high costs. According to feedback from stakeholders, it has also to be considered that higher spin speeds bear the risk of earlier failure of certain parts of the washing machine, mainly the shock absorbers and the ball bearings, and require higher costs for better quality components. A high spin speed increases also the wrinkling of the laundry, which subsequent increases the energy demand of ironing, although this does not seem the major energy contribution to the washing-drying-ironing system (see section 4.1).

Washing machines do not usually apply the maximum spin speed for each programme, but only for the cotton programmes. For delicate laundry, wool or other special programmes, usually lower spin speeds are set. The maximum spin speed can also be modified manually by the users, e.g. to reduce the wrinkling effects to ease ironing.

Depending on the type of final finishing of the clothes different spin speeds are recommendable, as shown in Table 4.10.

Table 4.10: Recommended spin speed / spin drying efficiency of washing machines depending on the type of final finishing (own elaboration based on stakeholders feedback)

Type of final finishing of clothes	Recommended maximum spin speed / spin drying efficiency of washing machine
Drying in a tumble dryer	As high as possible, as minimum 1,200-1,400 rpm, Spin-drying efficiency class A (remaining moisture content <45%) would need much less energy than a class B.
Drying inside apartment (clothes line)	As high as possible, as minimum 1,200-1,400 rpm, Spin-drying efficiency class A (remaining moisture content <45%) is needed to dry faster and avoid damage to the rooms due to humidity.
Drying in in a special drying room (clothes line)	A) In a heated drying room: as high as possible B) In an unheated drying room, vented by outside air: as low as possible Spin-drying efficiency class A (remaining moisture content <45%) would allow faster drying Min 1,200 / 1,000-1,400 rpm may be recommendable
Drying outside apartment	As low as possible to save energy Spin-drying efficiency class A (remaining moisture content <45%) would allow faster drying Min 1,200 / 1,000-1,400 rpm may be recommendable
Ironing	As low as possible To judge – the wrinkling in the textile has to be respected Min 1,200 rpm may be recommendable After having tumble dried ironing usually is obsolete.

4.4.2.7. Option 7: Sensors and automatic controls

While the capacity of machines has increased, the loading behaviour of consumers seems to have not changed, i.e. under-loading regularly occurs. Efficient electronic controls to adapt energy, water and possibly detergent consumption to only partially loaded washing machines (and washer-dryers) are more and more important, both under standard and real life conditions. Today, partial load is part of the standard testing procedure of washing machines.Electronic controls are applied to different elements of the washing machine and washing cycle phases.

Automatic load detection

With the help of electronic controls, automatic load detection allows adapting the programme to the amount of load, at least to an extent. This is an important function, since partial loads occur more and more due to increased capacities of washing machines and washer-dryers

There are different types of methods to detect the load. These can be split between direct and indirect methods.

In case of indirect determination, the washing machine determines through the use of sensors the amount of water needed for drenching the laundry. The water intake takes place in several steps. The more laundry is filled into the machine, the more water is soaked into the fabric. As a consequence, the machine reacts by adapting the water and energy use as well as the programme duration to the amount of load detected. This feature is commonly implemented in all machines. Sensors typically measure the water pressure level, and can be either mechanical (cheaper) or electronic (more precise). According to manufacturer feedback, mechanical sensors are possible in all washing machines, whereas not all washing machines can use electronic sensors.

It is also possible to determine the load directly, for instance by means or sensors detecting the height of the tub or of the shock absorbers. With this system, the machine indicates the actual load before starting the washing programme. This could be useful to provide a direct feedback to users (e.g. through messages on an electronic display, or with LEDs) to enhance the loading of the machine (cf. section 4.4.2.8).

Load sensors are a standard technology for washing machines and washer-dryers (for both washing and drying cycles) although not implemented in all appliances. Multiple sensor technology is more expensive and, since different types of textiles absorb different amounts of water, not necessarily needed. Moreover, the benefits provided by sensors would be achievable only in practice and not under laboratory conditions, where the levels of load and soiling are standard.

Besides simple electronic controls, there are also sophisticated electronic controls (e.g. “fuzzy” controls) that enable the machine to determine a large part of the program by itself.

In the Ecodesign preparatory study ENER Lot 14 in 2007 it was assumed that about 90% of the machines on the market had at least partial electronic control, and that 50% of the machines on the market were equipped with more sophisticated electronic controls.

Today, according to stakeholder feedback, there are practically no appliances left in the market without automatic load detection. However, there are substantial differences in the ability to adapt the consumption figures according to the actual load. Results of the ATLETE II project (cf. in section 2.2.5) show that in practice with an actual load of 50% the reduction of the energy demand ranges from 0% to 41% (only 1,6% of the analysed models were able to reduce the energy demand by 40% or more).

A stakeholder said that the key is to educate consumers to use full-loads. However, this may be effectively possible only if the measurement of load is communicated to the user of appliance, e.g. on the display after or (preferably) during the cycle, or by turning LED lights proportionally to the load of the machine. Manufacturers agreed that this would be feasible for weight-based sensors, but drench sensors may provide indications only once the programme is running.

Automatic detergent dosage systems

With this option, liquid detergent is dosed automatically by the appliance from a pre-filled reservoir based on water hardness, amount of load and soiling of the load. Users do not have to decide how much detergent to dose potentially leading to avoidance of overdosing or under-dosing of detergents, detergent spilling and foam excess, which would ultimately result in saving water as less water is needed for rinsing.

(Blepp & Gensch 2013) as well as Gensch et al. (2010) quantify the reduction in detergent consumption of such systems to be around 30%. Further, research into the saving potential of water shows that, compared to a manual dosage, the automatic dosing function can allow saving up to 7,062 litres of water per year per machine (Sanner 2011). As liquid detergents do not contain bleaching agents as heavy duty detergents, these have to be added separately if necessary.

This option would only provide benefits under real life conditions and not under standard conditions, where the dosage is defined and fixed by the standards. However, in real life correct dosage becomes increasingly difficult as a consequence of the great variety of washing machines' capacities: the detailed dosage recommendations on detergents packaging are meant for fully loaded 4.5 kg machines, depending on water hardness and degree of soiling. Additionally, the user should take into account the rated capacity and the actual load of the machine.

It can be assumed that the use of a washing machine with automatic dosage dispensing leads to a further increase of the share of liquid detergents consumed on the market. The environmental impacts of this improving option have not been evaluated yet.

Several manufacturers offer washing machines in the upper market segment with automatic dosage of liquid detergent, with one or two detergent compartments (for two types of liquid detergent or for detergent plus fabric softener). .

Figure 4.8: Automatic dosage system presented at the IFA 2015 fair in Berlin by Samsung (top) and Haier (below); (source: own pictures)

The option can be considered as BAT for washing machines. So far no washer-dryer is equipped with this technology, i.e. it can be considered as BNAT. Due to space constraints it might be difficult however to implement this options in washer-dryers.

4.4.2.8. Option 8: Consumer feedback mechanisms

The following options are based on the existence of sensors measuring e.g. actual load (cf. section 4.4.2.7 above).

Display of the actual load

Due to improved load sensors, the indication of the actual load could be displayed on the machine, e.g. via LCD displays or a series of LEDs. This option tries to influence consumer behaviour towards full or higher loading of the machine. In 2007, machines with both LCD displays and load sensors were on the market in some high end-range machines, 0.5-1% of the market, however the loading was not necessarily displayed.

In the meantime, there are machines on the market with this option, i.e. machines displaying the actual loading detected while the user is loading the machine. Usually they also include a detergent dosage recommendation. Thus, on the one hand consumers might be influenced towards higher/full loading of their machine or (at least) lower dosage of the detergent if the machine is not fully loaded.

Display of resource consumption

Some manufacturers have developed appliances that provide indications on the estimated energy and water use of the chosen programme via a TFT (Thin Film Transistor) display, e.g. by different numbers of bars, cf. Figure 4.9. Thus the user can directly see differences in the consumption values of different programmes and might choose a more economic programme. Mostly, the indicated values are default values whereas the exact consumption values might differ from the estimation due to the actual load and soiling. This option does not lead to direct savings in water and energy in the standard programmes but enables consumers to do informed choices and might enhance a more sustainable washing behaviour. Some machines display the energy and water consumption at the end of the programme.

Figure 4.9: **Display of programme's expected energy and water consumption by bars presented at the IFA 2015 fair in Berlin by BSH (source: own picture)**

4.4.2.9. Option 9: Improved interconnectivity between appliance, user and technical systems

Internet connectivity (Smart appliances)

This option enables remote programme updates and machine diagnostic (thus can be seen as evolution of option "Electronic update of the programmes /diagnostics", see below). When connected to the internet the machine is linked to the company's servers and automatically reports service issues. The machine can be started and stopped via the internet connection. In the preparatory study ENER Lot 14 it was supposed that this technology was applied to none or only few (0.1%) of the models on the market. As a machine with this option has to remain in networked standby-mode, legislation 801/2013 applies to these low power modes. This option was considered as BNAT in 2007.

Today this option is offered for some high end models. It offers various functions to the user, e.g. to connect different household appliances with each other (like hobs and kitchen hood). It also allows displaying the status information of connected appliances on a central display located on one of the appliances, e.g. the oven in the kitchen. Furthermore with a central gateway the user can remote control and manage the appliances with a PC via the internet or with a mobile phone, e.g. start or stop certain programmes or functions. The appliances are also able to communicate with a customer service unit of the manufacturer, or – in case of automatic dosage systems – automatically order via internet new detergent in case of emptiness.

Electronic update of the programmes /diagnostics

An update of the washing programmes can be done by connecting the machine to an assistance PC. This option can also be used for machine diagnostics in case of failure. It allows for more efficient washing cycle management if external conditions change (e.g. development of a new detergent), however it has no immediate effect on water and energy consumption. In Lot 14 it was assumed that 20% of the models on the market have this option, to be used by an authorized after sales service. It can be assumed that today the share is much higher.

Smart grid ready (SG ready) products

Some "smart" appliances, i.e. appliances with internet connectivity also offer the possibility of communicating with the electricity grid, enabling the integration of renewable energy via load shifting (Vanthournout, Ectors, Bogaert et al. 2015). The vision of such smart appliance operation is that they autonomously start operation according to signals from the grid regarding the availability of electric energy within a consumer-defined time range (because of cost and/or environmental reasons). Thus electricity use can be shifted accordingly. Also signals from local electricity production systems based on renewables (e.g. photovoltaic systems) can be received to adjust the starting time according to the availability of electricity. There are no direct water or energy savings, but indirect emissions can be foreseen, as well as possible efficiency gains in the generation process. Besides a smart-grid ready appliance the consumers need a communication module (to be installed at the appliance) and a central gateway. The communication module communicates via powerline communication with the central gateway.

The appliances will be traditional household appliances which have been modified and redesigned for demand response (DR) by adding components and functionalities to be smart. There are several changes needed, which involves the functionalities of the appliance, because in most cases, it is not possible just to cut the power connection to the appliance. Instead, it is needed to do a more intelligent powering up and down of the appliance, which involves the full control system and the functionality of the product to maintain quality, safety, user comforts, privacy etc.

According to the technical analysis of the Ecodesign preparatory study ENER Lot 33 on smart appliances, smart appliances will typically contain the following additional components and design modifications compared to a non-networked and non-smart appliance (Viegand et al. 2015):

- Network connection (fixed and/or wireless connection), which depends on the network protocol and network interface technology used.
- Other control systems needed to be built-in to process and react on the Demand Response (DR) signals.
- Other components needed for the demand response ability e.g. energy storage (electricity, heat, cold), safety circuits, measurement circuits, sensors etc.

- Possible modifications in existing control system programming to take into account needed changes related to the DR mechanism relevant for the appliance for altering the electricity consumption pattern (e..g. energy storage, delay start of the next program step, set part of an appliance in an off-state, re-start after a DR mode)
- In some cases an additional power supply to handle the voltage requirements by the electronics and the low electricity consumption in a waiting for signal mode in order to comply with networked standby requirements.

Further, enabling periodical appliances for DR-functions requires new control software and an extension of memory capacities. The software needed depends on the level of smartness that is anticipated.

- In the case of signal activation, a software is required that recognizes signals from the grid (e.g. frequency sensing or direct signal from aggregator or via an energy manager) and activates the device before a predefined deadline is reached. Defining the deadline can be realized either by a start time function or an internal time function.
- Remote activation requires a software that allows bidirectional communication (e.g. to exchange of information on the expected energy demand of the programme or on the deadline set by the consumer) and activates the machine in response to the remote signal.
- As far as altered electricity consumption pattern is concerned, signal recognition software as well as an energy management software are necessary. The signal coming for example from the grid should include information on the shortage of energy and how long it may last. The energy management software needs to be able to find the most suitable reaction and transform it into action.

There are already coming networked appliances to the market – some of them are called “smart” in the meaning of having the capability of being controlled by a smart phone, computer etc. These appliances will typically not need a further network connection, but can use the existing one. There would typically be a need for other modifications to be DR enabled.

Currently, certain models of household appliances, also washing machines, are equipped with this feature. So far, however, it seems that the potential offered by this option cannot be fully exploited as other prerequisites have to be ready as well, like smart meters and a flexible electricity tariff that communicates directly with the gateway. The shift towards a market-driven approach for energy efficient appliances and demand-response has not been reached yet. This would require implementing structural changes to the current energy market and creating a real market for smart energy and efficient demand. There would be a need to develop market-based instruments adapted to consumers, as current mechanisms are tailored to match industrial and commercial demand response.

According to stakeholders, possible drawbacks could be that the consumers would have no full control of the appliance anymore and would not be able to decide to run the appliance whenever needed. Also negative effects on the performance parameters of the appliance (e.g. cleaning efficiency, energy demand) might be possible if the washing cycle is interrupted intermediately by signals from the smart grid (e.g. additional heating energy might be necessary if the cycle was interrupted and the water temperature dropped). Appliances that are SG-ready are of course more expensive compared to non-smart products and the Wifi-module has additional energy consumption.

4.4.2.10. Option 10: Material selection

Use of plastic materials

According to WRAP ([n.d.]a), Indesit has produced a plastic back panel for two of its washing machine models using 100 percent recycled content with similar characteristics to the previous part that was made from virgin material. The access panel is made by using recovered fridge waste, which is then shredded and made into a high grade polymer pellet. The plate was developed in a pilot project first, and is now being integrated into the back of the premium Hotpoint Aquarius and Ultima Washing Machines. According to WRAP ([n.d.]a), Indesit has achieved the same production cost for the recycled plates by achieving the same cycle time in the moulding process. This is combined with a 5 percent saving on raw material costs.

In its Sustainability Report 2013, Indesit Company informs that it has developed technological solutions and recycled materials or biopolymers or materials from renewable sources that can potentially reduce the amount of bitumen dampening material, soundproofing felts and, in certain models, also eliminate metal side panels and reinforced concrete counterweights. Over and above the obvious benefits in terms of energy savings for the industrial process (elimination of gluing in "hot melt" ovens) and the thermodynamic and acoustic performance of the product, the achievement of such objectives makes it possible to significantly increase the use of recycled materials (currently only 3% of the total) and facilitates dismantling at the end of the product's life (as well as improving the quality of the recovered materials). The project aims to limit, eliminate or replace certain materials habitually used in home appliances (and in particular direct oil derivatives in dishwashers) (Indensit Company 2014).

However, the use of bio-materials is still controversial. Materials based on biomass are in principle considered to save fossil fuel resources because of their renewability. However, embracing a system perspective may in some cases result in environmental trade-offs, for instance due to the additional demand for land, water, energy and chemicals for the production of biomass. Spatial and technical differences between different production chains can result in a complex range of environmental performances ((Börjesson & Tufvesson 2011); (Buchholz et al. 2009); (Cordella 2010); (Cordella et al. 2013) and (Fiorentino et al. 2014)). The selection of materials based on biomass may be supported in the future by standards and sustainability criteria currently under development (European Committee for Standardization 2011).

Sharp and Kansai Recycling Systems Co. Ltd. jointly developed a closed-loop plastic material recycling technology that repeatedly recovers plastic from used consumer electronics and reuses it in parts of new consumer electronics for the Japanese market. This technology has been in practical use since 2001. By combining of a high-efficiency metal removal line, high-purity PP (polypropylene) separation and recovery technology, and other property improvement/quality control technologies, Sharp has been able to recover recyclable plastic, as well as to find applications for its use, such as in the exterior panels of home appliances and as flame-retardant materials. Because recycled plastic can be reused numerous times, the practice has been adopted for use inter alia in washing machines (base frame and washing tub), and other similar home appliances sold within Japan which are subject to the Home Appliance Recycling Law (Sharp 2012).

According to the study "Material recycling without hazardous substances – experiences and future outlook of ten manufacturers of consumer products" of the Swedish Chemicals Agency cited in Dalhammar et al. (2014), the main barriers for increased use of recycled materials include risk of contamination, costs associated with avoidance of such risks, and limited availability. For some recycled materials, most notably plastics, it is difficult to find a material that complies with technical and quality requirements. The companies interviewed in the study see future opportunities in overcoming the barriers. Increased use of recycled materials depends on the development of cleaner material streams, which require cleaner input materials, development of better separation/cleaning technologies, and standards for recycled materials.

Also manufacturer feedback confirms that from a technical point of view, the use of recycled materials does not fulfil their technical requirements (mechanical stability, aging requirements, chemical requirements/REACH/RoHS, detergents resistance, colour, etc.), especially for functional components as the required quality levels cannot be reached. Some less critical components could eventually contain a certain level of recyclates. The share of implementing them in production depends on the quality level of recyclates fulfilling minimum quality levels, as well as the availability in sufficient quantities and at a competitive price in comparison with virgin materials.

Design for durability

Some manufacturers are producing appliances with increased durability. This is achieved through specific design choices and by the careful selection of materials (e.g. higher amount of metals instead of plastics). More durable products generally tend to be heavier and more expensive for consumers. Environmental impacts embedded in the product might also be higher than in case of use of cheaper materials, although the lifecycle impacts would be compensated by the possibility of using the appliance for a longer time. However, the overall environmental impact of different component materials has to be further analysed. As example, according to a manufacturer's feedback, the use of plastics instead of metals for the WM tub has advantages from an energy consumption and noise point of view. Plastics have lower heat conductivity, which leads to lower energy consumption; and plastics have a noise damping function.

While the arguments above justify the use of plastic for the tub, most manufacturers have also chosen to weld the two plastic halves of the tub, substituting the former use of screws and a rubber ring. This design shoice has saved some cents to the final WM price tag for consumers, but provides similar water tightness than a bolted drum. However, it creates considerable problems in case of repair, as all elements inside the tube cannot be replaced. In case of failure, the whole tub has to be exchanged, and this frequently costs more than half the proce of the original machine. Some consumer organisations have recently highlighted this issue, and conclude that the sealed tub is eemingly a damaging design choice from the perspective of consumers (Which, 2016).

According to one manufacturer feedback, appliances are developed for a minimum lifetime as expected by the customers. All components have to fulfil these requirements so that the choice of materials and product construction is entirely based on fulfilling this end-user expectation, with the respect of cost aspects in a highly competitive environment.

Fiberglass drum construction

Integrated fiberglass housing with a counterbalance moulded directly into the shell of the outer drum was described as technological option in the Ecodesign preparatory study ENER Lot 14. However, the potential benefits of fibreglass compared to traditional counterbalance materials (like concrete or steel) was not clear. No savings in energy and water consumption were foreseen. Today, there still seems to be one manufacturer offering washing machines with this kind of drum.

Materials used in motors

According to ENER Lot 14, also the construction materials used in motors could be optimised. Less iron and copper have no impact on energy/water consumption but reduce the material composition of the machine and the costs for manufacturers which can compensate raw material price increase. 5% less material with no modification of the other motor characteristics were seen as feasible. However, this does not seem applied yet to the models on the market and also the nature of the materials used is an important characteristic to take into consideration. It has to be discussed if the optimisation of materials in motors still is to be seen as possible improvement option, especially in light of high efficient, brushless, permanent magnet motors.

4.4.2.11. Option 11: Alternative washing systems

Ultrasonic cleaning technologies

The first time ultrasonic sound was discussed as technology to wash laundry was in the middle of the 1980ies in light of the strong environmental impacts of detergents at that times (e.g. over-fertilisation due to phosphates). In 2001 the Japanese manufacturer Sanyo then introduced such a washing machine, combined with water electrolysis to improve the washing performance. According to the wfk-research institute however, the washing performance of such machines is much worse than that of normal washing machines using detergents due to the fact that ultrasonic waves only clean good on hard surfaces (like eyeglasses or medical instruments). Also due the lack of detergent the dirt might be dissolved but then deposits again on the laundry resulting in greying (Deutschlandfunk 2006).

In January 2015 an ultrasonic washing device was introduced in the market ("dolfie", see http://dolfi.co/). It is primarily meant to wash individual pieces of laundry when travelling, or delicates that have to be washed by hand in the sink. The laundry pieces are put in water, detergent is added and the ultrasonic device which is then switched on. The ultrasonic sound waves form microscopic high pressure bubbles in the water (cavitation). When they implode "millions of micro-jet liquid streams" are created that wash away the dirt. It has been developed with the help of MPI Ultrasonics in Switzerland and is supposed to use "80 times less energy than a standard washing machine" (dolphi 2015). Delivery is supposed to start in August 2015.

Polymer bead technology

In 2010 a washing technology was presented that is supposed to clean the laundry mainly with nylon 6.6 beads as a 'solid solvent' plus a small amount of water to aid transfer of soils from the garment to the beads where it is absorbed. Under humid conditions, the polymer becomes absorbent. Dirt is not just attracted to the surface; after the water dissolves the stains, the dirt is absorbed into the centre of the beads, where it remains trapped. After the cycle is complete, the beads are spun out of the load through holes in the drum, where they then return back to a sump pump and are reused.

The company is called Xeros and is based in the UK. The system started as a way of scavenging dye in the fabric treatment industry (Prof Burkinshaw, Uni Leeds). According to stakeholder information it may be an interesting approach for commercial laundry where professional bead separation should be possible, but maybe not so attractive on the domestic side (although the manufacturer says they will launch in the US).

It is supposed to save up to 80% water (Financial Times 2015) (according to (Financial Times 2015; Süddeutsche Zeitung 2010) in 2010 even 90%: 5 litres instead of 50 litres for a standard cycle). As the residual moisture content after the washing process is also supposed to be much lower than in conventional washing machines also the energy demand for the subsequent drying could be reduced. According to stakeholder feedback, such machines have currently no market relevance and are not foreseen for normal / household usage.

Steam Care/Steam finishing

The laundry is treated not only with water but also with steam (mainly in the end of the wash cycle). According to (ISIS 2007a) the steam was initially meant to reduce micro-organisms and thus compensate for the low washing temperatures. Another effect which is currently more prominent in the marketing is the reduction of odours and of wrinkles. The latter one would result in lower effort for the subsequent ironing (in terms of both time and energy). Some steam machines also offer a so called "refresh" programme, where slightly used and soiled laundry is only treated with steam. This offers the possibility to "refresh" garment which is usually not suitable for washing in a washing machine but which has to be cleaned by professional dry cleaning, which may come with higher environmental impacts.

Although being a standard technology, this function does not bring proven energy savings. The drawbacks are that additional hardware is needed (the steam generator) and that the use of the steam option in a wash cycle increases the energy demand, as the steam has to be generated. This is less the case for washer-dryers where this function can be offered without any additional hardware effort.

Some manufacturers have in the market 'refreshment cabinets' for non-soiled clothes, which essentially remove creases, odours, and have a hygienisation function by means of air circulation while the clothes hang on the wardrobe.

4.4.2.12. Option 12: Reduction of the water consumption

Rinsing optimisation

Rinsing optimisation means to achieve a certain rinsing performance (amount of detergent residual in the washed laundry) with as little water as possible. The WASH II study already describes the improvement that took place in the period between 1993 and 1998: through improved rinsing efficiency and intermediate spinning the number of rinses could be reduced to 3 and also the amount of water used per rinse decreased. The WASH II-study notes a general acceptance of 3 rinses instead of 4 or 5, with a higher number of intermediate spins. Lot 14 does not describe in much detail a further rinsing phase optimisation that was supposed to be applied to 20% of the market.

Today, with a much smaller volume to load ratio (see section 4.4.2.1) rinsing performance is an important aspect to take into account. A standard on rinsing efficiency is currently under development which is an important prerequisite to further optimise the rinsing phase (see section 1.2.2.1)

Use of rain/well water

There are some washing machines on the market with two water inlet valves that can work with two water sources. Besides cold water it can also be connected to a second water source, either hot water (see section 4.4.2.4 on hot-fill) or alternative water supplies such as rain or well water. Two inlets are needed, as tap water is always used for the last rinse for hygienic reasons. When used with rain or well water the consumption of tap water can be reduced and partly also the consumption of detergent, as rain water usually is softer than tap water.

This option does not lead to energy savings but only to water and, possibly, detergent savings. Besides designing the washing machine with two water inlet valves also equivalent infrastructure in the house is needed. This option should principally be applicable also to washer-dryers however so far there is no such model on the market.

Water recycling

The storage of the last rinse water in a water tank to be used during the next cycle is an option that would allow for saving water since the water of the last rinse could be used in the next cycle. This is an “old” solution on the market, but not very much used for different reasons, e.g. increased costs, space constrains (especially in case of washer-dryers), risk of mould and bacterial growth in the storage tank and more complex internal controls and extra costs for the products. Several attempts to launch this technology in the market have failed due to the described drawbacks.

Currently no machine with this technology could be identified on the market.

4.4.2.13. Other features

Delay start

This option allows starting the washing cycle after a certain number of hours (delay), leaving the machine loaded and ready for start. It does not have an influence on the water or energy consumption of the washing cycle but allows running the machine during off-peak times with lower electricity costs. The 'delay start mode' however consumes a certain amount of power for the timer and respective electronic functions, which is not regulated by Regulation 1275/2008 for standby and off-mode, as 'delay start' is not defined as standby mode as not lasting for an indefinite time (cf. section 1.2.1.1).

A similar function was the then newly introduced option "time to end of the cycle" to end the cycle at a set time independent from the starting. In this case the user can set a certain end time or cycle duration and the program is adjusted accordingly. Faster cycles usually result in higher energy demand however.

In Lot 14 the option 'delay start' was supposed to be applied to 30% of the models on the market. It is supposed that today nearly all models are equipped with this feature as it improves the convenience for the user.

Noise reduction

Noise is generally caused by the motor and the water circulation during the wash phase and by the spin during the spinning phase. Noise reduction can be achieved by the use of direct drive and three phase motors, the optimisation of the drain pump and by unbalance control (see respective options above). Noise reduction can therefore be considered as positive side effect of other options that reduce water and electricity consumption.

Single stain removal system

In June 2006 a washing machine with a special stain removal system was introduced by one manufacturer. The system allowed the washing machine to be set to one of 14 different stain types and the wash cycle was to be adjusted accordingly (e.g. length and temperature of certain wash phases, detergent-guidance to users).

Today similar systems still exist on the market and also other manufacturers offer special stain removal options. The option was extended to more stains (16 to 23 different types of stains) and it is partly possible to choose up to 3 stain types in one washing cycle. The influence of this option on water and energy demand has not been evaluated; it presumably depends from stain type to stain type. The stated advantage is that no special detergent (stain remover) is needed.

Anti-crease systems

After the wash cycle the drum is rotated periodically to prevent creases. This option has a certain energy demand, however reduces the effort for subsequent ironing. The significance of such option in energy terms is however questionable.

Voice controlled appliances

In Lot 14 voice controlled appliances were considered as BNAT. However there seems to be no direct (positive) effect on the water and energy consumption but rather an improved convenience for elderly or disabled users, especially with regard to the increasingly complex controls of the appliances.

Mixed appliances

Lot 14 described a combination of washer/dryer/air conditioner that had been presented by Toshiba Consumer Marketing in November 2006 .The integration of different functions was to be addressed in the system analysis and as BNAT. Currently no machine with this technology could be identified on the market.

4.4.3. Performance characteristics of washing machines and washer-dryers

4.4.3.1. Base Cases selected in 2007 by Lot 14 for washing machines

Following the MEErP methodology, the definition and further environmental-economic assessment of base cases and design options are needed for the definition of ecodesign/labelling requirements. Base cases must be representative in terms of market share and implemented technology.

In the preparatory study “Lot 14: Domestic Dishwashers & Washing Machines – Task 5: Definition of Base Case” from July 2007 (ISIS 2007c), two Base Cases were defined for washing machines. Washer-dryers were not in the scope of ENER Lot 14 at that time, thus no Base Case was proposed for WD.

Table 4.11: Base case defined for washing machines in Lot 14

Characteristic	Base case washing machine
Type of machine	5 kg load machine, front loading
Energy consumption	0.956 kWh/cycle (energy efficiency class A)
Water consumption	50.4 litres/cycle
Spinning speed	1073 rpm
Washing performance	class A
Drying performance	class B or C
Noise	53dB(A) in washing / 70 dB(A) in spinning

The second Base Case represented a 6 kg front-loading machine with energy efficiency class A+/A.

The newer market data indicates that the average appliance capacity has increased since 2007, and over 30% of the machines are of 7 kg or more, representing the highest share of models, followed by 8 and 6 kg machines (each approximately 23-24%). Large (9 kg) and small (5 kg) machines each have a share of 7-8% of all models available in the market in 2013 (cf. Figure 2.22). However, it has to be noted that the market shares provided are calculated based on the number of models on the market and not on the relative sales volumes.

Regarding the formulation of new Base Cases for washing machines within this study, two different strategies might be possible:

- Taking the most common capacity as most representative base case for the spread of capacities, i.e. only one washing machine base case:
  - 7 kg front-loading machine, energy efficiency class A++/A+++
- Representing the market spread also within the Base Cases to analyse differences and impacts of smaller and larger appliances, i.e. two washing machine base cases:
  - 5 kg front-loading machine, energy efficiency class A+
  - 7 or 8 kg front-loading machine, energy efficiency class A+++

For washer-dryers, this revision study will assess the feasibility of including washer-dryers into the scope of the regulations.

- Market data shows that also for washer-dryers, the market shifts towards larger washing capacities (7 kg models had the highest market share in terms of number of models - NOT market share by sales volume - in 2013, with around 35%), followed by 6 and 8 kg models (each around 20%), and 9 kg models (15%). In 2013, nearly no 5 kg washer-dryer models were provided any more (cf. Figure 2.44). The share of energy efficiency classes is shown in Figure 2.52.
- For washer-dryers, it would thus make sense to propose a washer-dryer base case of a washing capacity of 7 or 8 kg, and a drying capacity of 4 to 5 kg, and energy efficiency class A (according to the current Commission Directive 96/60/EC).

The finally chosen Base Cases for washing machines and washer-dryers, discussed with stakeholders trying to reflect, as far as possible, recent market and socio-demographic changes, user behaviour, technology development and standardisation issues (e.g. observed evolution of the average size of households in the EU countries; supply of appliances with higher average capacity also as market response to the method for the EEI calculation for the energy labelling), will be presented in Task 5.

4.4.3.2. Top models of washing machines and washer-dryers on the market in 2015

Topten (www.topten.eu) is a web portal guiding consumers to the most energy efficient appliances in European Topten lists (TIG 2015b). (TIG 2015a) identifies the most efficient washing machines and combined washer-dryers among those available on the market. Some of these appliances may implement Best Available Technologies (BATs).

Most efficient washing machines listed at Topten.eu

All washing machines listed on Topten.eu have Energy efficiency class A+++ and spin-drying efficiency A, in accordance with the requirements set in the EU Energy Label. Moreover, the water consumption has to fulfil the EU Ecodesign requirements (minimum Topten.eu criteria for household washing machines). In addition, suppliers have to provide Topten also with the following data:

- Energy Efficiency Index (EEI)
- Energy consumption per cycle in kWh (60 °C full and half load, 40 °C half load)
- Programme time (60 °C full and half load, 40 °C half load)
- Power consumption in left-on-mode and off-mode
- Maximum spin speed
- Availability of a 20 °C programme (cotton)
- Availability of a water protection system (Aqua Stop, waterproof, water control system etc.)

According to (TIG 2015b), around 70 high efficient washing machines were listed on Topten.eu in February 2015. These present a capacity ranging from 6 kg to 11 kg and belong to 13 different brands. Their key characteristics are provided in the following table.

Table 4.12: Key data of household washing machine models listed on www.topten.eu with regard to energy consumption and programme duration; source: (TIG 2015b)

	Benchmarks: Range of washing machine models listed on **www.topten.eu**
Energy Efficiency Index (for comparison: A+++ threshold is EEI < 46)	Best EEI: 22.8 due to an integrated heat pump, i.e. 50.5% better than A+++). Other Topten-Models: 31.7 – 45.6
Energy consumption (kWh/cycle)	• 60 °C full load: 0.52 – 1.35 • 60 °C half load: 0.41 – 0.97

	Benchmarks: Range of washing machine models listed on **www.topten.eu**
	• 40 °C half load: 0.36 – 0.72
Energy consumption (kWh/year), based on 220 cycles per year	98 – 261 kWh/year
Programme time	• 60 °C full load: 2 h 20 min – 4 h 00 min/cycle • 60 °C half load: 1 h 35 min – 3 h 40 min/cycle • 40 °C half load: 1 h 30 min – 3 h 35 min/cycle

According to (TIG 2015b), the highest Energy Efficiency Index benchmarks of washing machines can be reached by the following means:

- Advanced technologies:
    - Inverter driven motors and permanent magnet motors
    - Heat pump technology (first introduction to washing machines in 2014 by V-Zug)
- High capacity: Since capacity is part of the EEI equation, a higher capacity with the same energy consumption lowers the specific energy consumption, which has a positive influence on the reached energy efficiency class on the Energy Label. However, there is a drawback: even if larger machines wash more efficiently per kg of rated capacity, more and more part load washing will occur, and the relative savings per kg nominal load then are lost. Ideally, half load (e.g. at 60 °C) would lead to a reduction of electricity consumption per cycle by 50% compared to a full load (e.g. at 60 °C). However, according to results of the ATLETE II project (cf. section 2.2.5), the reduction of the tested machines ranges from 0% to 41%, which leads in practice to an increase of the energy consumption per kg of laundry.
- Effective load sensors capable of estimating the weight of the laundry load and automatically adjusting the water and energy consumption. In particular this is meaningful for larger-sized washing machines, which frequently are not fully loaded by users.
- Lower temperature than declared: this leads to a better EEI and better classification because less water has to be heated. All machines guarantee the required washing performance (>1.03) despite these lower wash temperatures. However, in some cases this approach leads to hygiene problems, e.g. for users that select a 60C programme for hygienistation, in the belief that this temperature is in practice reached.
- Elongation of programme times: The increase of energy efficiency often goes along with longer programme times and lower temperatures (see below). On the other hand, there are washing machines on the market with comparably short times of the 'standard' programmes.

These factors, identified by Topten as most relevant for BAT models complement and confirm the specific improvement options described in section 4.4.2 above. According to one stakeholder, a prioritisation of technologies does not make sense, as in general only a well-adjusted combination of technologies allows for the lowest EEI-values.

Most efficient washer-dryers listed at Topten.eu

According to (TIG 2015b), washer-dryers must meet the following criteria in order to qualify for Topten.eu:

- Energy efficiency: max. 0.5 kWh per kg laundry (full wash and dry cycle / washing capacity)
- Water consumption: max. 12 litres per kg laundry (full wash and dry cycle / washing capacity)

These criteria are reached only when the appliance is equipped with a heat pump for the drying function. These heat-pump high-efficiency models consume 40% less energy. The energy consumption for washing and drying of the three models listed at Topten by end of 2015 is 3.67 to 3.8 kWh per cycle, while inefficient washer-dryers without heat pump use > 6 kWh for this process.

Due to the integrated heat pump, no cooling water is needed for drying (in conventional WD, some of the fresh water consumed is used for the purpose of condensing vapour and is then drained, and is not used for washing). Therefore water only is needed for washing, which saves 30% of water compared to conventional washer-dryers without heat pump. On average, the Topten-models use 69 litres / cycle, while inefficient models use around 100 litres and more (TIG 2015b).

Most efficient washing machine models with regard to standby and off-mode consumption

The European Union has decided in 2008 to limit the standby and off-mode energy consumption of a board range of products and equipment. This decision followed the '1watt' call from the international Energy Agency in the 2000's. According to EU Regulation 1275/2008/EC (cf. section 1.2.1.1), household appliances, households IT equipment, consumer electronics, electric toys, leisure and sports equipment have to fulfil the requirements in Table 4.13 (Topten.eu 2013).

Table 4.13: Power consumption requirements

	Since January 2010	From January 2013
Maximum power consumption in off mode	1 Watt	0.5 Watt
Maximum power consumption in a passive standby mode without information display	1 Watt	0.5 Watt
Maximum power consumption in a passive standby mode with information or status display	2 Watt	1 Watt

Based on the Topten.eu (2013) studies, Table 4.14 indicates the best available technologies presented in the market in September 2012 in aspect of standby and off-mode energy consumption.

Table 4.14: Most efficient technologies presented on the market in September 2012 with regard to standby and off-mode energy consumption (Topten.eu 2013)

Product group	TVs	Monitors	DVD players*	Washing machines	coffee machines	inkjet printers	laser printers	luminaires
Number of products in Topten sample	*118*	*48*	*11*	*24*	*24*	*19*	*37*	*61*
Average off-mode power (W)		0.34		0.25		0.36	0.34	
Best performer off-mode (W)		0.1		0.05		0.2	0.1	
Average passive standby (W)	0.24	0.41	0.51	1.3	0.43			0.47
Best performer passive standby (W)	0.1	0.1	0.2	0.75	0.15			0.2
% of products with a hard-off switch or quasi-0 W mode	*3%*	*15%*		*29%*	*24%*		*38%*	*43%*

These figures are not representative of the entire market, but give a good indication of what manufacturers are able to do. It appears that off mode and passive standby modes can technically go below 0.3 W (Topten.eu 2013).

Further data regarding the use of standby and off-modes has been collected by the ATLETE II project (cf. section 2.2.5). They show that for the so called "stable left-on mode", most of the analysed washing machines have a left-on mode power of 0.5 W; around 6% of the appliances under test did achieve left-on mode power values in a range of 0.01 to 0.1 W. For the off-mode, the lowest power values were in a range between 0.01 and 0.02 W, most of the analysed appliances had 0.07 to 0.08 W off-mode power.

Further, since 2013 household appliances are obliged to have a power management system requiring the appliances to automatically switch from left-on-mode into off-mode (not exceeding 0.50 W) after each cycle after a certain time.

4.5. Production, distribution and end-of-life

4.5.1. Production and Bills-of-Materials (BOMs)

In general, large white goods, such as washing machines and washer-dryers, are composed of the following materials/metals (UNEP 2013):

- Metals (steel, copper, aluminium, stainless steel and their alloys).
- Diverse plastics, including their additives (e.g. fillers, stabilizers), as well as other organic materials: rubber, wood, textile, fibres, etc.
- Inert materials, such as glass and concrete (incl. ferrite-containing concrete in washing machines).
- Low value printed wire boards (PWB) and electronics containing precious and platinum-group metals.

Table 4.15 provides a first general average material composition of washing machines based on 2011 data, although without specifying geographical and technical representativeness (UNEP 2013).

Table 4.15: Average composition of washing machines; source: UNEP (2013)

Material (%)	Washing machine
Iron/Steel	52.1
Copper	1.2
Aluminium	3.1
Stainless steel	1.9
Brass	0.1
Plastics	6.8
Rubber	2.8
Wood	2.6
Other organic	0.1
Concrete	23.8
Other inert material	1.9
PWB	0.4

Material (%)	Washing machine
Cables (internal / external)	1.1
Other materials	2.2
Total	100

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used the following average production input data for a washing machine model in 2007:

Table 4.16: Average production input data for a 5 kg washing machine model used by Lot 14 in 2007; source: (ISIS 2007c)

Materials type	Material	WM 5 kg (g)
Ferrous metals	cast iron	6,214
	Iron	4,978
	Stainless Steel	1,939
	Stainless steel sheet	564
	Steel	12,521
	Steel strip	6,145
Sum Ferrous metals		32,361
Non ferrous metals	Al	1,503
	Aluminium sheet	1
	Aluminium casting (recycled 80%)	729
	Brass	14
	Copper sheet	0
	Copper wire	348
	Cr	1,761
	Cu	869
	Ni	1
	zinc die-casting	85
Sum Non ferrous metals		5,311
Plastics	ABS	1,145
	EPDM - rubber	1,675
	PA	6
	PA 66-GF(Glass Fibre Reinforced)	0
	PA66	88
	PC	188
	PC-G (Glass Reinforced)	2
	PE	10
	Plastics, others	1,037
	POM	41
	PP	5,402
	PP-K40	2,533

Materials type	Material	WM 5 kg (g)
	PPO (=PPE)	2
	PPS-GF	76
	PVC	221
	PBT	8
Sum Plastics		12,434
Various	Bitumen	38
	Concrete	18,180
	Electronic, boards, switches, lamp, etc	165
	Filter	28
	Glass	1,773
	Gravel	25
	Oil - Feet	28
	Others	204
	Paper (booklets etc)	106
	Wiring	88
	Wood	1,573
Sum Various		22,206
Sum TOTAL		74,225

In case of washer-dryers, generally additional components compared the BOM of washing machines are required to provide the hot air venting system: air ducts (plastic materials), heating elements (consisting of metals for resistance wire and copper wires), ventilator including electric motor, heat exchanger, electronic components for control), including moisture sensor.

The following variations compared to the values of the BOM for the Base Case of 2007 as provided in Table 4.15 might be observed at individual washing machine and washer-dryer models:

- Higher content of ferrous metals in devices with balance weights from steel (and correspondingly the absence of concrete)
- If the machine is equipped with a permanent-magnet synchronous motor (PMSM): on the one hand, PMSM motors are lighter, their weight is reduced from around 6.5 kg to 3.5 kg; further there might be presence of rare-earths in some of the permanent magnets. However, according to stakeholder feedback, current permanent magnet motors of washing machines and washer-dryers have no rare earths, as these have been substituted by permanent magnets based on ferrites (cf. section 4.4.2.2).
- In cases where heat pumps are used (for washing in washing machines, for drying in washer-dryers), about 10kg of additional components are required: copper pipes for the cycle of refrigerant, a compressor system consisting of an electric motor and the compressor itself (mainly made of steel), a heat-exchanger (commonly made of aluminium and copper) and electronics for the control unit.
- Where heat pumps are being used additional components are required: copper pipes for the refrigerant circuit, a compressor system consisting of an electric motor and the compressor itself (mainly made of steel), heat-exchanger (commonly made of aluminium and copper) and electronics for the control unit. If the system works with latent heat storage, additional material is required. In addition, a refrigerant is used (e.g. 200-400g of R134a -1,1,1,2-tetrafluoroethane, that is an HFC with a GWP of 1430 kg CO_2-e)

-
- Some machines are available with automatic dosage systems. Those machines additionally require dosage pumps (electric motors, pump housings [plastics], and pump wheels), possibly magnetic valves (brass, copper, resin) reservoirs for detergents (plastics) as well as electronics for the control units.

According to (UNEP 2013), the composition of white goods strongly varies from product to product, and as they become 'greener', their resource efficiency increases. Valuable materials are mainly found in the control electronics, i.e. on Printed Wiring Boards (PWB). According to a study by UNU 2007 cited in (UNEP 2013), large white goods contain on average

- 20 ppm palladium (Pd),
- 160 ppm silver (Ag) and
- 38 ppm gold (Au).

Further, the components of PWB contain often tantalum (electrolytic capacitors), gallium (semiconductors), antimony (casting compounds), graphite (resistors) and magnesium (cooling elements).

However, these amounts are normally lower than in printed boards from appliances where high speed and performance is required, such as computers.

An updated Bill of Material of washing machines and washer-dryers is presented in Task 5.

4.5.2. Assessment of the primary scrap production during sheet metal manufacturing

The EcoReport tool calculates the primary scrap production during sheet metal manufacturing as a percentage of the total sheet metal manufacturing value.

Primary scrap is considered in MEErP as "the material that is lost during the fabrication of semi-finished products (rolled sheets, extrusions, castings, etc.) and finished products (e.g. metalwork products). It is brought to the internal furnace (fabricator scrap) or to an external smelter (traded scrap) and recycled within a matter of minutes/hours (when inside the same factory: the so-called 'run-around-scrap') or at the most weeks (when collected and transported to the smelting plant). It is relatively uncontaminated and pure material that can be re-used with little or no pre-treatment".

Deviating from the default value of 25% given in the EcoReport tool, the Ecodesign Preparatory Study Lot 14 (ISIS 2007c) chose 5% as the percentage of sheet metal scrap generated, which leads to following values:

Table 4.17: Average input data for sheet metal scrap of washing machine manufacturing used by Lot 14 in 2007; source: (ISIS 2007c)

	Washing machine 5 kg
Sheet metal manufacturing	23,717 g
Sheet metal scrap (5% of the sheet metal manufacturing)	1,186 g

Indications from stakeholders suggest that for the production of a complete washing machine housing (made out of steel), this value could range from negligible (0.18%) to 12.2%.

4.5.3. Packaging materials, volume and weight of the packaged products

According to WRAP ([n.d.]b), different product packaging is possible: typically used across the industry is a mixture of cardboard and expanded polystyrene (EPS). The use of PE foams in place of the EPS should be considered, as it will help with recyclability. If practical, the use of all corrugated carton board for packaging needs should also be considered. The corrugated carton board used for the caps could be changed to use newer flute designs (such a P Flute) which provide the same strength but use less material and are therefore lighter.

The Ecodesign Preparatory Study Lot 14 (ISIS 2007c) used following average production input data for the packaging of a washing machine model in 2007:

Table 4.18: Average production input data for packaging of a washing machine model used by Lot 14 in 2007; source: (ISIS 2007c)

Materials type	Material	WM 5 kg (g)
Packaging	Cardboard	107
	EPS	678
	Paper (booklets etc)	10
	PE - foil	175
	Plastics, others	56
	PP	8
	Wood	879
Sum Packaging		1,912

The packaging of a product serves to protect the product throughout its journey from the manufacturing plant till the end consumer. A high level of protection is needed as products have to withstand conditions of mechanical stress in warehouses, loading and transportation, fall tests. In reply to a questionnaire circulated to stakeholders on March 2015 (JRC IPTS 2015b), the following indicative examples were provided, for both washing machines and washer-dryers. The example for washer dryers represents an imported product from a China factory for which extra protection was needed.

Table 4.19: Average data for packaging of a washing machine and a washer dryer; source: stakeholder information

Material (g)	Washing machine	Washer dryer
Carton box	200	3,000
EPS	700	1,000
PE	300	---

In terms of final volume and weight of the packaged product, the following indications were reported by the above sources.

Table 4.20: Input data for volume and weight of packaged washing machines and washer-dryers used by Lot 14 in 2007 (ENEA/ISIS 2007c) and by stakeholders (JRC IPTS 2015b)

Model	Volume of final packaged product (m^3)	Weight of final packaged product (kg)
Washing machine, 5 kg capacity (Lot 14)	0.360	74.22
Washing machine (stakeholder information)	0.447 (product only: 0.319)	62 (product only: 61)
Washer dryer (stakeholder information)	0.450 (product only: 0,320)	88 (product only: 84)

An analysis of the CECED databases reveales that the average weight of washing machines (around 70 kilograms) has not changed significantly over the past years (cf. Figure 4.10). Remarkable is, however, the broad span between lightest (less than 50 kg) and heaviest products (more than 100 kg).

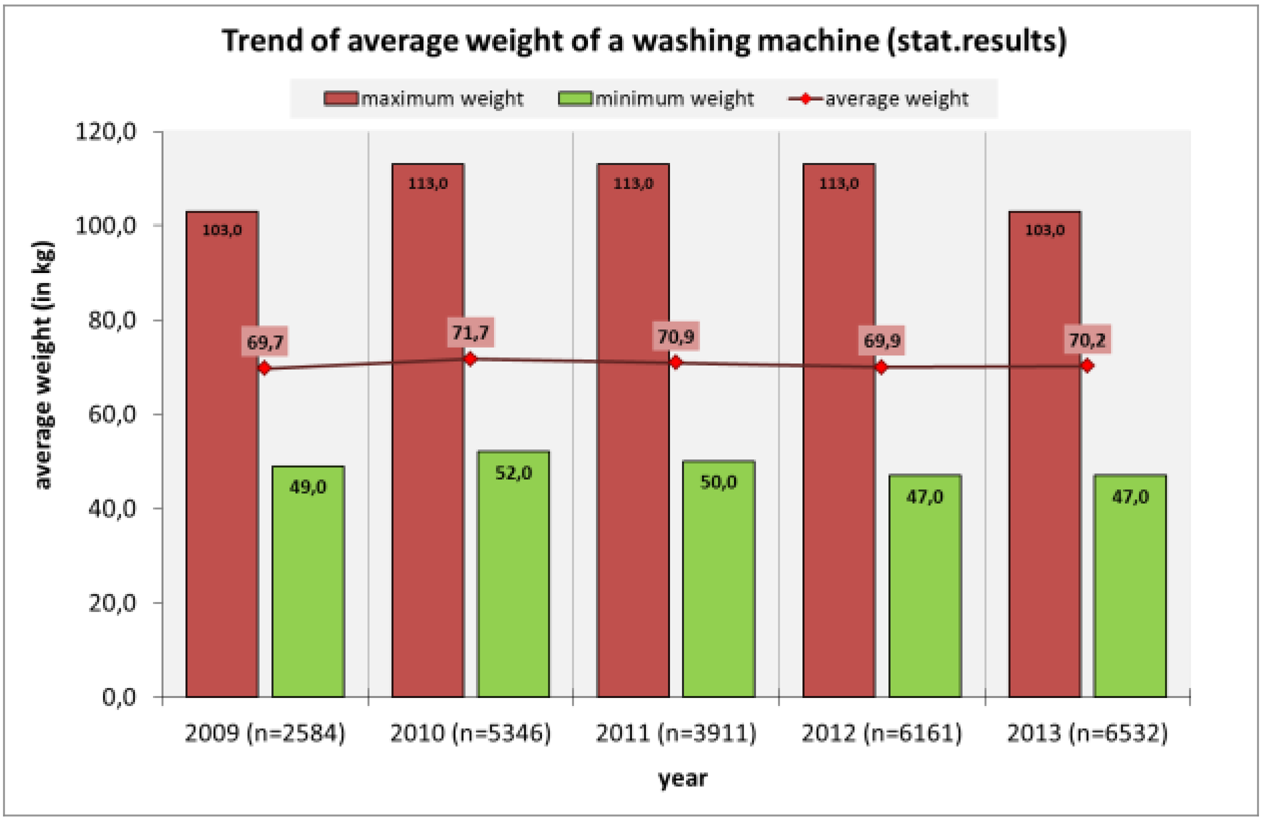


Figure 4.10: Trend of the average weight of washing machines 2009 to 2013 (Source: CECED databases)

The overall weight of washing machines inter alia depends on the rated load capacity, as Figure 4.11 shows. Machines with 3.5 kg capacity are less than 50 kg, whereas 7 kg machines are between 70 and 80 kg. There seems to be a trend towards lighter washing machines in all categories over the past years.

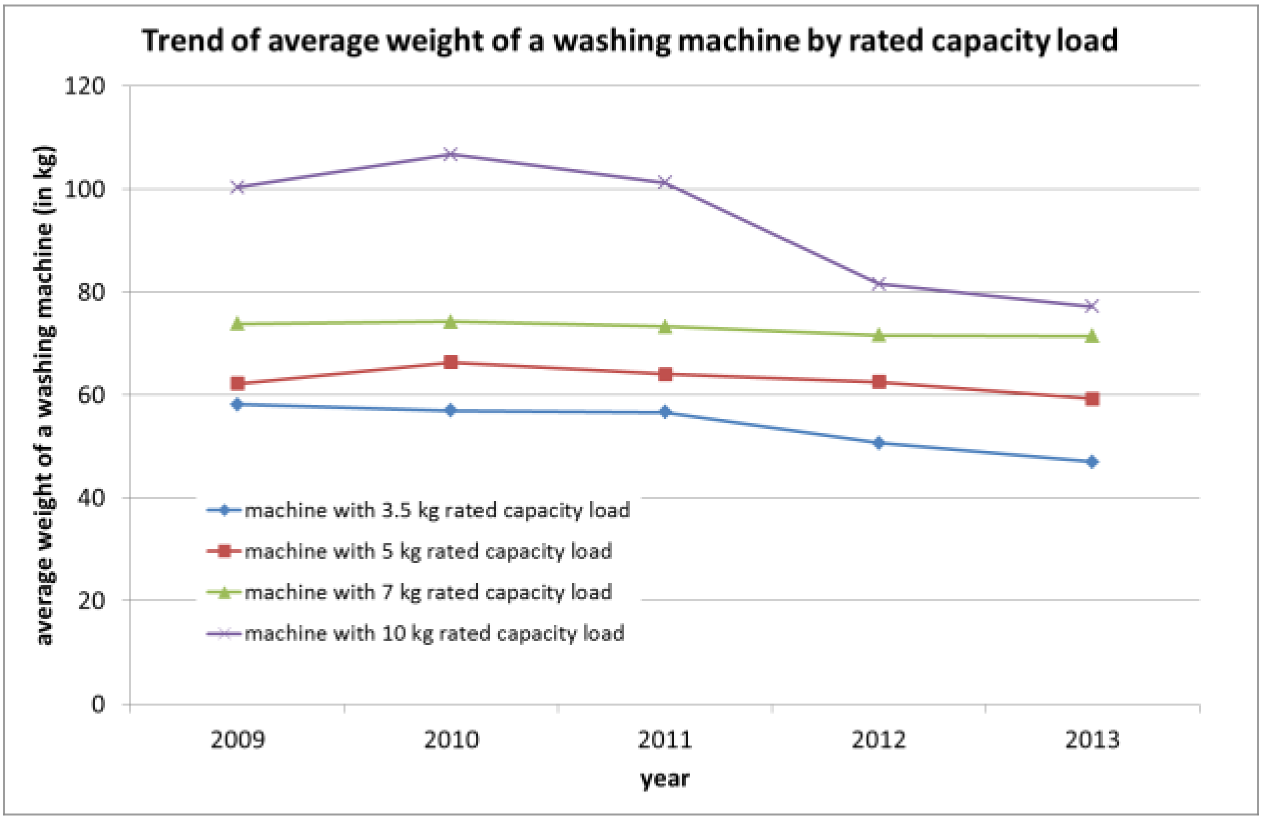


Figure 4.11: **Trend of average weight of washing machines by rated capacity load 2009 to 2013 (source: CECED databases)**

4.5.4. Transport of components, sub-assemblies and finished products

The EcoReport 2011 software tool uses average mix of transport modes by type of product. If for the appliances in scope the real transport mix deviates substantially from the average transport mix, this can be corrected ex-post giving the industry sectors with an environmentally-friendly transport policy (local suppliers, ship instead of airplane) an option to take their effort into account.

As an illustration, Bosch and Siemens Hausgeräte GmbH informs in their Group Sustainability Report 2013 about the share of transport means of exported appliances from Germany. In 2013, 33% of the total export transport volume was per rail, 40% per truck, 14% per short sea shipping (Europe) and 13% per general sea shipping. (BSH Bosch und Siemens Hausgeräte GmbH 2013)

The Ecodesign Preparatory Study Lot 14 (ISIS 2007c) used the following input data for the transport distance of washing machines: 648 km.

However, since the main environmental impacts for these types of appliances are in the use phase, the assumptions made for this stage in the EcoReport tool should be satisfactory for the purposes of the study.

4.5.5. Technical product life (time-to-failure of critical parts)

4.5.5.1. Data on technical product lifetime of washing machines

The Ecodesign Preparatory Study Lot 14 (ENEA/ISIS 2007c) used and average lifgetime of 15 years for a washing machine model of 5 kg load capacity.

(VHK 2014 / Status 2013), has been commissioned by the European Commission to systematically monitor and report on the impact of Ecodesign, Energy Labelling, Energy Star and Tyre Labelling measures. Their study with regard to the application of a newly developed accounting method to the existing Ecodesign preparatory studies and impact assessment reports available on 1 November 2013 inter alia calculated sales and stock data as well as impacts of household washing machines (cf. also section 2.2). These data were also based on a product lifetime of 15 years for washing machines.

Prakash et al. (2015) analysed various international literature with regard to the lifetime of washing machines. The retrieved product life data vary between 9 and 20 years for washing machines. The large variations are explained with different countries (Netherlands, Greece, UK, Canada, China) and years (2005-2014) of the analysed studies, as well as very different survey and calculation methods used (e.g. official statistics, consumer surveys, calculations based on sales data, surveys in households and electrical stores).

Further, Prakash et al. (2015) analysed data of the Society for Consumer Research (GfK) for large household appliances in Germany with regard to the developments of the average “first useful service-life”. This indicator is the timespan in which the product is used only by the first consumer; it is – however – not to be confused with the technical product life-time, which is longer if the appliance is still functioning and is passed on or resold to third persons. Whereas the user related service-life is already described in section 3.3.2, in the following information shall be given about the overall technical lifetime which was derived for those products that were replaced due to a defect (cf. comparison in Table 4.21). The results of Prakash et al. (2015) based on GfK data show that the average life-span of large household appliances at all (covering washing machines, dryers, dishwashers, ovens, refrigerators and freezers) in Germany which had to be replaced due to a defect (i.e. technical product lifetime) decreased from 2004 to 2012/2013 by one year and now lies at 12.5 years. On an average, the product replacement of large household appliances due to a defect slightly decreased from 57.6% in 2004 to 55.6% in 2012. This means that a defect still is the main cause of the replacement; on the other hand, it is important to realise that almost one third of the replaced large household appliance was still functional.

Extracting the data specific only for washing machines, the results show that for appliances which were replaced due to a defect (i.e. technical product lifetime), the first useful service-life was 12.5 years in 2004 and 11.6 years in 2012/2013.

Table 4.21: “First useful service life” of washing machines in Germany in 2012/2013 compared to 2004; source: Prakash et al. (2015) based on GfK data

	2004	2012/2013
“First useful service life” of washing machines - replaced due to a wish for a better appliance (i.e. only those still functional!)	13.1 years	13.2 years
“First useful service life” of washing machines - replaced due to a defect (i.e. only those being defective = technical product lifetime)	12.5 years	11.6 years

According to (Prakash et al. 2015), the need for replacing devices less than 5 years old due to a defect has increased. The proportion of washing machines which had to be replaced within less than 5 years due to a defect rose from around 6% to 15% of all defective washing machine replacements between 2004 and 2012.

According to some stakeholders the number of cycles might be a better indicator for assessing the durability of a product. Indicative correlations between expected number of cycles a product is designed to last and equivalent years of use of the appliance have been also provided by stakeholders. A more durable product might last for 5,000 washing cycles, against 1,800-3,000 cycles of typical appliances. This might for instance lead to lifetime extension up to 20 years.

In reply to a questionnaire circulated in March 2015 (JRC IPTS 2015b), one stakeholder from industry reported that the products are not deliberately designed to fail, but the components and whole assembly are designed with a given target lifetime in mind. Consumers are provided with a wide range of products responding to their different, individual needs such as convenience, performances, energy efficiency, design, robustness, after-sales service, and affordability.

Very different information has been collected on failure age and replacement rates. According to stakeholder feedback via the questionnaire (JRC IPTS 2015b), one stakeholder provides results of a study from 2006 analysing what usually breaks down in dishwashers and washing machines (cf. also section 7.3.6.1). The following information is given regarding the age of the dishwasher (no information available for washing machines) when it broke the first time:

- 0-2 years: 16%
- 2-5 years: 21%
- 5-10 years: 29%
- > 10 years: 17%
- Don't know: 17%

Most failures occur after the two year warranty expired.

Another stakeholder informs that internal testing shall ensure a minimum lifetime of 10 years but there are also some appliances in households which are much older, i.e. exceed the lifetimes for which the appliances have been tested. During the development process all stages of the product life cycle are taken into consideration in order to maximise quality and durability. Some companies provide after sales service which is involved in ensuring good reparability of the appliance. The instruction for installation should be followed carefully, otherwise there might be problems (e.g. do not bend the inlet/outlet hose).The lifetime itself, independent from the product, is dependent of the use and maintenance of the appliance.

:

Warranty

Extended warranty options vary across EU countries. For washing machines, as for all products in the EU markets, the warranty provided by retailers is 2 years (0.5 year where the consumer has no need of presenting evidence of maluse, and 1.5 year of consumer right to claim but where he/she has to prove that the failure is not due to misuse). This can be extended voluntarily, e.g. between 2 and 5 years, depending on the model.

- Warranty by manufacturers is provided according to the national requirements. Sometimes consumers can buy an extended warranty up to 5 years. Some features may have a longer warranty, e.g. a 10 years warranty for a tub against corrosion or an extended warranty for the motor.

- Some retailers may offer extended warranties at the point of purchase, either free of charge – mostly proposed by a commercial action – or against a fee.

One stakeholder reports a free 5 years parts guarantee in many EU countries for consumers who register their appliance and the parts being fitted by one of the authorised engineers. Certain manufacturers offer warranties of e.g 10 years or lifetime for the WM motor. Another stakeholder informed that they offer extended warranty of up to 10 years, but without specifying if for certain components or the whole product. Extended guarantee plans (e.g. 5 or 10 years after purchase of the washing machine) are also offered for a fee, which then cover full risks of non self-caused breaks downs; the defective component or product is either repaired, or – if a repair is uneconomic or not possible – is replaced at all (cf. for example (Miele [n.d.]a). Finally, some retailers may offer extended warranties at the point of purchase, either free of charge – mostly proposed by a commercial action – or against a fee.

4.5.5.2. Common causes of breakdowns and product design with regard to durability and reparability

A number of studies dealing with reparability have been analysed, reporting typical defects and failures of household washing machines and washer-dryers. These also include recommendations for proposed design improvements. More general studies on integrating resource / material efficiency aspects as possible Ecodesign measures can be found in section 1.3.4.

RReuse study

The Reuse and Recycling EU Social Enterprises network (RREUSE) is a European umbrella organisation for national and regional networks of social enterprises with re-use, repair and recycling activities. They cover 42,000 Full Time Equivalent (FTE) employees and over 200,000 volunteers working throughout 22 member organisations across 12 EU Member States.

In 2013, RReuse has conducted an investigation into some of the main obstacles its members encounter when repairing products, inter alia for washing machines and dishwashers, to provide part of the basis for setting requirements within implementing measures to improve the reparability of products, and thus their material and resource efficiency. Based on a questionnaire sent out through their network, the findings are answers from 9 individual reuse and repair centres from four national networks of social enterprises namely AERESS (Spain), Repanet (Austria), Réseau Envie (France) and the Furniture Reuse Network (UK).

The study revealed the following examples of common causes of break downs for household washing machines (RReuse 2013):

- Concerning the durability of components, many washing machine shock absorbers and their anchor points to the tub/housing cannot withstand 1600 rpm for a long period of time and wear out quickly. Ball bearings which were designed for washing machines which centrifuge at 300 rpm are also often used in today's washing machines which operate at 1000 or 1200 rpm, which also leads to quick degradation. However, the most important reason of failure of bearings is apparently water intrusion from the drum, due to poor design of sealings. In addition, it can happen that the bearings can get pressed into the plastic outer casing of the washing machine drum and stops the drum from rotating, which can also deform or even break the drum spider.
- The seals of the pumps which are made out of rubber degrade quite often and this can easily block the pump. Finally, the membrane of pressure switches (pressostat) can degrade over time which leads to the washing machine to take on more water than it is originally designed for.
- The heaters can stop working prematurely, especially in regions with hard water (high lime content), often due to a lack of regular maintenance of the machine

- The electronic steering components linked to the timer can fail, which is a problem as it is increasingly difficult to identify the problem. These problems were not encountered in the past when the steering mechanisms were primarily mechanical.
- Faults relating to the interlock.

With regard to product design, (RReuse 2013) suggests some measures to help improve the reparability of washing machines.

Design for disassembly for repair

The product should be able to be disassembled non-destructively into individual components and parts without the need for special proprietary tools to do this. If special tools are required however, these must be **readily and freely available** to every repair shop (not just to the after sales service providers of the manufacturers). Design for better disassembly could include for example:

- Seals on electronic boards should be easily removable for repair of the electronic board. Some manufacturers seal with silicone the printed boards, which makes very difficult to change faulty components.
- The tub containing the drum must not be sealed, and it must be possible to open it to repair the components inside (bearings, drum, paddles, axis). Instead, it should be designed again as it has been practice for many years, fixed with bolts/clams and a rubber ring.

Potential standardisation of components

Simplification of specific components as well as the potential standardisation of key components across different brands would significantly increase the efficiency of repair. This could include, for example, the rubber tubes or sealants, especially for the drum shaft.

Improved durability of components

Increasing the durability of parts that are known to wear out or get damaged easily can significantly prolong the lifetime of a product. Examples are:

- Bearings and shock absorbers.
- Drum shaft seals
- Door hinges.
- Motors: Choosing a motor known to not degrade too quickly as for example brushless motors or single-phase motors would also help prolong the lifetime of a washing machine, although it is recognized that these are more expensive.

Protection of electronic and mechanical components

Construct electronic boards to be protected by fuses. In addition a fuse should be included at the input of the device to protect the electronics from power surges.

WRAP study

In the UK, WRAP has been working between September 2013 and March 2014 with a consortium of specialists to develop outputs through targeted research and engagement with industry and other bodies with regard to evidence around perceived failure rates and opportunities for life extension for the product group washing machines (WRAP 2013d). There are no standards on washing machine durability, thus the WRAP study requires specifications for durability of: Motor, control electronics, bearings and seals; paddles, latches and hinges, the heating element as well as for facia switches and dials.

For motors, bearings and seals, the specifications required by (WRAP 2013d) are for example 3,000 hours (i.e. around 8-9 years) with no maintenance.

Table 4.22: Examples for failures of washing machines: source: (WRAP 2013d)

Failure mode	Cause	Time of failure usually arising (early/late)
Motor	Worn brushes; overload / burn out	Late
Bearing	Leaking seal or gradual wear	Late
Electronics	Poor design; poor connectors; no surge protection; no humidity or vibration protection	Both early and late
Drum paddles	Poor attachment to drum	Both early and late
Heating element	Corrosion / poor connectors	Both early and late
Facia dials and switches	Poor design / manufacture / wear	Can be both
Door latches, hinges and interlocks	Poor design / manufacture / corrosion / wear / user error	Can be both
Blocked filters / pump	User error or poor filter design	Can be both
Water inlet valve or level sensor failure	Poor design / manufacture / wear	Can be both
Dampers – resulting in noise and vibration	Poor design / manufacture / wear	Late most likely

WRAP research on design for durability and reparability of washing machines

WRAP has conducted a case study analysing and presenting measures that extend the product's life of washing machines (WRAP 2011b). The specifications were developed by assessing a range of washing machine price-points, through research with manufacturers, retailers and repairers, and also by carrying out machine 'teardown' to identify design features that facilitate durability and repair. Two models have been used to demonstrate the practical application of many of these good practice features.

According to WRAP (2011b), washing machines are mainly constructed with the same basic components; with regard to durability, products either vary in the positioning of these parts, but more fundamental differentiations between washing machines arise by the quality of their build and components.

The study found that parts that are more prone to wear and that are more likely to need replacing are:

- door seals and hinges (items becoming caught in the seals, or deterioration of the rubber);
- inlet and outlet hoses;
- water heating elements;
- drum bearings (failure due to water leaks);
- motors (particularly from wear on brushes);
- soap drawer (misuse, or detergent solidifying causing blockages); and
- motor and drum bearings (due to overloading).

Besides of these parts, the study reports that Bosch has found that electrical failure is currently the leading fault, particularly of the PCB (printed circuit board) caused by fluctuations in mains voltage supply, although surge protection is provided with these machines. Electrical faults can also occur as a result of water leaks from poor installation of the machine in the household and blockages in the soap drawer or inlet and outlet pipes. Further, Bosch has found that failures of other electrical components such as motors and pumps are becoming less common (WRAP 2011b):

Table 4.23: Examples for durable design of washing machines; source: own adaptation based on WRAP (2011b), WRAP ([n.d.]c), WRAP ([n.d.]d)

Part / component of the washing machine	Design to facilitate durability	Effect
Chassis	Steel, coated	Prevents rusting
Rear panel	Stainless steel	Provides greater corrosion protection
	Solid enclosed base	Provides resistance to vibration and rigidity to the machine
Front control panel casing and dials	ABS (acrylonitrile butadiene styrene) or PCABS (a poly-carbonate ABS blend)	Robust engineering polymers being ideal for this type of application where the surface is subject to wear and tear
	Sufficient wall thickness of the panels	Provides rigidity, limits flexing during use and offers protection to the internal parts
Motor	Entirely enclosed brushless motor; some brushless motors have been certified to last for at least 20 years / 4,400 cycles (220 p.a.)	Improved energy efficiency and speed, increased stability, reduced damage; decreases noise and vibration (eliminates the need for a belt drive)
	Longer brushes	Prevents brushes to be worn to early
	Improve quality of windings, improve surge suppression, fit re-setting thermal overload switch	Prevents motor from overload / burn out
Bearing	Overload and unbalanced load sensor; use better or shielded seal; better quality bearings (e.g. case hardened roller bearings)	Prevents leaking seal or gradual wear
Heating element	Ceramic element	Prevents corrosion
Detergent drawer, inside	Polypropylene	Provides good water and chemical resistance
Drum housing (outer tub)	Plastic, supported by springs and dampers	Prevents the drum vibration being transferred to the chassis where it can cause electrical failure
	Four steel transit bolts	Secures and protects the drum during transportation and can easily be removed and reused for further transportation
Drum paddles	Make them an integral part of the steel drum (screw or bolt on instead of clip fit or rivet)	Prevents loosening
Internal hoses	Securely fixed to the chassis with pipe clips	Prevents movement during use, provides damping and reduces vibration noise
Component and cable fixing	PCBs secured with clips	Enables quick and easy replacement over numerous access cycles Dampens and resist vibrations more effectively compared to screws
	Electrical connectors secured firmly with snap-fits	Resists vibrations
	Use of plastic connectors rather than soldered joints	Allows easier access for parts
	Internal cables are routed around the inside of the chassis and secured by cable ties or clips; length of the wiring is	Prevents movement which could cause failure from flexing

Part / component of the washing machine	Design to facilitate durability	Effect
	kept to a minimum	
Facia dials and switches	Individual micro-switches per position rather than potentiometer type / brush connector	
Leak protection	Most electronics located at the top of the machines; electronic components below the tub are covered	Prevents water damage
	Positioning of wiring looms and connectors	Minimises electrical failures
	Motor cabling with plastic shroud	Protects from potential leaks
Sensors		Detect and prevent major causes of damage and failure in washing machines: • load weighting (recommending appropriate wash programmes and/or improving load distribution to prevent uneven wear on the bearings), • leaks (resulting in shut down) • foam / detergent sensor (to control rinse cycles)

Table 4.24: Examples for repairable design of washing machines: source: own adaptation based on WRAP (2011b), WRAP ([n.d.]c), WRAP ([n.d.]d)

Part / component of the washing machine	Design to facilitate repairs	Effect
Casing of the machine	Minimal amount of screws and fixings (snap-fits and lugs); Screws standardized in size and head type Brass threads	Allows quick and easy access for repair cycles Avoids tool changes during repair Allows simple and numerous access cycles
Top cover	Reduce number of fixings to assemble the top cover within the frame; or Design the frame with a ledge so that the top cover can be pushed in and secured with an adhesive strip	Enables these parts to be separated for ease of repair or replacement
Back panel	Single cover plate with one screw; large profile of the back panel	Good access to key components like rear of the drum, drive belt, internal water hoses and motor
Front panel	Using locator lugs at the bottom, and screws at the top of the machine; or Increasing the lip of the front panel edge so that it tucks under the base and can be held in place with screws located vertically	Avoids weaken the joint in case of repeated removal of the front panel
Motor and drive belts	Few bolts and locator lugs Easy access to drive belts	Easy to unhook Removing by hand possible without tools needed
PCBs	PCBs should be coated and dried before inserting into the cover	Avoids that conformal coated PCBs cannot be removed from their housing as the

Part / component of the washing machine	Design to facilitate repairs	Effect
		coating has been applied after they were inserted into the housing
	Using screws, lugs and easy snap-fits with release catches in the same direction; or Integrating a slot in the chassis	Snap-fits partly don't need tools to open Allows the main PCB and housing to pull out and separate for part repair or replacement
Drum Tubs	Bolted together instead of being ultrasonically welded	The non-permanent joint provides easy access
Internal hoses	Simple metal spring clips	Easy removal and replacement
Rubber door seals	Secured with two metal tension rings on the inside and outside of the drum	Simple removal of tension rings by unclipping
Doors	Using bolts	Easy removal and replacement

Additional information from stakeholders

According to feedback from stakeholders, in 2015 the Belgium consumer organisation Test Achats published the results of durability and reparability test of 2 washing machine models (for the testing conditions, cf. also section 1.3.3.1, sub-section "Product endurance tests of consumer test magazines (Stiftung Warentest (DE), Test Achats (BE))".

The following failures have occurred in 4 out of 24 machines already before the test has been finished:

- the sealing of the porthole (3 times)
- a disconnected motor's driving belt,
- a defective pump.
- total starting problems of a machine which did not detect the door being closed.

The following failures have occurred after the test has been finished:

- Abrasion of the motor's driving belt (9 machines);
- Abrasion of a hose (5 appliances);
- Defective shock absorbers (4 appliances);
- Abrasion of the porthole sealing (12 machines);
- Balance / counterbalance with tears or defective fixing (4 machines);
- Reduced effectiveness of mountings and shock absorbers (3 machines); and
- Corrosion (4 appliances).

According to feedback from stakeholders, in March 2015 the Spanish consumer organisation OCU (OCU 2015) published the results of a survey of more than 23.638 users (4.821 of which amongst its Spanish subscribers) aiming to discover what was their level of satisfaction with regards to domestic appliances such as washing machines, dishwashers and fridges. Aside from Spain, the survey also covered geographically Italy, Portugal and Belgium.

With regards to washing machines the most frequent failures reported concerned

- the door (12%),

- the filter (11%),
- the spinning function (10%),
- the drain pump (9%), and
- water leakage (9%).

According to stakeholders, also environmental parameters can influence the product lifetime negatively, such as exceptional humid environment, power supply outside the tolerance value for stability of supply and, exceptionally, hard water for scale build up on the heating element.

One stakeholder from industry informed that as part of their continuous improvement efforts, some broken components are sent to the design laboratory to investigate the causes for breakdown and use information to improve reliability and durability. Further, if during the warranty period it is necessary to exchange a defective product rather than repair it, whenever this is cost effective, the appliance could be shipped to service warehouse and repaired, so that it can be placed on the market again as second or third choice. The most frequent failures in the first years of life are regularly monitored to take early actions and improve design and production quality in order to constantly reduce the failure rate. For critical components as electronics, motor etc. there are specific reliability tests to ensure a robust design and rigorous suppliers quality control.

According to stakeholders, examples of actions taken by manufacturers to facilitate the repair operations are:

- A quick and reliable technical assistance service.
- Fault code indicated in the user interface through LEDs indicating the suspected cause of the failure.
- PC diagnostic tool which allows, once the machine is connected to a PC, performing a complete check-up of the product, detecting any faults, and even updating the software to the latest version available.
- Some broken components are sent to the design laboratory to investigate the causes for breakdown and use information to improve reliability and durability.
- If, during the warranty period, it is necessary to exchange a defective product rather than repair it, whenever this is cost effective, the appliance could be shipped to service warehouse and re-paired, so that it can be placed on the market again.

A focus on components that are crucial for the correct functioning of appliances is fundamental, i.e. if that component breaks down, the appliance cannot be longer used for the main functions of use for which it was intended. There should therefore be a clear differentiation of a component that is critical to the main functions versus the auxiliary functions of the product.

4.5.6. Materials flow and collection efforts at the end-of-life and waste management (landfill/ incineration/ recycling/ re-use)

The following sections provide an overview of European end-of-life management paths of household washing machines and washer-dryers. In this context, the Waste Framework Directive 2008/98/EC (European Parliament 2008) provides the following definitions for possible end-of-life operations:

- ‘Re-use’ means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived. In this context, ‘preparing for re-use’ means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing.

- ‘Recycling’ means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.
- ‘Recovery’ means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. Annex II of Directive 2008/98/EC sets out a non-exhaustive list of recovery operations, including energy recovery.
- ‘Disposal’ means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I of Directive 2008/98/EC sets out a non-exhaustive list of disposal operations, such as for example landfill.

4.5.6.1. Collection rates

Washing machines are classified under category 1 “Large household appliances” of the WEEE-Directive 2012/19/EU (cf. section 1.3.1.2). From 15th August 2018 on, new WEEE categories will be imposed in the EU. Within this categorisation, most washing machines will fall under the new category 4 (large equipment – any external dimension more than 50 cm). Devices using refrigerants or any other fluids other than water for heat exchange will fall under category 1 (temperature exchange equipment), including Wm and WD equipped with heat pumps.

In any case, this means that special collection and management systems for end-of-life washing machines are in place within the EU.

Generally, the current category 1 equipment (large household appliances) is, on a weight base, the most significant WEEE-category and makes up 49% of the EEE put onto the EU-market and 43% of the WEEE collected in the EU in 2010 (Eurostat 2013).

High collection rates of category 1 equipment are crucial in order to achieve the collection targets laid out in Article 7 of the WEEE-Directive. From 2016 on, the minimum collection target over all categories will be 45% on a Member State level and will further increase to a minimum of 65% from 2019 on (calculated on the basis of the total weight of WEEE collected as a percentage of the average weight of EEE placed on the market in the three preceding years on a Member State level).

A 2008 review of the WEEE-Directive 2002/96/EC revealed that only 16.3% of the arising waste of this product-category was collected within the formal system in the EU in 2005 (Huisman et al. 2007). Data from Eurostat suggests that this situation has somehow improved until 2010, when 4,693,199 t of category 1 equipment was put onto the EU-market (EU27 + Iceland + Norway) and 1,512,920 t (i.e. 32%) of the same category were collected (Eurostat 2013), however very large variations are detected among Member States.

Feedback from one stakeholder indicates that for washing machines and washer-dryers, the collection rate (waste units collected from the market) is at an average of 33-40% of the appliances sold on the market. These quantities are collected and recycled through official channels managed by producers. The percentage is low due to the fact that these devices have a high metal content and are actively sought and recycled also by commercial channels for the purpose of metal recovery, effectively bringing the collection rate probably up to 87-100% (for general illustration, cf. Figure 4.12). However, the alternative treatment channels do often not perform the depollution prescribed in WEEE.

The fate of devices not collected cannot be exactly quantified. Nevertheless, the following pathways can be considered for the majority of the items not collected:

- Prolonged storage in households and offices (including for reuse);

- Recycling within the EU but without collection being covered by official member state statistics;
- Export as used EEE or end-of-life equipment to non-European destinations.

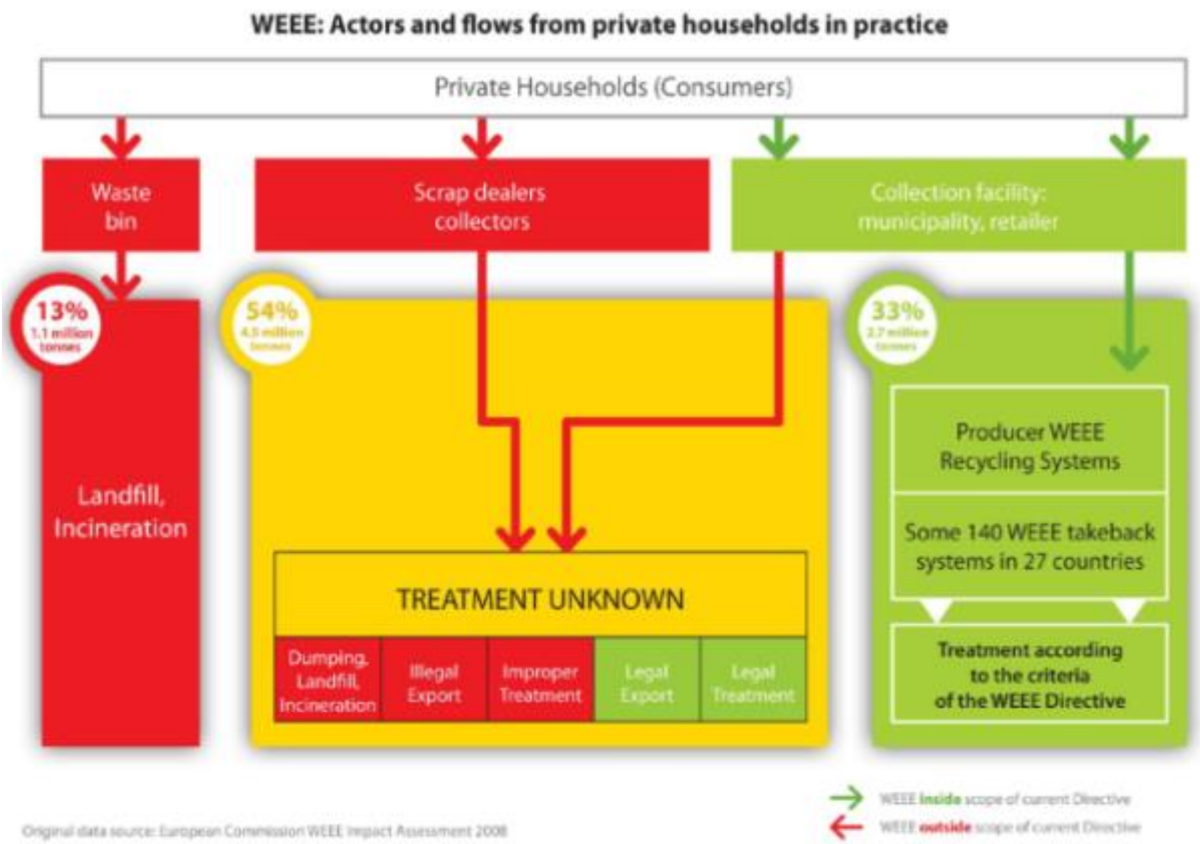


Figure 4.12: WEEE actors and flows from private households in practice; source: stakeholder information

Regarding exports to non-European destinations, no product group specific figures are available. Regarding second-hand markets outside the EU, visual impressions from EEE-trading hubs in Nigeria and Ghana suggest that second-hand washing machines meet a comparatively low demand in the West-African region (Manhart, personal communication 2014). Information from other potential second-hand markets such as Eastern Europe is not available.

Generally, washing machines have a stable positive net-value in the European recycling markets (Henkes 2012). This net-value applies to equipment that has already been collected. In case collection costs are also taken into account, the net-value is mostly negative (Huisman et al. 2007). This is largely based on the high metal content and the comparably low content of materials requiring separate and costly treatment and disposal. Therefore, there is no obvious economic motivation for illegal exports into non-EU countries as this is observed for other types of WEEE. There might be cases when washing machines are not fully functional when exported or where used devices are not properly packed and certified. Although in such cases, the devices are classified as WEEE according to Annex VI of the WEEE-Directive, it can still be assumed that the primary motivation for export is reuse and not recycling and disposal (which would probably handled not in full compliance with the WEEE Directive.

According to Digital Europe et al. (2013), recycling within the EU – but without collection being registered officially – is quite significant in some member states and might – if these volumes would be accounted for in official figures – lead to a collection rate of around two thirds of the volumes placed onto the market.

Due to the large size of devices, disposal via the municipal household waste is theoretically possible but considered to be not relevant in terms of quantities.

4.5.6.2. Recycling process

Different materials are recycled into raw materials and used to make new products. Some of the equipment is not collected separately, but as part of waste fractions where WEEE waste is mixed with other waste. Some of this is sorted and then becomes available for further processing and recycling. The rest ends up in the waste incinerators or at a landfill.

The devices collected within the formal WEEE-System in the EU undergo recycling treatments, which can be classified into the following steps:

- Preparation for reuse;
- Pre-processing / dismantling (including depollution, and material resource recovery);
- End-processing and final disposal.

Preparation for reuse, i.e. checking, cleaning or repairing, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing. This is mostly conducted with devices deemed suitable in terms of age, product model, appearance and spare part availability.

Pre-processing: 1. depollution: The majority of end-of-life washing machines are passed-on to the pre-processing stage, which may start with a a depollution step, which requires a selective treatment during which certain substances, mixtures and components are removed from the WEEE stream. In other cases, the first step is shredding, followed by sorting, and final depollution.

If depollution is the first step, it is important that parts to be removed are identifiable and accessible. In this step, the following components are removed from the devices for separate treatment:

- Power-cables,
- Large accessible printed circuit boards > 10 cm^2. According to (Ardente & Talens Peirò 2015), printed circuit boards can be removed preventively, by specific dismantling, hand-picking or mechanical sorting after preliminary and fine shredding.
- Capacitors with a height >25mm and a diameter >25mm might contain substances of concern. In particular old capacitors might contain polychlorinated biphenyls (PCB). Capacitors, generally included in printed circuit boards, are generally manually separated after the removal of the printed circuit boards.
- Some modern devices might contain LCD displays > 100cm2, which have to be removed for separate treatment to comply with the WEEE Directive. (Ardente & Mathieux 2012) state that new washing machines introduced in the market embody some LCD screens. All the recyclers interviewed within the study of (Ardente & Mathieux 2012) agreed that LCDs in WMs ideally have to be preventively extracted, because potentially contaminating other fractions (for example PCBs without LCD) causing a potential downcycling of recyclable resources.
- Devices containing volatile hydrofluorocarbons (HFC) or hydrocarbons (HC) – which might be the case for modern devices with integrated heat pumps – have to undergo degassing to prevent emissions to the atmosphere. Devices containing volatile hydrocarbons need to be handled specifically (also during collection, transport and storage) as uncontrolled leakages might cause fires and explosions (CENELEC 2012), and have to be treated in a similar way to refrigerators.

Pre-processing: 2. .material recovery: In the subsequent pre-processing, appliances are treated to reclaim and concentrate the various materials such as steel, aluminium and plastics. This is either done by manual disassembly, or by mechanical means (shredding and automated sorting). Pre-processing (manual and mechanical) typically yields the following output fractions:

- Steel
- Stainless-steel
- Aluminium
- Copper (insulated or liberated)
- Plastics (including thermoplastics, thermosets and rubber)
- Glass
- Concrete (from balance-weight of washing machines)

Some of the above listed fractions undergo further treatment and/or sorting (examples: liberation of insulated copper-cables, sorting of aluminium in different grades, further sorting of plastics according to colour and polymer-types). Depending on the technology sequence of the recycler, depollution may preceed or take place after material sorting.

In most treatment plants in Europe (likely >95%, although no clear statistics are available), most treatment is purely mechanical, with limited manual treatment intervention. The sequence described above is reversed: the first treatment stage is shredding, followed by mechanical separation, and only in specific cases there would be manual separation of certain components. One of the concequences of this is that the separated fractions have a lower purity (and therefore market value) than the fractions obtained with manual separation. Normally, large-volume treatment plans are essentially mechanical. The few plants in Europe base their treatment in manual separation operate relatively low flows of appliances.

End-processing: The outputs are generally fed into end-processing units, which can be described as follows:

- Steel and stainless-steel is fed into secondary steel plants;
- Aluminium is fed into secondary aluminium smelters;
- Copper is fed into copper-refineries;
- Printed circuit boards are fed into integrated smelters to recover copper, precious metals and other metals as by-products (e.g. lead, tin, indium); however, according to stakeholder feedback, PCBs of domestic appliances are not comparable to those of ICT, as they have a lower content of copper and other precious metals;
- Plastics are either recycled (material recovery of thermoplastics) or incinerated (energy recovery);
- Glass is fed into glass recycling, when feasible, or otherwise landfilled;
- Concrete is disposed together with inert construction/demolition waste. According to feedback of one stakeholder via questionnaire, the concrete might create dust formations if not extracted before the shredding process, however this rarely occurs and can easily be prevented.

According to feedback from stakeholders, in general washing machines have a high metal content, with some plastic and concrete where this is present. Metals and some plastics have good recycling values.

4.5.6.3. Recycling and recovery rates

The Ecodesign Preparatory Study Lot 14 (ISIS 2007c) used the following input data for end-of-life parameter:

Table 4.25: Input data for end-of-life handling of household washing machines used by Lot 14 in 2007; source: (ISIS 2007c)

End-of-life handling	Share for household washing machines, 5 kg model (%)
Dismantling	26,70
Recycling	70,00
Energy recovery	3,30
Total	100%

In their study, (ISIS 2007c) assumed that the share of re-use and closed-loop recycling of the plastics in washing machines is 0%.

In general, recyclers of large household appliances are obliged to achieve a minimum re-use and recycling rate of 75% and a recovery target of 80%. In contrast to recycling, the term recovery additionally includes the use of waste for other useful purposes, including energy recovery. These targets will be raised to 80% and 85% after 14 August 2015 (see Table 4.26).

Table 4.26: Re-use and recycling targets specified in Directive 2012/19/EU (European Parliament 2012a)

Quantitative targets for WEEE category 1	Until 14 August 2015	After 14 August 2015
Re-use and recycling target	75%	80%
Recovery target	80%	85%

Feedback from stakeholders indicates that recycling rates of household washing machines and washer-dryers can be up to 80.8-95% depending on the recycling technologies. Up to 5% (foams and non-recyclable parts) are incinerated with recovery of energy.

However, according to UNEP (2013), legal recycling-rate targets have two implicit weaknesses: They do not differ between individual substances, but are calculated solely by weight based on an entire fraction. Hence, to achieve the targets, recovery of mass substances such as plastics, glass or steel becomes much more important than recovery of precious and special metals, which are usually only present in small amounts. And, as the targets do not consider metallurgical steps, the high legal recycling targets pretend a recycling quality that in reality is not obtained. If smelting and refining are included, real recycling rates will be much lower, especially for precious and special metals.

For large white goods, usually the recycling focuses on the recovery of bulk commodity materials (primaryly metals) according to WEEE recycling guidelines. According to UNEP (2013), printed boards containing palladium, silver and gold form a very small part of this recycling stream and are mostly lost. If recovered, physics limit the production of clean recyclates from printed boards, which makes subsequent processing in metallurgical plants difficult. Printed boards will, because of the nature of mechanical separation plants, be spread throughout the recyclates of commodity materials (steel, aluminium, etc.). After that, they get lost during the metallurgical processes for these commodity metals, which do not cater for the thermodynamics that maximize recovery of these elements.

4.5.6.4. End-of-life treatment of permanent magnet (PM) motors

According to stakeholder feedback, it seems that washing machine manufacturers have in the last years moved away from motors using rare earth metals because of cost reasons. This might change again in the future as the cost strongly depends on the metal market.

According to (Ardente & Mathieux 2012) motors represent one of the key parts of washing machines. Motors are economically one of the most valuable parts for recycling. Motors are sometimes preventively manually disassembled when time for its separation is reasonably low (assumed lower than 50 sec in the EoL scenario assessed by (Ardente & Mathieux 2012)). Otherwise, washing machines are shredded and motors are afterwards separated (by hand-picking or further mechanical separation) which is a process that yield lower recycling rates.

Indeed, studies in the literature analysed by (Ardente & Mathieux 2012) evidenced that shredded motors imply more difficulties during the next treatments for separation of metals, with larger losses. Furthermore, avoiding pre-shredding could reduce the contamination among metals, reducing the risk that some copper fractions could contaminate steel batch. However, detailed figures about such losses are not available.

Furthermore, although copper and steels can be partially separated from pre-shredded motors, other elements, including rare earths, could not. For the recovery of such elements, a selective dismantling of motor and further extraction of magnets would be necessary. For example, neodymium and other rare earth contained in some motors (magnets for high efficiency devices) could be only recovered after a selective disassembly. Neodymium represents, among rare earths, one of the most used in terms of overall flows, and particularly relevant for some emerging technologies including permanent magnets (with high energy efficiency)

Dalhammar et al. (2014) conducted a case study in 2012 on the potential inclusion of permanent magnet (PM) motors in the Ecodesign Regulation for electric motors. The objective was to see how the Ecodesign Directive could promote eco-innovation for resource use in PM motors (cf. also section1.3.4.6). Within their study they researched that to-date methods for post-consumer rare earth element (REE) recycling are inexistent. However, one technological niche is constituted by a Siemens led motor recycling project which investigates options for the extraction of REE from electric motors. Also the Danish REEgain project (cf. http://www.reegain.dk) represents a technological niche, as various representatives from industry and academia collaborate to investigate both different processing options for rare earth ores and the recycling of REE.

According to Dalhammar et al. (2014), to date only about 10 to 15% of machines with REE (typical hard disc magnets) can be recycled, the remainder ends up as dust in scrap yards or as pollutant in steel melts. There are currently many uncertainties. These include for example, if – and how – the magnetic properties of REEs and combinations of materials will last if the material is crushed into a material mix, or if the material must be separated into pure streams. The latter option would require much more energy at the recycling stage.

Buchert et al. (2014) describe in their study on permanent magnets motors that the production of these motor types has only reached in the past 10 to 15 years a significant increase; due to their long life, however, so far only few magnets containing valuable rare earths arrive at the potential recycling streams. A general recycling process of permanent magnet motors is not yet established, although some manufacturers of industrial permanent magnet motors already disassemble magnets at their end-of-life and store them for potential future recycling purposes. To establish a future recycling process on an industrial-scale basis in the near future, some hundreds of tons magnet materials would have to be available, which requires a collection and disassembly system to separate the permanent magnets from the motors ideally at European level.

Buchert et al. (2014) point out that rare earths containing magnets are mostly installed in their appliances in such a way that specific expert knowledge is necessary to detect them. Further, todays established pre-processing technologies cannot separate magnets to pure fractions but rather sort them together with the steel fraction where the rare earths get dissipative lost. Also according to assessment of one stakeholder, although in a manual recycling process brushless motors can be simply identified at first sight, a further differentiation for example between asynchronous inverter driven motors and permanent magnet motors (cf. section 4.1.3.2) is difficult.

This is why Buchert et al. (2014) request for a marking obligation for industrial appliances containing a minimum weight of permanent magnets (for example > 10 grams) which shall inform about the following aspects:

- Are permanent magnets included in the appliance?
- If yes, which type of permanent magnet is included?

Such a marking obligation, which is proposed to take place for example in the current revision of the Ecodesign Regulation on motors (cf. section 1.2.1.1), would facilitate recycling companies localising valuable magnets.

For washing machines and washer-dryers, this would be relevant in case of increasing market shares of Permanent Magnet motors containing rare earth elements. However, most recent PM motors are not based on rare earths, but on ferrites (cf. section 4.4.2.2).

4.5.7. Overall product lifetime

The information collected so far has been used to estimate an 'overall' lifetime of washing machines and washer-dryers, which takes into account the average fate of the product after its first useful life.

The 'overall' lifetime of products can provide an indication about the annual flow of disposed products. Annual sales of new products in a certain year will need to compensate for the disposed fraction of the stock in the same year and the stock variation between 2 subsequent years. Some products will be reused or will see their lifetime extended, thus remaining in the stock for some additional years.

A streamlined EOL model has been built based on the following assumptions:

- After the first use, 86% of products are prepared for disposal, 8% of products are prepared for reuse, 6% are refurbished for lifetime extension (Magalani et al. 2012)
- Of the disposed products, 76% out of 86% (88%) are broken, whilst the rest is still functioning (thus constituting a failure of the EOL system). (Prakash et al. 2015)
- 95% of the products prepared for reuse are actually reused, whilst the remaining 5% is disposed.
- 1% of the products prepared for disposal is reused (thus compensating partially the failure of the EOL system), whilst the remaining 99% is disposed (WRAP 2011a)
- Of the broken fraction of disposed products, 30% was repaired once in their lifetime (23% of all product) whilst 70% was not repaired (53% of the total)
- No EOL export of products is considered, so that all products stay in the EU system

As a result,

- 53% of products are disposed broken without having been repaired
- 23% are disposed broken, being repaired once in their lifetime
- 9% are disposed still working, but (probably) defective

- 8% are working and reused before their disposal
- 6% are disposed after having been refurbished to prolong their lifetime

An average lifetime must be assigned to each fraction to calculate the average 'overall' lifetime of the product (weighted over the actual disposal share):

- 13.1 and 13.2 years have been considered for the products disposed still working in 2004 and 2013 (Prakash et al. 2015), lifetime extension has been considered to prolong this lifetime by 50%
- 12.5 and 11.6 years have been considered for the products disposed broken in 2004 and 2013 (Prakash et al. 2015), which in 2013 would correspond to 10.4 years for the unrepaired fraction and 14.5 years for the repaired fraction if it is considered that repair can increase the lifetime of broken products by 40% (Tecchio et al. 2016)

As a result, 12.3 and 13 years have been calculated as the average 'overall' lifetimes in 2013 and 2004. Values for other years could be calculated by linear Interpolation/extrapolation of these two values.

5 Task 5: Environment and economics

The aim of this section is to assess environmental and economic impacts associated to different Base cases of household washing machines and washer-dryers. The assessment is based on the updated version of the EcoReport Tool (v3.06), as provided with the MEErP methodology (COWI and VHK 2014), and published online in December 2013 on
http://ec.europa.eu/growth/industry/sustainability/ecodesign/index_en.htm

5.1 Product specific inputs

According to MEErP methodology, Base cases (BC) should reflect average EU products. Different products of similar functionalities, Bill of Materials (BoM), technologies and efficiency can be compiled into a single BC. Therefore, in most of the cases, it does not represent a real product on the selves. The base case is used a reference for modelling the stock of products together with their environmental and economic impacts and the available improvement design options.

For the identification of the Base cases for household washing machines and washer-dryers, the analysis presented in the previous Task 1 (scope and definition), Task 2 (Markets), Task3 (Users) and Task4 (Technologies) have been used.

5.1.1 Base case for washing machines

Section 2.2.3 reveals that the majority of household washing machines models offered on the market are standard washing machines with a width of approximately 60 cm. In this category appliances with larger rated capacities are increasing in market shares. Washing machines models with a rated capacity of 7 kg show an upward trend from a market share close to 5% in 2007 to 35% in 2014. On the contrary, washing machines with a rated capacity of 6 kg or less are decreasing their market share from 84% in 2007 to 41% in 2014. Standard washing machines with a rated capacity of 7 kg have the highest market share in 2014.

Only one base case has been chosen to represent the washing machines on the market. However, the policy measures until now have followed a division between the washing machines with a rated capacity higher or lower than 4 kg. Washing machines with a rated capacity of 4 kg or lower are a niche market and account for negligible sales amounts (Table 2.14) of the models on the market in 2014. This kind of washing machines is therefore discarded as a base case and for further calculations.

Table 5.1 Performance characteristics of the chosen Base case for washing machines and the reference 'Standard Data'summarises the detailed performance characteristics chosen for the washing machine including the respective underlying sources and assumptions (a more detailed description of the assumptions can be found in the sections 5.1.1.3 to 5.1.1.4).

As commented in section 1.2.1 most available data on the operation of washing machines stem from testing under standard conditions (IEC/EN 60456). These values are communicated to the consumers throughout the Energy Label and have an impact on their purchase decisions. However, the operation conditions under the real user behaviour in EU (Alborzi et al. 2015), lead to values very different from those of the standards. This means that the energy consumption, water consumption, time and other parameters have been estimated for the base case based on the information related to the user behaviour.

Therefore, Table 5.1 Performance characteristics of the chosen Base case for washing machines and the reference 'Standard Data' shows not only the estimated parameters for a base case washing machine with a rated capacity of 7 kg but also the reference standard values that for this base case washing machine would be communicated to the consumers and the market authorities. These values are shown in Table 5.1 Performance characteristics of the chosen Base case for washing machines and the reference 'Standard Data'to highlight the mismatches between the current policy measures and the user behaviours but will not be considered for further calculation.

Table 5.1 Performance characteristics of the chosen Base case for washing machines and the reference 'Standard Data'

	'Standard Data'	Base case	Sources/Comments
Nominal rated capacity (kg)	7	7	Standard Data WM and base case: Task 2, figure 2-14, shows that >30% of WM models in 2013 had 7 kg capacity. Michel et al. (2015), figure 25: shows that 7 kg machines is the second most important share of total 2014 EU sales with decreasing trend of smaller machines and increasing trend towards 7 kg and higher capacities; figure 34: largest share of A++/A+++ sales in 2014
Number of cycles per year	220	220	Standard Data WM: Based on the standard number of annual cycles used in the current Ecodesign and Energy label regulations for household washing machines to calculate the Energy Efficiency Index. Base case: Results of the 2015 consumer survey on washing behaviour (Alborzi et al. 2015) are still in line with the number of standard cycles (229 vs 220).
Average loading (kg)	5 (1100 kg/yr.)	3.3 (726kg/yr.)	Standard Data WM': Weighted loading of 7 cycles in the standard measurement (3 times full load at 60 °C, 2 times half load at 60 °C and 2 times half load at 40 °C) referred to in the standard measurement method of the Ecodesign and Energy label regulations: 5= (3*7+4*3.5)/7 Base case: Based on (Kruschwitz et al. 2014) the average amount of laundry washed per cycle in washing machines is 3.3 kg. Data refer to 2,762 wash cycles for different programmes and mainly refer to the use of a 5 kg washing machine. The results of the 2015 user survey on 11 EU countries suggest that the average load per cycle does not depend on the capacity of the washing machine (Alborzi et al. 2015).
Observed Retail Price (ORP) (€)	413	413	Standard Data WM and base case:: Based on Michel et al. (2015) and screening of market prices in France, UK, Germany, Spain and Italy in November 2016, average price of 7 kg WM sales in 2014: 413 €; The ORP is considered to be 30% lower than the RRP (range: -23% to -33%)
Recommended Retail Price (RRP) (€)	578	578	Standard Data WM and base case: based on stakeholder's feedback and manufacturers information
Manufacturing cost (€)	148	148	Standard Data WM and base case: Starting from the RRP, the following assumptions allow to estimate the manufacturing costs (MC): RRP=MC x (1+MP) x RP x (1+VAT), where: MC=manufacturing costs MP=manufacturing average % profit margin, ~28% (range: 20 to 30%, depending on many aspects such as volume of sales, business model, etc.) RP=aggregated (wholesale-retailer) sales margin: factor 2.5 (range:1.5 to 4, depending on the number of steps in the chain, inclusion of e.g. aftersales service, transport, installation and the retailer's costs e.g. showroom) VAT: average EU VAT 2015: 21.6% (Eurostat) As a result, RRP = 3.9 x MC and ORP = 2.8 x MC
Maintenance and repair costs for the consumer (in €/lifetime)	45	45	Standard Data WM and base case: Task 2, table 2-22, based on stakeholders' feedback it is assumed there is one repair during lifetime, that approx. costs 150 € per repair (Prakash et al. 2015) and an Internet consumer survey performed in Germany found that 42% of washing machines were repaired during their lifetime. For EU28 it is assumed that a lower share of 30% of washing machines are repaired once in their lifetime at 150 €
Energy	0.84	0.644	Standard Data WM: Michel et al. (2015), figure 23: average energy

	'Standard Data'	Base case	Sources/Comments
consumption wash (kWh/cycle)	(average standard programme, correspondi ng to 0.168 kWh/kg)	(correspond ing to 0.195 kWh/kg)	consumption of 2014 EU sales: 185 kWh/year; divided by 220 wash cycles per year; Task 2, figure 2-16: average energy consumption of 2013 EU models: 0.84 kWh/cycle. These average energy consumption values are based on the average of 7 measured cycles in the standard cotton programmes (3x60 °C full load, 2x60 °C half load, 2x40 °C half load) and also include a low share of low-power and off-mode energy consumption (cf. Task 2.2.4.2, ATLETE measured data for off-mode (average: 0.2 W/cycle) and left-on mode (on average: 0.6 to 0.9 W/cycle) Base case: A broad programme portfolio is considered, with statistics about the frequency of use of different programmes from (Alborzi et al. 2015). Consumption values estimated from analysis of data for products on the market (see **Error! Reference source not found.**). For 'normal' cotton rogrammes a correction factor for under loading has been considered based on (Lasic et al. 2015). For 'standard' cotton programmes a correction factor has been applied based on linear extrapolation of data for full and partial loads. Details: cf. Section 5.1.1.3
Water consumption (L/cycle)	45 (average standard programme, correspondi ng to 9 L/kg)	43.5 (correspond ing to 13.2 L/kg)	Standard Data WM: cf. Task 2, figure 2-26: average water consumption of 2013 EU models: 45.1 litres/cycle Michel et al. (2015), figure 24: 2014 average water consumption of EU sales: 9,900 litres/year, divided by 220 cycles per year These average water consumption values are based on the average of 7 measured cycles in the standard cotton programmes (3x60° full load, 2x60° half load, 2x40° half load) Base case: A broad programme portfolio is considered, with statistics about the frequency of use of different programmes from (Alborzi et al. 2015). Consumption values estimated from analysis of data for products on the market (see **Error! Reference source not found.**). For 'normal' cotton rogrammes a correction factor for under loading has been considered based on (Lasic et al. 2015). For 'standard' cotton programmes a correction factor has been applied based on linear extrapolation of data for full and partial loads. Details: cf. Section 5.1.1.3
Detergent (solid or liquid) consumption (g or ml per cycle)	100 g, solid	75 g, solid (or 75 ml, liquid)	Standard Data WM: For WM, the dosage according to the standard testing method is 40 g + 12 g/kg wash load, with 5 kg average wash load taken as basis (3x full load, 4x half load cycles) Base case: see average dosing of liquid and solid detergents following user surveys, Task 3, Table 3.12. This amount is also in line with the recommendations from detergent manufacturers cf. Task 1, table 1-27 and table 1-28, and similar to use of the standard testing method (40 g + 12 g/kg*3.3=79.6g).
Washing performance class	A	A (for the standard programme s only)	Standard Data WM: cf. Task 2, figure 2-22; since 2011 all machines have to fulfil A-performance in standard programmes; Base case: Performance and consumer expectations can be lower for programmes different from the standards ones.
Spin drying performance class	B	B (for the standard programme s only)	Standard Data WM: cf. Task 2, figure 2-23: 56% of 2013 EU models have spin-drying class B; Base case: Performance and consumer expectations can be lower for programmes different from the standards ones.
Noise washing/spinning (dB(A))	56/75	56/75	Standard Data WM and Base case: cf. Task 2, figure 2-32: It was assumed that the noise in normal cotton 60°/40° programmes is the same as in the standard programmes
Cycle time (min)	171	121	Standard Data WM: cf. Task 2, table 2-10: average programme time of 50 tested models of 2012/2013 (Stamminger and Schmitz 2016) Base case: A broad programme portfolio is considered, with statistics about the frequency of use of different programmes from (Alborzi et al. 2015). Consumption values estimated from analysis of data for products on the market (see **Error! Reference source not found.**). For 'normal' cotton

	'Standard Data'	Base case	Sources/Comments
			rogrammes a correction factor for under loading (i.e. from full load to 3.3kg)has been considered based on (Lasic et al. 2015). For 'standard' cotton programmes a correction factor has been applied based on linear extrapolation of data for full and partial loads. Details: cf. Section 5.1.1.3
Lifetime (years); calculation basis	12.5	12.5	Standard Data WM and base case: cf. Task 4, Section 4.5.7: an average lifetime of 12.5 years has been considered for washing machines In the absence of reliable data, it is assumed that the lifetime is not significantly influenced by the use of different programmes (cf. **Error! eference source not found.**), and especially the loading (full load has a high strain on the mechanics, but partial load poses also mechanical strain in the form of e.g. unbalanced load under spinning). It is also assumed that some programmes of the 'real life' portfolio are more and some less demanding thermally and mechanically than the standard programmes (e.g. normal cotton 90 °C vs short programmes for synthetics or delicate).

Compared to the base case used in the ecodesign preparatory study of 2007 ("Lot 14) by ISIS (2007c) the current base case has a larger rated capacity. The selected base case in the ecodesign preparatory study 2007 was a 5.36 kg washing machine since the models with a rated capacity of 5kg and 6kg had the highest market shares. The current base case presents however a similar load capacity than the load capacity used in the ecodesign preparatory study 2007 (3.3 kg vs 3.4 kg).

The declared energy consumption for the current base case as well as its energy consumption under real user behaviour conditions is significantly lower than for the used in Ecodesign 2007. Water consumption has also decreased in the current base case while it shows an increase in the noise emission levels declared.

5.1.1.1 Raw materials use and manufacturing of the products: Bill of Materials (BoM)

The manufacturing phase includes the extraction and production of materials, including the following steps necessary to produce and assemble one product. The MEErP 2011 EcoReport tool contains a detailed list of materials and processes for which defined environmental indicators are provided as default values.

5.1.1.1.1 Materials input

The Bill of Materials (BoM) of the Base case product has been selected based on the analysis of the information provided by stakeholders (mainly personal communication with the manufacturers). Manufacturers provided information on 5 models for washing machines with a rated capacity between 6 kg and 9 kg and with an energy class between A++ and A+++. In order to define the average model for the base case the data collected were analysed and aggregated or averaged regarding the type of material.

To compile the BoM considered for the household washing machine base case, it is important to note that some materials are missing in the database available in the EcoReport tool. Similar existing material categories have been taken as proxy for those materials not included in the database. The following assumptions were made:

- EPDM rubber has been considered as LDPE. This assumption was also done in Lot 14 (ISIS 2007b). According to stakeholder's feedback, the environmental impacts are not comparable to those of LDPE. However, this assumption is considered to not affect results considerably since rubber content in the product is much lower than other materials.
- Glass for the door / window complex has been considered as 'glass for lamps'. This approach was also followed in Lot 14 (ISIS 2007b). According to stakeholder's feedback, the environmental impact of this borosilicate / sodium glass is not comparable to glass for lamps impact. However,

this assumption is considered to not affect results considerably since glass content in the product is much lower than other materials.

- POM has been considered as HDPE as this approach was chosen in Lot 14 (ISIS 2007b). Contribution of POM to the BoM is marginal
- Electronic components have been considered as controller boards.

An overview of the general material categories is provided in Table 5.2 comparing it to the composition of the household washing machine taken as base case in the preparatory study in 2007 (ISIS 2007b). A detailed BoM list including underlying manufacturing processes is provided in the Annex 8.3.

Table 5.2: Aggregated BoM considered for the current household washing machine base case and the base case used in Lot 14 (ISIS 2007b)

Component / Material	BC (2015) / Weight (g)	BC of Lot 14 (ISIS 2007b) Weight (g)
Bulk Plastics	5,982	11,536
Technical Plastics	6,457	298
Ferrous metals	28,527	33,850
Non-ferrous metals	4,082	3,804
Electronics	225	172
Extra (paper)	66	0
Auxiliaries (detergents)	0	0
Refrigerant (only relevant for design options equipped with heat pumps)	0	0
Miscellaneous (mainly glass, concrete, paper and wood from packaging)	24,266	22,653
SUM	**69,603**	**72,313**

NOTE: The category 'Extra' refers to office paper used in the booklet of instructions and other documentation furnished with the product upon sale.

Compared to the base case used in the Ecodesign preparatory study of 2007 by (ISIS 2007b) (cf. Task 4.2, Table 4.13), the total weight of the analysed 7 kg washing machine is lower compared to that 5,36 kg model of 2007. The current base case has less ferrous materials, and slightly more non-ferrous and miscellaneous materials. The overall the differences are however small (<4%). A noticeable difference is the larger share of technical plastics and the lower share of bulk plastics. However, the total weight of plastics is comparable indicating possible differences in interpretation of the definitions of technical vs bulk plastics. In light of these data, it is not possible to draw general conclusions regarding the material composition change in the washing machines from 2007 to 2015. The differences found may be due to the different models or the different allocation of material categories.

5.1.1.1.2 Manufacturing process

The manufacturing process is mainly fixed in the EcoReport tool. The only variable which can be edited is the percentage of sheet metal scrap. The default value is 25%.

According to section 4.5.2 Lot 14 has used 5% as input for the sheet metal scrap, whereas stakeholder feedback in case of washing machines ranged from negligible (0.18%) to 12.2%. For further calculation of the environmental impacts, a value of 5% sheet metal scrap is taken.

The EcoReport tool does not allow introducing energy consumption values for the manufacturing process of a WM. According to feedback from stakeholders, the energy consumption can vary from 37.1 kWh/unit to 60.4 kWh/unit, depending on the extent of automation. This variation is negligible in comparison to the energy consumption during the use phase (2-3%) and therefore no modifications to the EcoReport tool have been applied.

5.1.1.2 Distribution phase: volume of packaged product

This phase comprises the distribution of the packaged product. According to the MEErP Methodology report (COWI and VHK 2011b), the section on Final Assembly and Distribution covers all activities from OEM components to the final customer. The only design variable, however, is the volume of the final (packaged) product.

According to Section 4.2.3, the average volume of the final packaged product is 0.447 m3 for washing machines and 0.450 m^3 for washer-dryers. Given the similarity of both values and for convenience, for both washing machines the input is set to 0.450 m^3.

5.1.1.3 Use phase

To calculate the environmental impacts of the use phase, the input parameters for the EcoReport tool are set as follows.

5.1.1.3.1 General inputs

For the base case only direct ErP (energy) impacts are considered.

According to data collection in section 4.5.5.1, the product service lifetime is assumed to be 12.5 years (which corresponds to the first useful service-life of washing machines which are replaced due to a defect according to Pakrash et al (2016). This technical lifetime corresponds to 2,750 cycles (assuming 220 cycles per year).

It is assumed that this average corresponds to the real use of washing machines, using a mix of programmes (and not only the standard programmes).

Regarding refrigerants (refill) it is assumed that no refill of refrigerant is needed during the use phase. This is only an issue for a heat pump equipped appliance which is a technology recently introduced in the market. Therefore this is not taken into account for the base case as heat pumps are not used in average appliances. A washing machine equipped with a heat pump is described as a possible design option in section 6.1

In Lot 14 (ISIS 2007c), the travelling distance of ‘maintenance and repair services’ over the product life of a washing machine has been assumed to be 160 km. For the purposes of this report the same distance is assumed. The input parameter for the weight of spare parts is automatically fixed in the EcoReport tool as 1% of the total weight of the analysed product

5.1.1.3.2 Loading conditions and number of cycles per year

The loading of the washing machine base case under the real user behaviour conditions is much lower than its declared rated capacity. Kruschwitz et al. (2014) carried out a study for 2762 wash cycles and reported an average loading of the washing machine of 3.3 kg. The study was performed mainly on 5 kg washing machines, but the results of the 2015 user survey on 11 European countries suggest that the average load per cycle does not depend on the capacity of the washing machine (Alborzi et al. 2015). Therefore, the loading conditions of 3.3 kg would also be suitable for a 7 kg washing machine.

The 2015 consumer survey (Alborzi et al. 2015) shows that in real-life the European average number of wash cycles has not significantly changed over the past years (4.4 cycles per week, i.e. 229 cycles per year). Based on this, the number of cycles has been kept to 220 also for the base case.

The annual load of laundry washed per year would be 726 kg per year (approx. 47% of the annual rated capacity).

5.1.1.3.3 Water and electricity consumption

During the use phase, household washing machines generally consume electricity in on-mode, low-power modes (e.g. delay-start, left-on mode) and off-mode (e.g. standby for the internal clock).

For the electricity consumption, the energy consumption under real user behaviour conditions was estimated. Data on the real life use of the different programmes and data on the energy consumption of various programmes are used. The real-life selection of programmes is derived from the latest EU consumer survey (2015) and the energy consumption of the different programmes is defined according to direct stakeholder input. The assumptions are outlined in more detail in the following paragraphs.

According to the results from consumer surveys reported in Task 3, consumers use regularly a mix of programmes. The standard cotton 40 °C and 60 °C programmes represent 10% and 7% of all chosen cycles respectively (Alborzi et al. 2015). To wash cotton textiles, 'normal' cotton programmes are also selected: 15% for the normal cotton 40 °C programme and 11% for the normal cotton 60 °C programme (Alborzi et al. 2015). The normal programmes may reach higher temperatures and have shorter duration than the standard programmes, but would consume more energy and water. Besides the cotton programmes, other programmes are used by consumers, as the following results of the 2015 consumer survey on washing machines show (Alborzi et al. 2015).

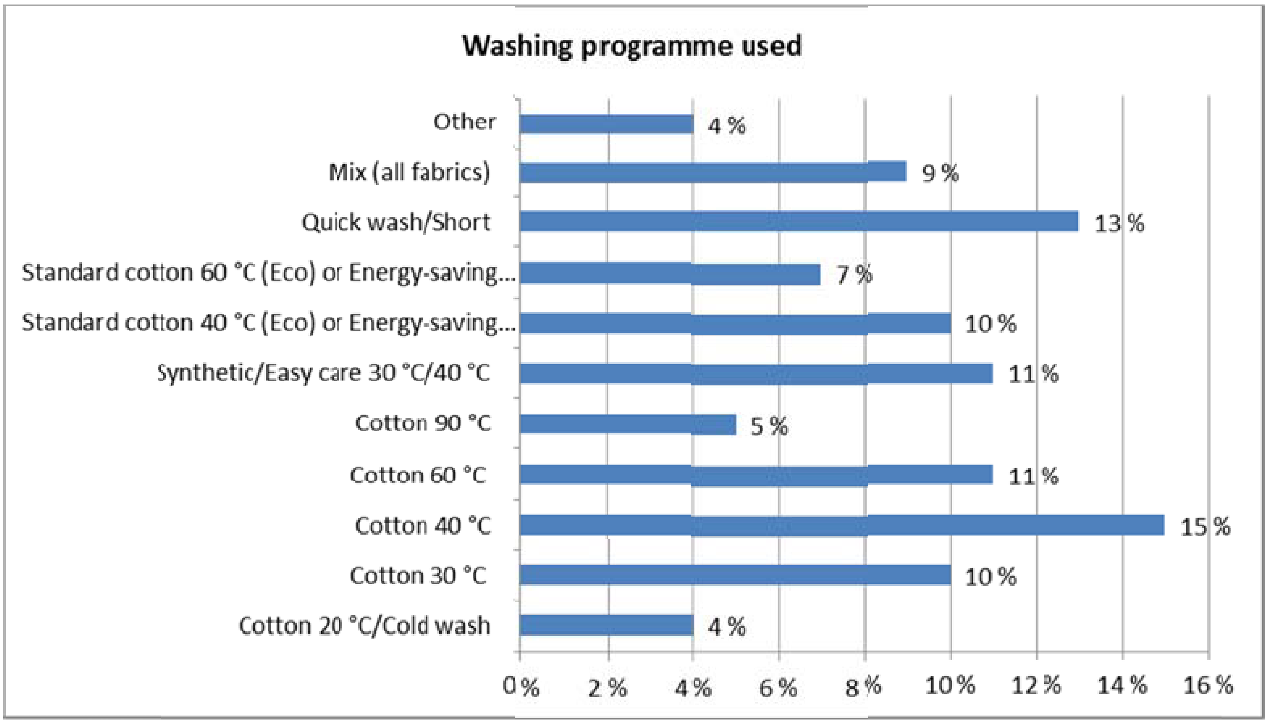


Figure 5.1: Washing behaviour of European consumers 2015, washing programmes used (source: (Alborzi et al. 2015))

Consumption values for typical programmes offered in washing machines have been gathered from manufacturers, user manuals of the most sold machine models and information available in the literature. The estimated average consumption values are shown in Figure 5.1. Split values have been estimated for 'standard' and 'normal' 40/60°C cotton programmes. Two quick wash / short programmes have been considered: super quick (20-30 min) and normal quick (45-70 min). Reported parameters can differ from those of specific models, depending on machine and programme design. The data presented cover 95% of the wash cycles selected.

It should be noted that only the values for standard cotton programmes at 60 °C (full and partial loads) and 40 °C (partial loads) are standardized. Other values have been disclosed by the manufacturers without necessarily being based on the measurement standard. It was assumed that these values include the consumption of the low-power modes and off-modes, being estimated as up to 2.5% of the overall energy consumption.

The declared energy consumption values as well as the values provided by the manufacturers for other programmes are given for full load cycles. Therefore, these values were corrected to take into account the loading of the machines (3.4 kg). Correction factors have been estimated for each programme. For cotton programmes these have been based on the model provided in (Lasic et al. 2015). Although specifically built for cotton programmes, the model has been used to estimate correction factors for other non-cotton programmes (quick/short, synthetic/easy care, mix programmes) and are reported Table 5.3: Frequency of use and average consumption of energy and water for washing programmes estimated for the Base case modelling (Sources: (Alborzi et al. 2015) and own elaboration based on data collected for different products on the market).

Based on the assumptions listed above, a weighted average energy consumption of 0.644 kWh/cycle has been calculated for the base case. The fraction of programmes excluded from the modelling (5%) is likely to consume less energy and water than the calculated weighted average. Real consumption values may thus be slightly lower

As reference, the declared energy consumption for the base case has also been included in the Table 5.1.The declared energy consumption value also includes low-power and off-modes energy consumption.

The same procedure has been applied to estimate the consumption of water. The estimated value reaches 43.5 litres/cycle while the declared value was estimated as 45 litres/cycle.

Table 5.3: Frequency of use and average consumption of energy and water for washing programmes estimated for the Base case modelling (Sources: (Alborzi et al. 2015) and own elaboration based on data collected for different products on the market)

Programme	Share of use (%)	Actual Temperature (°C)	Average rated capacity (kg)	Real life capacity (kg)	Average Water Cons.* (L/cycle)	Average Energy cons.* (kWh/cycle)	Average programme duration *	Comments / sources
Standard cotton 40 °C, full load	10%	40	7.00	3.40	51.2	0.750	190	Extrapolated from 15 machines of 7 kg rated capacity tested in the Atlete II project
Standard cotton 60 °C, full load	7%	48	7.00	3.40	49.2	0.965	204	Based on 15 machines of 7 kg rated capacity tested in the Atlete II project
Normal cotton 40 °C, full load	15%	40	7.00	3.40	64.0	0.931	173	Based on data for 10 machines of 7 kg rated capacity
Normal cotton 60 °C, full load	11%	60	7.00	3.40	60.3	1.181	166	Based on data for 10 machines of 7 kg rated capacity
Quick/Short programme - Super quick (20-30 min)	5%	32	2.83	1.75	34.8	0.207	21	Based on input from manufacturers
- Normal quick (45-70 min)	8%	42	4.50	3.75	49.5	0.510	54	Based on input from manufacturers
Synthetic/easy care, rated capacity	11%	35	4.00	2.82	62.0	0.630	122	Based on data for 9 machines of 7 kg rated capacity
Cotton 30 °C, full load	10%	30	7.00	3.40	53.3	0.367	105	Based on data for 3 machines of 7 kg rated capacity
Mix, rated capacity	9%	40	5.00	3.70	68.6	0.738	94	Based on data for 6 machines of 7 kg rated capacity
Cotton 90 °C, full load	5%	85	7.00	3.40	66.8	2.189	152	Based on data for 8 machines of 7 kg rated capacity
Cotton 20 °C, full load	4%	20	7.00	3.40	82.9	0.331	181	Based on data for 6 machines of 7 kg rated capacity
Other programmes (e.g. wool/delicates)	5%		NC	NC	NC	NC	NC	NC

*** Referring to the average rated capacity**

NC: not calculated

Table 5.4: Correction factors estimated for 'real life' loading adaption of different programmes (source: own elaboration based on available data and on (Lasic et al. 2015))

Programme	Load (kg)	Max. rated capacity (kg)	Temp (°C)	time (min)		Water cons.		Energy cons.				Comment
				min	Correction factor	L/cycle	Correction factor	kWh/ cycle	Correction factor	kWh/ kg	Correction factor	
Standard cotton 40 °C	7.0 3.4	7 7	40 40	190 177	93%	68.3 46.6	68%	0.88 0.70	79%	0.13 0.21	163%	Based on Lasic et al. 2015
Standard cotton 60 °C	7.0 3.4	7 7	48 48	204 190	93%	68.3 46.6	68%	1.08 0.90	83%	0.15 0.26	171%	Based on Lasic et al. 2015
Normal cotton 40 °C	7.0 3.4	7 7	40 40	173 152	88%	68.3 46.6	68%	0.84 0.64	76%	0.12 0.19	157%	Based on Lasic et al. 2015
Normal cotton 60 °C	7.0 3.4	7 7	60 60	166 142	85%	68.3 46.6	68%	1.23 1.02	83%	0.18 0.30	171%	Based on Lasic et al. 2015
Super quick	2.8 1.8	7 7	32 32	21 19	87%	43.2 36.6	85%	0.13 0.07	59%	0.04 0.04	100%	Based on Lasic et al. 2015
Normal quick	4.5 3.8	7 7	42 42	54 47	87%	53.2 48.7	91%	0.48 0.43	90%	0.11 0.11	108%	Based on Lasic et al. 2015
Synthetic / Easy care	4.0 2.8	7 7	35 35	122 106	87%	50.2 43.1	86%	0.49 0.40	82%	0.12 0.14	116%	Based on Lasic et al. 2015
Cotton 30 °C	7.0 3.4	7 7	30 30	105 91	87%	68.3 46.6	68%	0.48 0.29	61%	0.07 0.09	126%	Based on Lasic et al. 2015
Mix	5.0 3.7	7 7	40 40	94 82	87%	56.3 48.4	86%	0.56 0.48	85%	0.11 0.13	115%	Based on Lasic et al. 2015
Cotton 90 °C	7.0 3.4	7 7	85 85	152 132	87%	68.3 46.6	68%	1.69 1.49	88%	0.24 0.44	182%	Based on Lasic et al. 2015
Cotton 20 °C	7.0 3.4	7 7	20 20	181 157	87%	68.3 46.6	68%	0.46 0.26	55%	0.07 0.08	113%	Based on Lasic et al. 2015
Other programmes (e.g. wool/delicates)	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

NC: not calculated

5.1.1.3.4 Detergent

In the measurement standard for testing the performance of washing machines, the detergent consumption is determined based on the machine's average loading. For the base case, an average dosage of 75 g of solid detergent per cycle has been assumed, based on user behaviour survey results (see Table 3.12). This amount is also in line with the recommendations from detergent manufacturers cf. Task 1, table 1-27 and table 1-28, and similar to use of the standard testing method (40 g + 12 g/kg*3.3=79.6g). This reflects the fact that users would not use the full loading potential of the WMs and would not adapt significantly their dosage behaviour to the capacity of the machine.

In the EcoReport tool, only a dataset of environmental unit indicators for production, use and disposal of dishwashing detergents is included. This has been adapted to washing machines in accordance with the data provided by Golsteijn et al., (2015) for compact detergents. Only those indicators for which specific unit values were defined were modified whereas for other indicators, the default values for dishwashing detergents are taken due to lack of more specific information (cf. 1.3.2.4). PEF for HDLL (AISE. [n.d.]) has been instead used to estimate roughly the quota of primary energy due to electricity consumption and the consumption of process water.

Additional auxiliaries such as fabric softeners or bleaching agents have not been taken into account due to missing input data. If used, they would increase the environmental impacts caused by consumables.

Table 5.5: Environmental unit indicators for washing detergents

Indicator	Unit	Value	Source
Primary Energy	MJ	45.00	Golsteijn et al. (2015) for compact detergents
Electrical energy	MJ	1.98	PEF for HDLLD (AISE. [n.d.])
Feedstock energy	MJ	0.00	Default value for dishwashing detergents in EcoReport
Process Water	L	0.76	Default value for dishwashing detergents in EcoReport
Cooling Water	L	0.00	Default value for dishwashing detergents in EcoReport
Hazardous Waste	g	0.74	Default value for dishwashing detergents in EcoReport
Non-hazardous Waste	g	37.1	Default value for dishwashing detergents in EcoReport
Global Warming Potential	kg CO_2 eq.	2.32	Golsteijn et al. (2015) for compact detergents
Acidification	g SO_2 eq.	9.88	Golsteijn et al. (2015) for compact detergents
(Non-Methane) VOC	mg	0.01	Default value for dishwashing detergents in EcoReport
Persistent Organic Pollutants	ng i-Teq	0.21	Default value for dishwashing detergents in EcoReport
Heavy metals (to air)	mg Ni eq.	0.00	Default value for dishwashing detergents in EcoReport
Polycyclic Aromatic Hydrocarbons	mg Ni eq.	0.06	Default value for dishwashing detergents in EcoReport
Particulate Matter	g	0.18	Default value for dishwashing detergents in EcoReport
Heavy Metals (to water)	mg Hg/20	0.21	Default value for dishwashing detergents in EcoReport
Eutrophication	mg PO4	6349.00	Golsteijn et al. (2015) for compact detergents

5.1.1.4 End-of-Life phase (disposal and recycling)

Recycling of materials can avoid the extraction of raw materials and the production of virgin materials and this is modelled in EcoReport tool as credits (avoided impacts), i.e. negative impacts.

The 'product (stock) life', i.e. the period between the WM is purchased and discarded, 12.5 years has been assumed, the same as for the operational lifetime i.e. the period that the product is in used and operational. This assumption is made because consumers do not keep the product stocked after buying a new one. The same assumption is applied to washer-dryers (cf. section 5.1.2.4).

The value of "unit sales L years ago" was estimated from different sources. (VHK 2014 / Status 2013) indicated 9 million units sold in 1990 and 13.099 million units sold in 2010; Lot 14 calculated 9.5 million units sold in 2007. Therefore, the unit sales 12.5 years ago, was estimated as 11.6 million units (calculated as interpolation of VHK data).

The current fraction of materials contained in appliances on the market is calculated by the EcoReport tool based on the material shares of the current BoM (including packaging material), the calculated spare parts for maintenance and repair, and the auxiliary materials consumed during the use phase (detergent, softeners, etc.). For comparison the material inputs from Lot 14 are displayed as well in Table 5.6.

It is seen that the fractions of materials of household washing machines about 10 years ago slightly differ to that of today's washing machines. It has to be noted that this effect might be caused by the different data sources and the underlying assumptions.

Table 5.6: Comparison of the current share of materials in household washing machines with former fractions (including auxiliary materials)

Materials in % of total mass	Base case	Base case Lot 14
Bulk Plastics	2.2%	2.6%
Tec Plastics	2.3%	0.1%
Ferrous	10.3%	7.6%
Non-ferrous	1.5%	0.9%
Coating	---	---
Electronics	0.1%	0.0%
Misc.	8.8%	5.1%
Extra	0.02%	---
Auxiliaries (detergents)	74.8%	83.7%
Refrigerant	---	---

Further, the EcoReport tool requires input on the EoL destination of 5 fractions in mass: re-use, recycling (material), recovery (heat), incineration and landfill/missing/fugitive. In lack of more specific data on the destination of the material fractions of washing machines, the default values of the Ecoreport tool have not been changed with the exception of the auxiliaries and miscellaneous, as follows:

Only detergents are subsumed under the category of auxiliaries. As consumables, they are not undergoing any reuse, recycling or recovery process at their end of life but go with the wastewater to the respective treatment/discharge; thus, the default values in this EcoReport 'Disposal & Recycling' section have been changed to 100% fugitive accordingly.

The category of miscellaneous for washing machines and washer-dryers, covers mainly glass (from the door), concrete (as counterbalance weight), as well as paper and wood from the packaging. According to section 4.2.6.2, glass is assumed to be going either to recycling or landfill, and concrete – the main share per weight of this category – is disposed together with inert construction and demolition waste. Wood, paper and cardboard are recycled. The default values of the EcoReport tool assume a high percentage of recycling and fulfilment of waste hierarchy targets. A less ambitious share of EoL has been modelled instead. The EoL treatment has been adapted as follows: 10% material recycling instead of 64%, 88% landfill instead of 29% due to the large share of concrete and glass, 0% incineration without energy recovery instead of 5%; reuse and heat recovery (each 1%) remain unchanged

Two important parameters for the modelling are the recycled content and recyclability of materials. The recycled content is the proportion of material input to the production process that has been recycled in a previous system. The recyclability rate is the proportion of a certain material in the product that will be recycled in a subsequent system. This takes into account any inefficiency in the collection and recycling processes (Allacker et al. 2014).

The EcoReport tool requires to define qualitatively the 'EoL recyclability'. This relates to the potential of the new products to change the course of the materials flows, e.g. due to faster pre-disassembly or other ways to bring about less contamination of the mass to be recycled. Therefore it is economically likely that the recycled mass at EoL will displace more virgin material in other applications. The recyclability does not influence the mass balance but it does give a reduction or increase up to 10% on all impacts of the recycled mass. It is forward looking, e.g. values different from 'avg' (= base case) might only be filled in for certain design options. For the definition of the base case, an average recyclability of the fractions is chosen.

Figure 5.2: EoL destination of material fractions

Values in %	Bulk Plastics	Tec Plastics	Ferrous	Non-ferrous	Coating	Electronics	Misc. , excluding refrigerant & Hg	Refrigerant	Extra	Auxiliaries
EoL mass fraction to re-use, in %	1	1	1	1	1	1	1	1	1	0
EoL mass fraction to (materials) recycling, in %	29	29	94	94	94	50	10	30	60	0
EoL mass fraction to (heat) recovery, in %	15	15	0	0	0	0	1	0	0	0
EoL mass fraction to non-recovery, incineration, in %	22	22	0	0	0	30	0	5	10	0
EoL mass fraction to landfill/missing/fugitive, in %	33	33	5	5	5	19	88	64	29	0
TOTAL	100	100	100	100	100	100	100	100	100	0
EoL recyclability	avg	avg	avg	avg	avg	avg	avg	avg	avg	avg

5.1.2 Base case for washer-dryers

Section 2.2 indicates that the washer-dryer with a water-based condensation system had in 2014 about half of the market. Therefore the base case for the washer-dryers is based on this technology. Heat pump systems are however expected to expand rapidly.

Section 2.2.4.2 and section 2.2.4.3 confirm the trend in the last years with higher capacities for drying and washing. Until 2003 over 60% of all models has a washing capacity up to 5 kg and in the following years larger machines increased their market shares. In 2014 over 50% of the washer-driers have a washing capacity of 7 kg or higher. Comparable is the increase of the drying capacity. Before 2003, the majority of all models had a drying capacity up to 3 kg while in 2014 over 50% of all models offer a drying capacity between 4 and 7 kg. At the light of these data, the base case washer-dryer has a rated capacity of 7 kg.

The washing function of washer-dryer is assumed identical to the WM, both in terms of technology and use. Thus, an average loading of 3.3 kg and 220 cycles per year are assumed.

According to the 2015 user survey (Stamminger, R. et al. 2015) washer-dryers are used on average 4.6 times per week. In 63% of those cases, the clothes are then dried in the washer-dryer, either in continuous wash&dry operation (32.6%), or in interrupted wash and dry operation (30.4%). In the rest of cases (37% of cycles), other methods for drying are used, e.g. a clothes line. This study provided some indications about the energy and water consumption of the continuous wash&dry and of the dry-only functions in case of interrupted wash and dry for a tested machine that are discussed in more detail in section 3.1.2.2

Table 5.7 summarises the detailed performance characteristics chosen for the washer-dryer base case including the respective underlying sources and assumptions (a more detailed description of the assumptions can be found in the sections 5.1.2.1 to 5.1.2.4.

As commented in the washing machine's base case, the declared values for some parameters such as the water and the energy consumption differ significantly from the actual energy and water consumptions. Therefore, table 5.9 shows together with the parameters of the base case, the values that would be declared and communicated to the consumers and the market surveillance. These declared values are not considered for further calculations.

Table 5.7: Performance characteristics of the chosen base case for washer-dryers

	Base case	Source
Washing capacity	Rated capacity: 7 kg Loading capacity: 3.3 kg	Cf. Task 2, figures 2-34 and 2-35 show that the most (~35%) WD models in 2013 had 7 kg washing capacity. The real loading for washing has been considered the same as for WM.
Drying loading	Rated capacity: 5 kg Loading capacity: 2.1 kg	The 2015 user survey shows that 63% of the cycles run on a WD yearly include washing and drying, being it continuous (32.6%) or interrupted (30.4%), and the rest of washed laundry is not dried in the WD). As for the nominal capacity, Cf.Task 2, figures 2-34 and 2-36 show that most (~30%) WD models in 2013 had 5 kg drying capacity.
Number of wash cycles	220	Normalised to match the number of washing cycles. The 2015 survey on WD covering UK, IT, FR and DE concluded that the average number of cycles is 239.2 cycles/yr.
Number of drying cycles	Interrupted Wash&Dry only: 67 cycles out of 220	In 63% of the wash cycles, washed clothes are then dried in the WD, either in continuous (32.6% of the washes, ~72 cycles) or interrupted

	Base case	Source
	Continuous Wash&Dry: 72 cycles out of 220	(30.4% of the washes, ~67 cycles) wash and dry operations. In the rest of cases (37% of cycles), other methods for drying are used, e.g. a clothes line
Observed Retail Price (ORP) (€)	826	The retailer purchase prices are ca. twice for WD than for WM (based on the analysis of the first Top19 sales on a number of internet retailers).
Recommended Retail Price (RRP) (€)	1156	Based on stakeholder's feedback and browsing of the RRP in the websites of the manufacturers
Manufacturing cost (€)	296	As for WM, RRP = 3.9 x MC (or ORP = 2.8 x MC)
Repair and maintenance costs (in €)	45	Assumption: same costs as for WM, cf. Table 5.1
Energy consumption – interrupted wash & dry	Washing: 0.195 kWh/kg Drying: 0.607kWh/kg	Calculated from the contributions of: - Washing cycling = energy consumption of the base case washing machines. These values are comparable according to manufacturers for most sold models of washer-dryers (6-8 kg rated washed capacity). - Drying process = a weighted average consumption value from the data in Table 5.9 and Table 5.1. Washing process: 0.195 kWh/kg Cupboard drying: 0.95*0.611 kWh/kg=0.580 kWh/kg Iron drying: 0.05*0.542 kWh/kg=0.027 kWh/kg Total = 0.780 kWh/kg are consumed to dry 1 kg of laundry
Energy consumption – continuous wash & dry	0.823 kWh/kg	A weighted average consumption value has been estimated from the data in Table 5.9 and Table 5.1. Wash&Cupboard drying: 0.95*0.82 kWh/kg = 0.779 kWh/kg Wash&Iron drying: 0.05*0.88 kWh/kg = 0.044 kWh/kg Total = 0.823 kWh/kg are consumed to wash and dry 1 kg of laundry The contribution from washing process is 25% (0.206 kWh/kg)
Water consumption – interrupted wash & dry	Washing: 13.3 L/kg Drying: 6.8 L/kg	Calculated from the contributions of: - Washing cycling = energy consumption of the base case washing machines. These values are comparable according to manufacturers for most sold models of washer-dryers (6-8 kg rated washed capacity). - Drying process = a weighted average consumption value has been estimated from the data in Table 5.9 and Table 5.1. Following the same procedure as for the energy consumption, on average, 6.80 L of water are consumed to dry 1 kg of laundry
Water consumption – continuous wash & dry	16.1 L/kg	A weighted average consumption value has been estimated from the data in Table 5.9 and Table 5.1. Following the same procedure as for the energy consumption, on average, 16.1 L are consumed to wash and dry 1 kg of laundry (1.1 kg laundry dried each 3.3 kg of laundry washed in continuous operation). The contribution from washing process is 57% (9.1 L/kg).

	Base case	Source
Average consumption of WD	Energy: 1.93 kWh / wash cycle Water: 53.5 L / wash cycle	If the base case washer-drier operates 220 cycles/yr., based on the 2015 user survey results, they will be distributed as follows: washing only with drying elsewhere (37% of cycles), Continuous wash&dry (32.6%), And interrupted wash and dry (30.4%). Contributions from the washing process are: • ~34% for energy • ~73% for water In 37% of the wash cycles the laundry is dried elsewhere. The effort for drying such laundry could be estimated to be 0.172 kWh / wash cycle (or 0.052 kWh/kg), considering: • 3.3 kg of laundry washed per cycle; • Moisture content must be decreased from 50% to 1% by application of heat. 1% calculated considering 0% residual moisture content for 95% of drying processes (as cupboard drying) and 12% residual moisture content for 5% of drying processes (as iron drying); • ~54% of laundry is dried outdoor or in unheated rooms (heat available 'for free'); • Heat of evaporation is 0.63 kWh/k. Overall energy effort for drying: • ~194% of the energy consumption of the washing process of the same amount of laundry • ~26% of the energy consumption of the washing process for drying elsewhere
Detergent consumption (g/cycle)	75 g, solid (or 75 ml, liquid)	Same as BC WM Fixed detergent consumption in standard testing method
Washing performance class	A for the tested programme	Cf. Task 2, figure 2-46: >95% of 2013 EU WD models
Maximum spin speed (rpm)	1400 for the tested programme	Cf. Task 2, figures 2-47 to 2-49: average of 2013 EU WD models Lower spin speeds more meaningful for WM, which serve a broad range of drying conditions, but WD are meant for conditions where drying in the WD is likely (63% of occasions) and there a high spinning is desirable.
Noise washing/ spinning/drying	55/76/62 (dB(A))for the tested programme	Cf. Task 2, figure 2-53: average of 2013 EU WD models
Cycle time wash	121 min	As for the Base case washing machines
Cycle time wash + dry	290 min (wash ~121 min / dry ~169 min)	Washing process in accordance with the base case washing machine. Stiftung Warentest, test 10/2012; split of cycle time on wash / dry programme: own assumption
Lifetime	12.5 years	General assumption: same lifetime as for WM

In the Ecodesign preparatory study of 2007 by (ISIS 2007b), washer-dryers were no analysed being impossible to carry out any comparison.

5.1.2.1 Raw materials use and manufacturing process of the products: Bill of Materials (BoM)

The Bill of Materials (BoM) of the base case has been selected based on the inputs provided by stakeholders (2 models) completed with some modelling assumptions, as commented in section 5.1.1.1. Thus, the BoM of the base case as provided in Table 5.8 does not refer to a real product on the shelves, but to an average product considered to be representative of the 2014 market. Plastics and metals have approx. 7% higher share in washer-dryers than in the base case of washing machines, whereas electronics, glass and concrete, as well as the packaging remain unchanged.

Table 5.8: BoM considered for the household washer-dryers

Component / Material	BoM (2015) / Weight (g)
Bulk Plastics	6,393
Technical Plastics	6,954
Ferrous metals	30,724
Non-ferrous metals	4,396
Electronics	225
Extra	66
Auxiliaries (detergents)	0
Refrigerant (only relevant for design options equipped with heat pumps)	0
Miscellaneous (mainly glass, concrete, paper and wood from packaging)	24,266
SUM	**73,023**

As commented in section 5.1.1.1 the manufacturing process is mainly fixed in the Ecoreport tool and the only variable with can be edited is the percentage of sheetmetal scrap. This value was changed from the default value of 25% to 5% in accordance with Lot 14 (ISIS 2007) and manufacturers' information for washing machines.

Refrigerants as used in heat pump appliances are not taken into account for the base case; however, the share of washer-dryers equipped with a heat pump for condensing the water is expected to increase in the future.

5.1.2.2 Distribution phase: volume of packaged product

For the distribution phase of washer-dryers, the same assumptions as for washing machines have been applied (cf. section 5.1.1.2).

5.1.2.3 Use phase

5.1.2.3.1 General inputs

For some input parameters of the use phase, the same assumptions as for washing machines have been taken (cf. section 5.1.1.3 for details):

- Average product service life: 12.5 years
- Travel distance for maintenance, repairs and service: 160 km.
- Weight of spare parts: fixed at 1% of the total weight of the analysed product.

During their use phase, household washer-dryers generally consume electricity in on-mode, standby-mode and off-mode, as well as water and consumables (detergents).

Some other assumptions have been considered mirroring the base case for washing machines:

- Loading capacity for washing: 3.3 kg
- Number of cycles: 220 cycles / year
- Detergent consumption: 75 g per cycle
- Cycle time wash: 121 min

5.1.2.3.2 Water and electricity consumption

Table 5.9 shows how consumption values of a machine could vary depending on the tested operation mode. Data seems comparable with the data received from manufacturers in response to JRC questionnaires

Table 5.9: Indications on tested consumption values for WD (Stamminger, R. et al. 2015) based on feedback from stakeholders

	Loading	Energy consumption	Water consumption
Drying only for interrupted wash and dry	7 kg – Cupboard dry	~4.28 kWh/cycle ~0.611 kWh/kg	~48 L/cycle ~6.85 L/ kg
	3.5 kg – Ironing dry	~1.9 kWh/cycle ~0.542 kWh/kg	~20 L/cycle ~5.71 L/ kg
Continuous wash&dry	5 kg – Cupboard dry	~1.0+3.1= 4.1 kWh/cycle ~0.82 kWh/kg	~45+35= 80 L/cycle ~16 L/ kg
	2.5 kg – Ironing dry	~0.8+1.4=2.2 kWh/cycle ~0.88 kWh/kg	~30+15=45 L/cycle ~18 L/ kg

At the light of the data of the table, the following approximate rules can be drawn:

- Drying energy is proportional to load (in weight).
- Half load washing reduces energy consumption by approximately 20%.
- Iron dry compared to cupboard dry saves 10% of energy.

Based on feedback from stakeholders, the cupboard drying programme is used in 95% of the drying cycles, with the remaining 5% of drying processes using iron dry programmes. The cupboard dry programme consumes more energy than the iron dry programme since it removes more moisture from the laundry. One of the advantages of the cupboard dry programme is to provide ready-to-store laundry, whilst ironing of laundry is typically needed after the iron dry programme. Nevertheless, ironing can take place also after the cupboard dry programme, after having increased again the laundry moisture content. The ironing makes the extra drying of the cupboard dry programme useless (and the additional energy consumption).

The values in Table 5.9 give an idea of the total amount of water and energy consumed in washer-dryers under different testing conditions. However, it should be noted that in this table similar energy consumption values have been estimated for continuous and interrupted wash and dry processes. Actually, energy consumption values could be slightly lower for the continuous wash and dry cycle due to the use of residual heat from the washing cycle for the drying process. However, this only occurs if the drying process is performed relatively soon after the washing process and the appliance has been designed for this purpose (see Section 6).

For the electricity consumption, three operation modes have been considered as depicted in Figure 5.3.

- Energy consumption of the washing process alone: the overall energy consumption of this cycle is estimated the energy consumption of the washing machine base case (0.195 kWh/kg)
- Energy consumption in interrupted wash&dry cycle: the overall energy consumption of this operation mode is estimated as the sum of the energy consumption in the washing process and the energy consumption in the drying process. The energy consumption in the washing process is the same as the energy consumption of the base case washing machine (0.195 kWh/kg). The energy consumption in the drying process has been estimated based on the frequency of each drying process types (see **Error! Reference source not found.**) and the related energy consumptions (see Figure 5.3.). This eans:
    - Washing process: 0.195 kWh/kg
    - Cupboard drying process: 0.95*0.611 kWh/kg = 0.580 kWh/kg
    - Iron drying process: 0.05*0.542 kWh/kg = 0.027 kWh/kg

    Total 0.780 kWh/kg
- Energy consumption in the continuous wash&dry cycle: the overall energy consumption of this operation mode is estimated as the weighted average of continuous wash&dry cycle with a cupboard drying process and with an iron drying process. This means
    - Cupboard drying process: 0.95*0.82 kWh/kg = 0.779 kWh/kg
    - Iron drying process: 0.05*0.88 kWh/kg = 0.044 kWh/kg

    Total 0.823 kWh/kg

The average energy consumption of the base case is finally calculated as a weighted average of the three operation modes. The percentages of use of each operation mode are given in Figure 5.3. This means

- Washing process: 0.370*0.195 kWh/kg = 0.072 kWh/kg
- Interrupted wash&dry: 0.304*0.780 kWh/kg = 0.237 kWh/kg
- Continuous wash&dry: 0.326*0.823 kWh/kg = 0.268 kWh/kg

Total 0.577 kWh/kg

Considering that the loading capacity of the base case is of 3.3 kg /cycle the average energy consumption will be 1.904 kWh/cycle

The average energy consumption of the base case does not include the low-power modes and the off-modes since they are of minor relevance for the total energy consumption of WD (cf. section 1.4.2.5 of Task 1).

Water is consumed in drying for direct contact or heat exchange water-air condensation, and for fluff flushing. Air condensation, HP or air venting technologies may thus not use water for drying. The same procedure was applied to calculate the water consumption of each operation mode and the average water consumption.

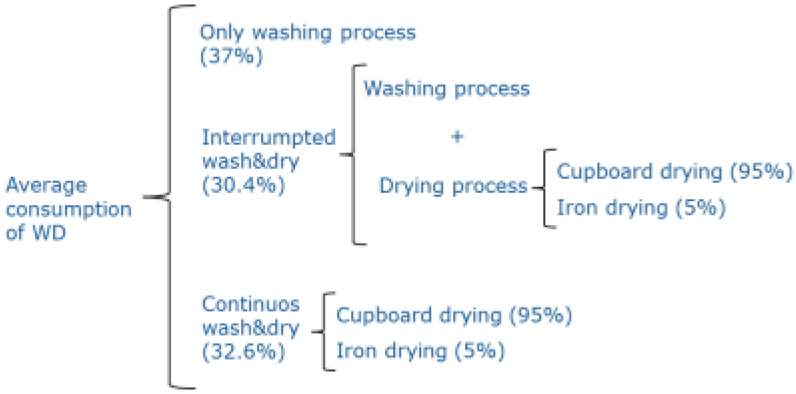


Figure 5.3: Calculations to estimate the average energy consumptions of the washer-dryers.

5.1.2.4 End-of-Life phase (disposal and recycling)

For the EoL phase of washer-dryers, the same assumptions as for washing machines have been applied (cf. section 5.1.1.4).

No data is available for the unit sales of washer-dryers 12.5 years ago ("unit sales L years ago"). Assuming that sales of washer-dryers are proportional to washing machines, 0.7 million units of washer-dryers are assumed as sales 12.5 years ago (2002-2003).

5.1.3 Life Cycle Cost (LCC) inputs for washing machines and washer-dryers

In the EcoReport tool the total Life Cycle Costs for end users are expressed in Euros and calculated according to equation 5-1:

Eq. 5-18: $$LCC = PP + \sum_1^N PWF * OE + EoL$$

With:

- LCC: Life Cycle Costs for end-users
- PP: Purchase price (including installation costs)
- OE: annual operating expenses for each year of use
- EoL: End-of-life costs for end-users (i.e. costs for disposal)
- PWF: Present Worth Factor, calculated according to Equation 5-2

$$PWF = 1 - \left(\frac{1+e}{1+d}\right) \cdot \left[1 - \left(\frac{1+e}{1+d}\right)^N\right] \qquad (d \neq e)$$

Eq 5-2

Where

- e is the aggregated annual growth rate of the operating expense ('escalation rate')
- d is the discount rate in %
- N is the product life in years.

5.1.3.1.1 Discount and escalation rate

To calculate the PWF the discount rate (d) and the escalation rate (e) of the operating expenses have to be defined. (COWI and VHK 2011) recommend to apply 4% for the discount rate (d = interest - inflation), which is also the required discount rate of the impact assessment guidelines of the Commission. The 4% result from an assumed MEErP interest rate of 6.5% and an inflation rate of 2.5%.

The escalation rate (e = inflation corrected running cost price increase) is the weighted average of the annual growth rates of the different operating expenses. (COWI and VHK 2011) suggest a default value of 4% which is assumed to reflect satisfactorily the situation.

In that case, as the discount rate is the same as the escalation rate, then the Present Worth Factor is 1 to the power of the product life N. Additionally; end-users in Europe do not have separate costs for the disposal of household washing machines or washer-dryers. The formula can be thus simplified as shown in equation 5-3.

$$\boldsymbol{LCC = PP + \sum_{1}^{N} OE} \qquad \textbf{Eq. 5-3}$$

5.1.3.1.2 Stock and sales data for washing machines

For the calculation of the EU totals, data on the annual sales and the stock are taken into account.

Regarding stock data, (VHK 2014 / Status 2013) assumes for the year 2015 a stock of 196.8 million units of washing machines (cf. Task 2, Table 2.8). 201.4 million units of washing machines (+2%) would result by considering housing in the EU and an average EU penetration rate of 92% (cf. Task 2.2.3.2).

For sales data of washing machines, (VHK 2014 / Status 2013) projected annual sales for 2015 of around 13 million units. According to (Michel et al. 2015) based on GfK data, annual sales have been 15.2 million units in 2014 for EU-21 which covers all EU Member States with the exception of Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Luxembourg and Malta. All these mentioned countries together represent only 3% of all European households (Eurostat 2011). Adding the missing 3% to the GfK sales data for EU-21, the EU-28 the sales would be approximately 15.7 million units. The ratio between stock and sales of washing machines in 2015 is 12.5 yr., which is the average lifetime estimated, meaning that the number of sold and replaced appliances matches

According to some stakeholder's feedback (cf. Task 2, section 2.2.3.3), in 2013 the sales of washing machines were around 25 million units. However, this number seems high, and would mean a stock 66% higher than in 2015 in 2030, considering a replacement of 15.7 million units per year.

The estimation of evolution of the sales on a saturated marked differs from a constant value. Several reasons may cause a variation on the annual sales such as the increase/decrease of the lifetime of appliances or change in the number of households. At EU level the population stabilized but the size of households decreased and consequently the number of households increased (about 4% from 2010 to 2030) (European Environment Agency 2005). Therefore, the sales for washing machines are expected to increase in the coming years. Additionally, there is an increasing number of populations owning a second or third residence, as shown the overall increase in holiday residences.

Assuming the nearly saturation of the market and an increase in the number of households of 4% between 2030 and 2015, the stock of washing machines in 2030 would be 204.7 million of units. Based on these data the expected annual sales are calculated as the sum of the machines needed to replace old and defective appliances (15.7 million units per year in 2015, 16.0 million as average for the period 2015-2030) and the increase in the stock according to the assumptions made (0.5 million units per year for the period 2015-2030): 16.6 million washing machines sales per year is taken as average for further calculations.

5.1.3.1.3 Stock and sales data for washer dryers

Regarding stock data for washer-dryers, the average EU penetration rate is assumed to be around 4% (cf. Task 2.2.3.2), which would result in a stock of around 8.76 million washer-dryers.

According to stakeholder feedback (cf. Task 2, section 2.2.3.3.), sales were around 1 million units in 2013. 1 million units of washer-dryers are considered to be sold in 2015 and to increase by 4% from 2010 to 2030 due to an increase of the number of households in Europe, in analogy with washing machines. The number of units replaced can be estimated as the ratio between stock and lifetime (i.e. only 0.68 million per year in 2015). This would mean an increase of the penetration rate, which is in alignment with the findings of Task 2.

Based on these assumptions, the stock would increase by 35% from 2015 to 2030, for a penetration rate of about 5% in 2030 (compared to the current 4%).

5.1.3.1.4 Product prices and installation costs for washing machines

A price range is observed for appliances that meet the specifications of the base case. Manufacturers usually communicate a recommended retail price (RRP) which is often higher than the observed retail price (ORP) for which the appliance is sold on the market (both prices include VAT). The difference depends to a large extent on the retailer, the trade channels, the brand and also the local circumstances or sales (e.g. in case of special sales). Not only is there a difference between the RRP and the OPR, but also a variation on the RRP for similar appliances. These price variations might be due to additional features that are not related to energy and/or water consumption or aesthetic options.

The average sales price in 2014 for 7 kg washing machines was 413 € according to (Michel et al. 2015). According to GfK data for 14 Western European countries, the average price per unit was 434 € in 2012 with an overall declining trend over the past years (cf. Task 2, section 2.3.1). According to stakeholder feedback (cf. Task 2, section 2.2.3.3), in 2013 the average sales price of *all* machines was around 220 € per unit. This value is quite far from other market data on sales prices, and therefore it was discarded. Based on this information, an observed retail price of 413 €/WM is taken for further calculations (VAT included).

In principle there is no fixed correlation between the RRP and the ORP. Stakeholders' feedback showed that the difference between ORP and RRP can vary between 23% and 33%. For further calculations in section 6 however a multiplication factor has to be derived to estimate the increase of price related to a specific design option.

The factor between the manufacturing costs and the RRP is derived from the assumption in ISIS (2007d) (slightly updated with the current VAT rate). From the RRP the manufacturing cost was derived assuming that the manufacturing cost

- Increases by 28% due to manufacturer's marketing and administration
- Is then multiplied by a factor of 2.5 to account for the sales margin and
- Is finally increased by 21.6% for accounting for the average EU VAT 2015

This results in an overall factor of 3.9, i.e.

Recommended retail price (RRP) = Manufacturing cost x 3.9

Applying the inversed procedure starting from the RRP of the base case, this results in a manufacturing cost of 148 €

The ORP was estimated to be on average 413 € for base case washing machines and was based on Michel et al (2015) that estimated that an average price of a 7 kg washing machine in 2014 is around 413 €. Applying the same procedure as explained above, the multiplication factor between the ORP and the manufacturing cost was derived resulting a factor 2.8 for this base case.

Observed retail price (ORP) = Manufacturing cost x 2.8

Installation costs for consumers are in most cases included in the price of the machine. Only in some countries an authorised installer is required.

5.1.3.1.5 Product prices and installation costs for washer driers

Research on washer-dryers indicates purchase prices of washer-dryers are approximately the double than of washing machines. Thus, an observed retail price of 826 € per washer dryer is estimated, VAT included. Recommended retail prices are instead 578 € per washing machine and 1156 € per washer dryer.

A similar procedure was applied for estimating the prices and manufacturing costs for the base case of washer-dryers. Applying the same procedure as explained and considering a multiplication factor equal to the washing machine base case (multiplication factor 2.8), the manufacturing cost for the washer dryer is 296€.

The RRP was estimated based on the feedback of the stakeholders that proposes a difference of among +40% (range: +30% and +50%) between the ORP and the RRP.

Table 5.11 gives a summary below of the assumptions regarding the prices and multiplication factors of both base cases.

Installation costs for consumers are in most cases included in the price of the machine. Only in some countries an authorised installer is required.

5.1.3.1.6 Maintenance and repair costs for both washing machines and washer dryers

For maintenance and repair costs, assuming that about 30% of all washing machines are repaired once in their lifetime and the average cost of the repair amounts to 150 € (Prakash et al. 2016), the repair cost for all washing machines can be set at 45 € per product service life of 12.5 years VAT included. The same assumptions were applied to washer-dryers

The assumptions regarding the repair costs have a relative high uncertainty too. Several reasons can be pointed out such as the difference in labour costs and income across Europe, the lack of identified frequent failures in the machines or the cost of spare parts. According to stakeholders feedback the average split for repairs in France for washing machines is 40 % for the cost of the spare parts and 60 % for the cost of the service, while (Que choisir?, 2015) provides an example that showed that the total repair costs for washing machines could even consist of approximately 75% for the cost of the spare parts and the 25 % for the cost of the service.

In this study a higher and a lower repair rate are proposed to be assessed as the effect would be similar to higher or lower costs per repair respectively[1]. An increase in the repair rate of 35 % resulted in an increase in the repair costs of 36%.

5.1.3.1.7 Consumables (electricity, water and detergents) for both washing machines and washer dryers

The electricity rate has been calculated according to (Eurostat 2015). The EU-28 average electricity price for households was 0.208 €/kWh in 2014 (including taxes, levies and VAT). The electricity prices vary between Member States by a factor of three: the highest prices are found in Denmark (0.304 €/kWh) and Germany (0.297€/kWh), whereas the lowest prices are found in Bulgaria (0.090 €/kWh) and Hungary (0.115 €/kWh). High prices are also registered in Spain (0.237 €/kWh) and Italy (0.234 EUR/kWh), while France (0.175 €/kWh) and the UK (0.201 €/kWh) have a medium price level.

Regarding water prices, (European Environment Agency 2003) states that there are wide variations in water charges within individual countries, and between different countries in Europe. This is because of the wide range of factors that determine local water prices, and whether there is a full recovery of costs - including those for water treatment and supply, for sewage treatment and for environmental damage. (COWI and VHK 2011) proposed taking 3.70 €/m^3 as European average for the year 2011. (COWI and VHK 2011) also proposed long-term growth rates for electricity rates (5%) and water rates (2.5%). Applying the growth factor of 2.5% to deduce the current water rate from the 2011 costs, in 2014 the water rate would be 3.98€/m^3.

[1] The impact of repairs has been analysed by means of a sensitivity analysis in the parallel preparatory study for household dishwashers (Boyano et al, 2017).

For detergents, according to stakeholder feedback it is rather difficult to derive average costs at EU level as there are many variations in the kind of detergents (powder, compact, liquids, heavy duty detergents, colour detergents, etc.) and different purchase prices within the Member States. Task 2, section 2.3.2 indicates a range between 0.11 € and 0.32 € per cycle for compact solid laundry detergents in Germany. For further calculations, an intermediate value of 0.20 €/cycle is taken for both washing machines and washer-dryers. Assuming a dosage of 75 g per cycle, the average cost for detergents would be 2.67 €/kg.

The price of 0.20 €/cycle is comparable with an estimation provided by the detergency industry association (A.I.S.E / Insites 2014, personal communication 2015): 0.23 €/cycle (+15%). AISE obtained this average price by dividing the total annual turnover of the sector by the total number of washes in the EU-28 per year (considered to be 34 284.3 million washes). AISE also provided the cost variation for different types of detergent in 2014 (Euromonitor / A.I.S.E, personal communication 2015) as shown in Table 5.10.

Table 5.10: Dosage, retail volume and wash cycles per year for several types of laundry detergents.

Detergent	Average cost (euro/cycle)	Dosage (g or ml/cycle)	Retail volume (unit / year)	Wash cycles (mill cycles/year)	Total value (M euro)
Solid laundry	0.225	75	1 024.1 ton	13 654.6	3 078.5
Liquid laundry	0.293	75	1 033.8 million l	13 784	4 044.6
Compact Powder Tablet	0.127	35	76.7 ton	2 191.4	278.2
Liquid Tablet	0.295	35	89.6 ton	2 560	754.5
Average	0.25				

This gives an average cost of 0.25 €/cycle (+27% compared to the average value considered for further calculations).

5.1.3.1.8 Ratio average new appliance vs stock for washing machines and washer dryers

Finally the ratio between the energy consumption of the new average new product and the energy consumption of the average product installed ('stock') has to be derived. The average product installed approximately equals the average new product a number of years ago. This number of years equals half the product life which is 6.25 years in the case of washing machines and washer driers. The ratio therefore has been estimated from the average energy consumption (according to the CECED databases) per cycle in 2014 and 2007. For the washing machines the average energy consumption in 2014 was 0.67 kWh/cycle and the average consumption per kg in 2007 was 0.85 kWh/kg. For the washer dryers the average energy consumption in 2014 was 1.28 kWh/kg and the average consumption per cycle in the years 2007 was 1.53 kWh/kg (see section 2.2.4).

5.1.3.1.9 Summary

Table 5.11 summarizes the data input for carrying out the economic assessment of the base cases with the Ecoreport tool.

Table 5.11 Inputs for the LCC for household washing machines and washer-dryers (data is considered to be representative for EU-28 in 2014)

Input parameter	Washing machines	Washer-dryers
Annual sales (million units/year)	16.6	1

Input parameter	Washing machines	Washer-dryers
EU stock (million units)	201.4	8.8
Manufacturing Price (€)	148	296
Recommended Retail Price (€)	578	1156
Observed Retail Price (€)	413	826
Installation costs (€)	0	0
Indicative maintenance and repair costs (€), referred to the total product service life	45	45
EoL costs to consumers (disposal and recycling) (€)	-	-
Product service life (years)	12.5	
Electricity rate (€/kWh)	0.208	
Water rate (€/m³)	3.98	
Detergent costs (€/kg)	2.67	
Discount rate (interest minus inflation) (%)	4.0%	
Escalation rate (annual growth of running costs) (%)	4.0%	

5.2 Environmental Impacts of Base-Cases

The environmental impacts have been calculated with the MEErP EcoReport tool, using the data inputs presented in the previous sections, in the categories:

- Raw materials use and manufacturing,
- Distribution,
- Use phase, and
- End-of-life phase.

Results are shown in this study as environmental impacts per product over its whole life cycle, and as environmental impacts of new models sold in the reference year over their expected lifetime. Lifecycle impacts per year of the installed stock are assumed to differ only for the energy efficiency correction factor described in section 5.1.3

5.2.1 Base case washing machines

Table 5.12 shows the material consumption of a washing machine with 7 kg rated capacity over the whole life cycle of 12.5 years. The material consumption during the production equals the input values of the bill of materials. The materials consumed during the use phase correspond to the materials consumed for maintenance and repair that account for 1% of the bill of materials, and the amount of detergents.(= auxiliaries) used over the life cycles. The material consumption during the End-of-Life phase is split in disposal, recycling and 'stock'. The latter value results from the effect that the mass discarded seldom equals the mass of new products sold.

Table 5.12: Life cycle material consumption of a household washing machine with 7kg rated capacity.

Materials	Unit	PRODUCTION	Distribution-	USE	END-OF-LIFE		
					Disposal	Recycling	Stock

Bulk Plastics	g	5 982		60	2 763	2 261	1 017
TecPlastics	g	6 457		65	2 506	2 051	1 964
Ferro	g	28 527		285	734	13 953	14 125
Non-ferro	g	4 082		41	87	1 652	2 383
Coating	g	0		0	0	0	0
Electronics	g	225		2	38	39	150
Misc.	g	24 266		243	8 673	1 183	14 653
Extra	g	66		0	26	41	0
Auxiliaries	g	0		206 250	161 945	0	44 305
Refrigerant	g	0		0	0	0	0
Total weight	g	69 603		206 945	176 773	21 180	78 597

Table 5.13 shows the environmental impacts over the whole life cycle of the base case washing machine assuming that it is used in accordance with the real-life consumer behaviour.

The results are also shown in terms of relative contributions (%) of each life cycle phase (i.e. production, distribution, use and end of life). Results are represented for each impact category as the sum of the contributions (%) of all the phases in absolute value summing up to 100% in absolute value. Negative values in the end-of-life phase represent credits, i.e. avoided impacts.

Table 5.13: Environmental impacts over the whole life cycle (12.5 years) of the base case washing machine

Life Cycle phases	Unit	PRODUCTION			Distribution	USE	END-OF-LIFE		TOTAL
		Material	Manuf.	Total			Disposal	Recycl.	
Resources & Waste									
Total Energy (GER)	MJ	3 312	934	4246	650	26007	38	-456	30 485
of which, electricity (in primary MJ)	MJ	816	560	1376	1	17109	0	-87	18 399
Water (process)	ltr	1 846	8	1854	0	166215	0	-316	167 753
Water (cooling)	ltr	2 377	261	2638	0	766	0	-264	3 140
Waste, non-haz./ landfill	g	36 110	3112	39223	376	16615	330	-6 770	49 774
Waste, hazardous/ incinerated	g	103	0	103	7	417	0	-9	518
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	229	52	281	43	1193	0	-36	1 482
Acidification, emissions	g SO_2 eq.	2143	224	2367	130	5212	2	-344	7 368
Volatile Organic Compounds (VOC)	g	6	0	6	9	375	0	-1	390
Persistent Organic Pollutants (POP)	ng i-Teq	455	14	469	2	87	0	-85	473
Heavy Metals	mg Ni eq.	2904	32	2936	19	198	2	-551	2 604
PAHs	mg Ni eq.	99	0	100	23	52	0	-12	163
Particulate Matter (PM, dust)	g	450	35	485	1539	108	5	-59	2 078
Emissions (Water)									
Heavy Metals	mg Hg/20	1963	1	1964	1	135	1	-356	1 745
Eutrophication	g PO_4	65	0	65	0	1313	3	-11	1 371

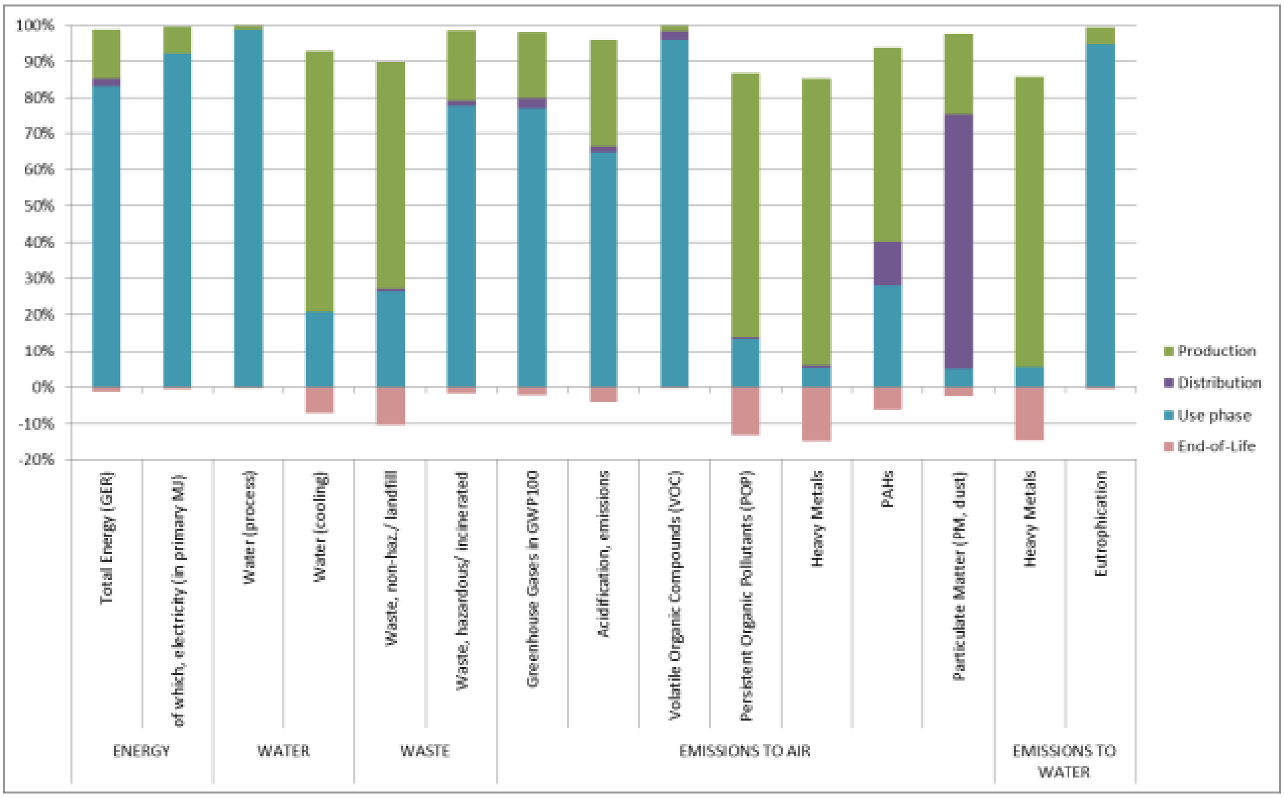


Figure 5.4: Relative magnitude of single life cycle stages to the environmental impacts of the base case washing machines. Note: 100% is the sum of the absolute values of the contributions from the life-cycle stages

The contribution of the use phase to these indicators is mainly due to the consumption of electricity. Impacts in the production stage stem largely from materials, but are potentially avoidable if the materials are recycled.

The results above in Figure 5.4 show that the use phase is the dominant contribution for

- Consumption of total energy (83%) and process water (99%).
- Production of hazardous / incinerated waste (78%).
- Global warming potential (77%), acidification potential (65%), emission of VOCs (96%), eutrophication potential (95%).

For the other categories, i.e. persistent organic pollutants (POP), heavy metals to air (HM air), polycyclic aromatic hydrocarbons (PAHs), particular matter (PM, dust) and heavy metal to water (HM water), and the use phase has a contribution ranging from 10% to close 50% of the total of each category. The process behind driving the high the contribution of the use phase is the consumption of electricity.

The production stage is the most important contribution for

- Production of non-hazardous waste (63%)
- Emissions of Persistent Organic Pollutants (POP=73%), Heavy Metals to air (HM air =79%) and water (water cooling = 72%)

For the emission of PAHs, the importance of the production stage (54%) in comparison to the use phase (28%) is not so relevant.

The distribution phase is relevant only for the emissions of particulate matter PM (70%) and PAHs (12%) and such impacts are due to the transport of the packaged products.

The EoL presents a significant negative impact in some categories. This is due to the credits (avoided impacts) that EcoReport tool assigns to the recycling of materials. For instance, the contribution of the EoL is -13% for the emissions of POPs, -15%, for the emissions of HM to air and -14% for the emissions of HM to water.

5.2.2 Base case washer-dryers

Table 5.14 shows the material consumption of a household washer-drier with a 7 kg rated capacity over the whole life cycle of 12.5 years. The same considerations made for washing machines apply to this product. The material consumption is higher for the base case of washer-dryer in comparison to the base case of the washing machine as a consequence of the heavier weight (+5%). Comparing both base cases, the washer-dryer base case presents:

- +7% bulk plastics;
- +8% technical plastics
- +8% ferrous metals
- +8% non-ferrous metals

Table 5.14: Material consumption of a household washer-dryer with a rated capacity of 7kg

Materials	Unit	PRODUCTION	Distribution-	USE	END-OF-LIFE		
					Disposal	Recycling.	Stock
Bulk Plastics	g	**6 393**		**64**	2 798	2 289	1 370
TecPlastics	g	**6 954**		**70**	2 699	2 209	2 115
Ferro	g	**30 724**		**307**	744	14 127	16 160
Non-ferro	g	**4 396**		**44**	88	1 673	2 679
Coating	g	**0**		**0**	0	0	0
Electronics	g	**225**		**2**	38	40	149
Misc.	g	**24 266**		**243**	8 781	1 197	14 530
Extra	g	**66**		**0**	26	41	0
Auxiliaries	g	**0**		**206 250**	163 967	0	42 283
Refrigerant	g	**0**		**0**	0	0	0
Total weight	g	**73 023**		**206 980**	179 142	21 576	79 286

Table 5.15 shows the environmental impacts of a household washer-dryer with a rated capacity of 7 kg over the whole lifecycle of 12.5 years under real life conditions. In general environmental impacts are higher than those calculated for the base case of washing machines (from +3.1% for Eutrophication Potential to +175.3% for emission of VOCs), because of the greater amounts of materials used in the manufacturing of the product and of the higher energy input needed to wash and dry the laundry. It should highlighted that, differently from washing machines, washer-dryers can fulfil two functions, i.e. washing and drying the laundry, to which such impacts are allocated.

Table 5.15: Environmental impacts over the whole life cycle (12.5 years) of the base case washer-dryers

Life Cycle phases	Unit	PRODUCTION			Distribution	USE	END-OF-LIFE		TOTAL
		Material	Manuf.	Total			Disposal	Recycl.	
Resources & Waste									
Total Energy (GER)	MJ	3 515	1 004	4 519	650	58 011	39	-465	62 754
of which, electricity (in primary MJ)	MJ	845	601	1 446	1	49 111	0	-89	50 470
Water (process)	ltr	1 979	9	1 988	0	204 386	0	-322	206 052
Water (cooling)	ltr	2 553	280	2 833	0	2 190	0	-280	4 743
Waste, non-haz./ landfill	g	38 842	3 346	42 188	376	33 134	341	-6 869	69 169
Waste, hazardous/ incinerated	g	109	0	109	7	922	0	-10	1 029
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	244	56	300	43	2 560	0	-36	2 866
Acidification, emissions	g SO_2 eq.	2 288	241	2 529	130	11 258	2	-349	13 570
Volatile Organic Compounds (VOC)	g	6	0	7	9	1 090	0	-1	1 105
Persistent Organic Pollutants (POP)	ng i-Teq	490	15	505	2	162	0	-86	583
Heavy Metals	mg Ni eq.	3 120	35	3 155	19	524	2	-558	3 141
PAHs	mg Ni eq.	104	0	104	23	127	0	-12	242
Particulate Matter (PM, dust)	g	470	37	508	1 539	237	5	-60	2 228
Emissions (Water)									
Heavy Metals	mg Hg/20	2 113	1	2 114	1	274	1	-362	2 027
Eutrophication	g PO_4	70	0	70	0	1 319	3	-11	1 382

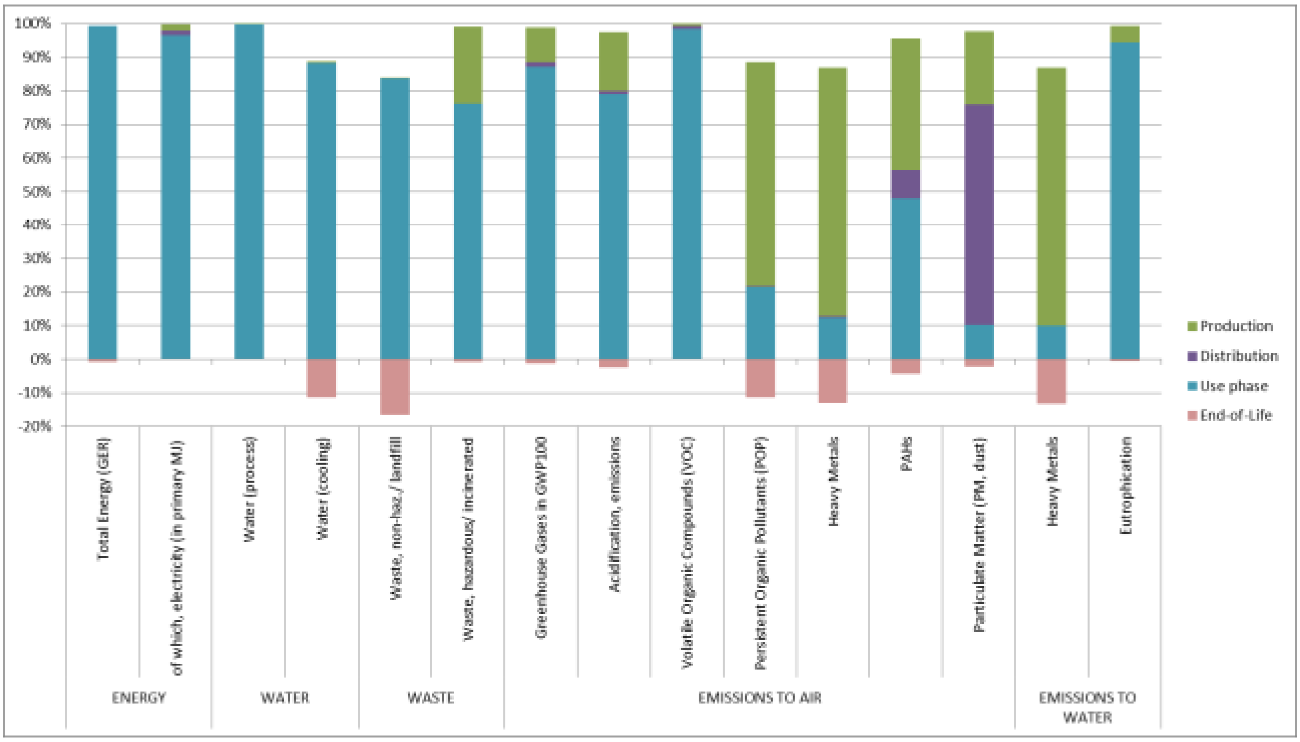


Figure 5.5: Relative magnitude of single life-cycle stages to the environmental impacts of the base case washer -dryers. Note: 100% is the sum of the absolute values of the contributions from the life-cycle stages

The results in Figure 5.5 above are similar to those of the base case washing machines, and show an even more dominant contribution of the use phase for:

- Consumption of total energy (91%), electricity (97%) and process water (99%).
- Production of hazardous / incinerated waste (88%).
- Global warming potential (87%), acidification potential (79%), emission of VOCs (98%), eutrophication potential (94%).

For persistent organic pollutants (POP), heavy metals to air (HM air), polycyclic aromatic hydrocarbons (PAHs), particular matter (PM, dust) and heavy metal to water (HM water) the use phase has a contribution ranging from 10% to close 50% from the total of each category. The process behind driving the high the contribution of the use phase is the consumption of electricity.

Once again, besides process water, which is essentially related to the consumption of water of the washing and drying cycles, and eutrophication potential, mainly due to the use of detergents, consumption of electricity is the main contributor to all the other indicators of these impact categories. (see Figure 5.5).

The production stage is the most important contribution for emissions of POP (67%), HM-air (74%) and HM-water (77%). Impacts in the production stage stem largely from materials, but are potentially avoidable if the materials are recycled. Impacts of production and use phase are more similar for production of non-hazardous waste (52% and 41%) and emission of PAH (39% and 48%).

The distribution phase is relevant only for the emissions of PM (66%) and PAHs (9%) and such impacts are due to the transport of the packaged products.

The EoL presents a significant negative impact in some categories. This is due to the credits (avoided impacts) that EcoReport tool assigns to the recycling of materials. For instance, the contribution of the EoL is especially beneficial in the cases of emissions of POPs (-11%) and the emissions of HM to air to water (both -13%).

The impact scores for washer dryers are in general higher than those for washing machines. The distribution phase for both appliances is exactly the same. The contributions from the production and end of life stages are slightly higher while the use phase scores in the case of washer dryers is 50% in average for all impact categories than for washing machines. This is a direct consequence of the higher electricity consumption of washer dryers to deliver the drying function in the use stage (see).

5.3 Life Cycle Costs of Base-Cases

Life Cycle Costs (LCC) per appliance for the whole life cycle of 12.5 years have been calculated through the EcoReport tool. The methodology and the assumptions (regarding product price, energy and water costs, repair and maintenance costs as well as costs for detergents) are described in section 5.1.3

The life cycle costs per appliance over a lifetime of 12.5 years are summarized for both base cases in Table 5.16. The costs are given both under the assumption of the recommended retail price (RRP) and the observed retailed price (ORP).

Table 5.16: Life cycle costs for the base cases under real life conditions over the whole product lifetime (in Euro)

Parameter	base case washing machines				base case washer dryers			
	Observed retail price		Recommended retail price		Observed retail price		Recommended retail price	
Product price	413 €	22.3%	578 €	28.6%	829 €	26.6%	1 156 €	33.6%
Electricity	368 €	19.9%	368 €	18.3%	1 104 €	35.5%	1 104 €	32.1%
Water	476 €	25.7%	476 €	23.6%	586 €	18.8%	586 €	17.0%
Detergent	551 €	29.7%	551 €	27.3%	551 €	17.7%	551 €	16.0%
Repair & maintenance costs	45 €	2.4%	45 €	2.2%	45 €	1.4%	45 €	1.3%
Total	**1 853 €**	**100%**	**2,018 €**	**100%**	**3 114 €**	**100%**	**3 441 €**	**100%**

5.3.1 Life cycle costs of base case washing machine

The contribution of the different cost elements for both the RRP and the ORP are shown in Table 5.16 for the base case washing machines. The total LCC reached 1 853 € considering for the ORP and 2 018 € for the RRP. The largest contributions to the overall costs are coming from the purchases of detergents, the expenditures in water and the purchase price of water. If the LCC is calculated with the RRP the product price contributes 28.6% to the overall LCC and is thus the biggest contributor. In case of calculation with the ORP, the product price only contributes 22.3% to the overall LCC. The share of the other costs elements is increased accordingly. In the latter case the costs of detergents have the largest share at the overall LCC, i.e. 29.7%. At this point, it is worth mentioning that as described in Section 5.1.3, the cost of detergents can vary largely depending on the detergent type, brand and dosing. The cost of detergents varies as much as -37% to +48% from the average value calculated.

The life-cycle costs of the consumables (including energy, water and detergent) over the lifetime exceed largely the average purchase price of the appliance. Product acquisition is on average ~20% of the LCC, while the operating costs make up for ~75%. Repairs & maintenance is on average a marginal cost.

5.3.2 Life cycle costs of base case washer dryers

The contribution of the different cost elements for both the RRP and the ORP are shown in Table 5.17 for the base case. The total LCC reached 3 114 € considering for the ORP and 3 441 € for the RRP. This is in particular due to the increased product price (approximately double than the base case for washing machines) and the higher energy consumption needed for washing and drying the laundry (+200%). The largest contributions to the overall costs are coming from the purchase price and the electricity costs, if the LCC is calculated with the RRP or on the contrary if it is calculated with the ORP. The increase of the water consumption costs is however not so significant.

5.4 EU impacts

The environmental impacts and the LCC data under real-life conditions are aggregated using stock and market data indicating

- The life-cycle environmental impacts of all new products designed in 2014 (reference year)
- The annual environmental impacts of the stock of washing machines and of the stock of washer-dries in 2014 (including production, use phase and end-of-life)
  The annual monetary costs for consumers (also for 2014) (including acquisition, use and maintenance and repair)

5.4.1 Environmental impacts in the EU-28

Table 5.17 and Table 5.18 show a comparison of the environmental impacts of washing machines and washer-dryers. The third column shows the environmental impacts of the stock of washing machines or washer-driers during for 1 year of use, the fourth column shows the environmental impacts caused for the whole lifetime of the new appliances put on the market in 2014 and the last column shows the environmental impacts of the new appliances per year of lifetime.

These data provide a rough indication of how much progress has been already made for these product groups. In particular, it is interesting to observe that impacts due to new sales of washer-dryers are higher than those calculated for the installed stock. The main reasons for that is its increasing sale trend.

Table 5.17: EU-28 total environmental impacts from the installed stock and the annual sales of household washing machines (BC WM)

Indicator	Units	EU28 environmental impacts		
		Stock, 1 year of use	Annual sales, whole life cycle	Annual sales, normalised to 1 year of use
Resources & Waste				
Total Energy (GER)	PJ	552	506	40.5
of which, electricity (in primary PJ)	PJ	333	305	24.4
Water (process)	mln. m^3	3 040	2 785	222.8
Water (cooling)	mln. m^3	58	52	4.2
Waste, non-haz./ landfill	kt	958	826	68.0
Waste, hazardous/ incinerated	kt	9	9	0.7
Emissions (Air)				
Greenhouse Gases in GWP100	Mt CO_2 eq.	27	25	2.0
Acidification, emissions	kt SO_2 eq.	136	122	9.8
Volatile Organic Compounds (VOC)	kt	7	6	0.5
Persistent Organic Pollutants (POP)	g i-Teq	9	8	0.6
Heavy Metals	ton Ni eq.	53	43	3.5
PAHs	ton Ni eq.	3	3	0.2
Particulate Matter (PM, dust)	kt	36	34	2.8

Indicator	Units	EU28 environmental impacts		
		Stock, 1 year of use	Annual sales, whole life cycle	Annual sales, normalised to 1 year of use
Emissions (Water)				
Heavy Metals	ton Hg/20	35	29	2.3
Eutrophication	kt PO_4	25	23	1.8

Table 5.18: EU-28 total environmental impacts from the installed stock and the annual sales of household washer dryers (BC WD)

Indicator	Units	EU28 environmental impacts		
		Stock, 1 year of use	Annual sales, whole life cycle	Annual sales, normalized to 1 year of use
Resources & Waste				
Total Energy (GER)	PJ	53	63	5.02
of which, electricity (in primary PJ)	PJ	42	50	4.04
Water (process)	mln. m^3	171	206	16.48
Water (cooling)	mln. m^3	5	5	0.38
Waste, non-haz./ landfill	Kt	70	71	5.53
Waste, hazardous/ incinerated	Kt	1	1	0.08
Emissions (Air)				
Greenhouse Gases in GWP100	Mt CO_2 eq.	2	3	0.23
Acidification, emissions	kt SO_2 eq.	12	14	1.09
Volatile Organic Compounds (VOC)	kt	1	1	0.09
Persistent Organic Pollutants (POP)	g i-Teq	1	1	0.05
Heavy Metals	ton Ni eq.	4	3	0.25
PAHs	ton Ni eq.	0	0	0.02
Particulate Matter (PM, dust)	kt	2	2	0.18
Emissions (Water)				
Heavy Metals	ton Hg/20	2	2	0.16
Eutrophication	kt PO_4	1	1	0.11

5.4.2 Economic impacts in the EU-28

Table 5.19 shows an estimation of the total annual expenditure in the EU-28 linked to the use and operation of new washing machines and new washer-dryers. It assumes that the BC WM and the BC WD represent the average appliance produced in 2014 (reference year). The values shown provide an idea of the order of magnitude of the yearly expenditure associated to the function of household washing machines and washer-dryers in the EU28.

Table 5.19: EU-28 total annual expenditure for household washing machines (ref. 2014) in millions of Euro (calculated considering the observed retail prices)

	EU total annual expenditure (millions of euro)			
	Annual sales of WM, whole life cycle (12.5yr)	Annual sales of WM, normalised to 1 year of use	Annual sales of WD, whole life cycle (12.5yr)	Annual sales of WD, normalised to 1 year of use
Product price	6 854	548	829	66.3
Electricity	5 935	475	777	62.2

	EU total annual expenditure (millions of euro)			
	Annual sales of WM, whole life cycle (12.5yr)	Annual sales of WM, normalised to 1 year of use	Annual sales of WD, whole life cycle (12.5yr)	Annual sales of WD, normalised to 1 year of use
Water	7 671	614	412	33.0
Detergents	8 873	710	388	31.0
Repair & maintenance costs	725	58	32	2.5
Total	**30 058**	**2 404**	**2 438**	**191.0**

As the table shows, the purchase and operation of new washing machines over the entire life cycle is about 30 billion euro, equivalent to almost 2.4 billion euro per year. The purchase and installation costs in the EU28 add up to about 7.5 billion euro, whereas the running costs amount to about 22 billion euro.

Because of the much lower penetration in the EU market, the total expenditure for washer-dryers is much lower: about 2.4 billion euro (8% of that for washing machine).

6 Task 6: Design options

6.1 Options

6.1.1 Overview of the selection of single design options

In Task 4, several possible design options for household washing machines and washer-dryers have been described in detail. Table 6.1 and Table 6.2 summarize the initial design options for washing machines and the washing programme of washer-dryers and the drying function of washer-dryers and provide a rationale for each selected option to be further analysed in Task 6 and Task 7.

Table 6.1: Overview of design options for household washing machines and the washing process of washer-dryers (the options selected for further analyses are highlighted in bold)

Design options	Description	Rationale for the selection of design options for further analyses
Option 1: Machine / drum construction	The drum geometry and/or the rated capacity can influence the specific energy and/or water consumption or performance of household washing machines. Possible examples are: 1a) Increasing the drum volume without increasing the rated capacity (i.e. increasing the volume-to-load ratio). This could be done by manufacturers to obtain better mechanical action and reduce programme times, energy and water use. This is not a common practice and therefore, it is assumed that the savings are lower than those obtained by fully loading the appliance's capacity. **1b) Increasing the rated capacity from 7 kg (base case) to 9 kg** 1c) Multi-drum washing machines (two side-by-side or above washing drums for parallel washing processes; water might be reused between the drums)	1a: Not selected; there is a general market trend of increasing the rated capacities 1b: Discussed separately. There is a trend towards higher capacities; however, under real-life conditions these capacities are not fully exploited, which leads to higher consumption per kg wash load in absence of user-behaviour changes. 1c: Not selected. These machines are popular in other markets (e.g. China) where e.g. children and adult clothes are washed separately. The concept has been presented in the EU market, but the separation is done between normal and delicate clothes. An improvement in efficiency is not expected due to this design option unless the small drum also can handle normal washes. In this case, a fully loaded small drum may be more efficient.
Option 2: Increased motor efficiency	Compared to the older universal commutator motors with brushes, more energy efficient motors have become common in household washing machines. Advantages are also claimed in terms of better steering options, lower noise, partly less volume and weight, and longer lifetime due to absence of brushes. Examples are : 2a) Brushless, inverter driven asynchronous DC motors **2b) Brushless, permanent magnet synchronous DC motors (PMSM)**	2a: Not chosen as assumed that most appliances on the market already have a brushless DC motor (BLDC). For the BC, the average of the two motors above has been considered. 2b: chosen; higher motor efficiency would have a positive effect on all programmes
Option 3: Temperature - time trade off	Using lower temperatures that those declared combined with increasing cycle times. This ensures the same washing performance with lower energy consumption for heating. Examples are: **3a) Extension of programme duration and lowering of washing temperature - moderate scenario (e.g. 4-5 hours)** 3b) Extension of programme duration and lowering of washing temperature - extreme scenario (e.g. up to 6.5 hours)	3a: chosen; 3b: Not chosen; currently the maximum duration of the standard programme is 4.8h (with a temperature decrease to 25C for the cotton 40C and to 35C for the cotton 60C programme). A further extension of the programme duration (e.g. up to 6.5 hours with a temperature decreased to 20 °C) is not an surveys conclude that increases beyond 3h of the progamme leads to lower acceptance by consumers.
Option 4: Alternative heating systems	Alternative heating systems to reduce the electricity demand of the washing machine for heating up the water by using (totally or partially) external heating sources. Examples are **4a) Heat pump technology for the washing function:**	4.1.a) chosen; HP adds are already available although they have additional drawbacks in terms of speed of heating, duplication of heating systems and EoL management. 4.1.b) considered as BNAT.

Design options	Description	Rationale for the selection of design options for further analyses
	4.1a) either with common refrigerant R134a or 4.1.b) with alternative refrigerant with lower GPW (e.g. propane, isobutene) **4b) Heat-fed machines:** The electric heating elements of the appliance are replaced by a hot water circulation loop that, using a heat exchanger, transfers the heat from a hot water circulation to the machine. The hot water is generated e.g. by central or district heating and does not need to be drinking water. The appliance itself is connected to the cold water tap. **4c) Hot-cold fills (connection of the appliance to hot and cold water supplies):** the machine has 2 water inlets, one for hot-water heated by an external heating system, e.g., solar heating or a gas boiler and one for cold-water. The water is not heated by the machine, and it is just blended with cold water to reach the right temperature.	The potential use of alternative refrigerants with lower GWP (i.e. HCs) could have important limitations if the refrigerant content is above 150g, due to the stricter safety conditions to be met. 4b: Discussed separately; electricity needed only for motor, electronics and heating above 55-60 °C. Energy demand depends on the external installation. 4c: Discussed separately; electricity needed only for motor, electronics and heating above 55-60 °C. The efficiency of the system depends largely of the nature and efficiency of the heating system that supplies the hot water, and the length and insulation of the hot water pipes.
Option 5: Improved drenching systems / improved detergent dissolution	Different systems are available on the market for improving the laundry drenching using less water, as well as for a better process of detergent dissolution, distribution and penetration in the fabrics. These effects can be achieved by recirculating fractions of water and by mixing air, water and detergent, and it is claimed to result in improved washing performance, less detergent loss and, sometimes, lower water and energy use. Examples of those systems on the market or in development are improved Water Circulation, Ecobubble™ technology, Spray-technology, or PowerWash 2.0 technology.	Chosen: Manufacturers offer different variations of such systems.
Option 6: Higher water extraction by spinning	The more water is removed mechanically (i.e. spinning at the end of the programme) the less thermal energy is required for subsequent drying and/or ironing. The additional energy demand through higher spin speed is much lower compared to the thermal energy needed for drying in tumble dryers and indoor clothes line. **Compared to 1400 rpm of the Base case, the maximum spin speed can be reasonably set at 1600 rpm**	Chosen; Estimation of a credit to drying process with low spinning. Fewer wrinkles are formed if clothes are hung up when not all the water has been removed.
Option 7: Sensors and automatic controls	Certain electronic controls can steer the use of energy, water and detergent dosing. Examples are: **7a) Improved load detection and partial load adaptation** **7b) Automatic detergent dosage systems**	7a: chosen; there are different systems. Systems based on water level (pressure) gauges in the tub and mostly installed and can be 8-10% more efficient than other system when adapting to the real load and textile type. Water-level systems work once the machine is loaded and the programme starts, and therefore the information can be used by the consumer in the next loadings. Other systems such as weight sensors are more seldom installed, but they allow feedback to consumer while loading and before starting the

Design options	Description	Rationale for the selection of design options for further analyses
		programme, helping to change user washing habits right away. 7b: chosen; There is a trend toward the installation of automatic systems. This system avoids under or over-dosing of detergents leading to an optimisation of the washing process and resource savings
Option 8: Consumer feedback mechanisms	Feedback to consumer (via display, led lights, etc.) on certain aspects of the functioning of the machine might lead to optimized consumer behaviour in terms of e.g. loading and dosage. Examples are: **8a) Displaying the actual loading (e.g. by weight sensors on the drum)** 8b) Displaying a detergent dosage recommendation 8c) Displaying the energy and water consumption of the chosen programme 8d) Displaying maintenance requirements (e.g. 90 °C machine hygiene programme, filter clogging)	8a: chosen, stimulating more efficient loading of machine 8b: Not chosen; since this is very much dependant on the type of detergent 8c: Not chosen; frequency of use of low-energy consumption programmes may increase but depends strongly on user behaviour rather than on technical aspects; no data to quantify the effect 8d: Not chosen; difficult to quantify the effect. For qualitative aspects this information is to be well available on the user manual
Option 9: Smart appliances	Interconnectivity between appliance, user and technical systems can improve the flexibility of use of the product. Examples are 9a) Internet connectivity (Smart appliances) 9b) Electronic update of the programmes / diagnostics in case of failures **9c) 'Smart-grid ready' products, with the ability to operate on a demand-response basis**	9a / 9b: Not chosen as they don't provide direct improvement potential on energy efficiency. 9c: Not chosen, but some of the potential impacts are discussed separately
Option 10: Material selection	The choice of materials might not have direct impacts on the energy or water consumption of washing machines but might improve the overall resource efficiency or durability of the appliances. Examples are: 10a) Use of recycled materials (plastic) **10b) Increased durability of appliance / components**	10a: Not chosen: currently no possibility to systematically use recycled materials. 10b: Discussed separately
Option 11: Alternative washing systems	Examples are 11a) Ultrasonic cleaning technologies (an ultrasonic device brings high pressure bubbles into the water (cavitation); the system is assumed to save energy) 11b) Polymer bead technology (the nylon beads added to the water are supposed to better absorb the dirt - savings of water are claimed and lower residual moisture content of the laundry which shall lead to lower energy demand of the subsequent drying processes 11c) Steam care / steam finishing: the laundry is not only treated with water but also with steam (to reduce micro-organisms at low washing temperatures, reduce odours and wrinkles); usually separate programmes to be selected in addition to the 'normal' wash programmes	11a / 11b / 11c: Not chosen: No data available to quantify the effect

For household washer-dryers, it is assumed that for the washing process only, the design options listed above for washing machines are applicable. For the drying and continuous wash&dry cycles, the following specific design options are proposed, and selected for further follow-up.

Table 6.2: Overview of design options for the drying process of household washer-dryers (the options selected for further analyses are highlighted)

Improvement options	Description	Rationale for the selection of design options (for further follow up)
Option 1: Alternative condensing systems	Compared to common water condensing systems, the technology used for the base-case, alternative condensing systems are in place to reduce the electricity and/or the water demand of the washer dryer: **1a) Air condensing systems (reduces water consumption)** **1b) Heat pump technology (reduces water and energy consumption)**	1a / 1b chosen
Option 2: **Improved design of combined wash&dry programmes**	Increasing temperature reduces the viscosity of water, thus when warm textiles are spun, the remaining moisture will be lower than if they were cold. In a continuous wash&dry process, thermal spinning can be applied after a temperature increase at the beginning of the drying phase, to extract additional water. Removing water by mechanical action (spinning) is less energy intensive than by evaporation.	Chosen;
Option 3: Heat pumps for washing and for drying	Heat pumps can potentially offer energy saving for both washing and drying processes. This may take place with two distinct heat pumps (in a limited space), another for water-refrigerant and other for air-refrigerant, or a single pump that is able to deliver heat to two condensing elements, one for water (washing), and one for air (drying).	Not chosen: not on the market, technically too complex and very costly
Option 4: Energy storage systems	Normally, the heat of the washing water is drained away with the drainage water. To save energy, it could be possible to use as much energy from the washing phase as possible for the subsequent drying phase. This can be done for example through internal heat exchangers and/or storage systems based on phase change latent heat,	Not chosen: not on the market, lack of data
Option 5: Alternative heating systems	Electricity for the drying process could be substituted with alternative sources of heat such as central/district heating.	Not chosen: not on the market, lack of data, performance strongly depending on system conditions.

6.1.2 Washing Machines

6.1.2.1 Assumptions regarding the selected design options

Based on a questionnaire distributed during the summer 2015 and further follow-up consultations, manufacturers were asked to provide specific technical and cost data of the above listed design options and combinations thereof. To assess the design options, stakeholders were also asked to estimate the current and likely future market penetration of certain improvement options as well as to give an indication of which of the single options are compatible with other options. No information on the market penetration has been provided.

Comparisons are made to the base cases (base case washing machines and base case washer-dryers) which are defined in section sections 5.1.1 and 5.1.1, respectively. Stakeholders were asked to provide information about changes induced by the design options compared to the base cases with regard to:

- Performance parameters (e.g. consumption of energy, water and detergents, noise, cycle time)
- Variation of material resources (compared to the BoM of the Base cases)
- Variation of the product lifetime
- Variation of the manufacturing costs and maintenance and repair costs

Based on this input and additional expert knowledge, the project team has assumed the input for further calculations as described in the following sections.

6.1.2.2 Environmental saving potentials

In the case of the single design options, average values for the saving potential of the different options have been taken into account. This results from the fact that there is a variety of technical realizations of some options (e.g. heat exchangers).

These average saving potentials have been derived as follows:

- Where applicable and taking into account stakeholder feedback, the absolute and relative saving potential (in terms of energy and water) were determined for the standard programmes of the base cases.
- The relative saving was applied to other programmes, sometimes with exceptions: e.g. that the moderate increase of programme duration only affects the standard programme
- For estimating the savings through consumer feedback mechanisms related to the selection of programmes, no savings in the standard programme or other programmes are established. Savings result from a shift in programme usage under real life conditions, e.g.: it is assumed 10% more use of the standard programme and 5% less use of each normal cotton 40C and normal cotton 60C.
- For estimating the savings through consumer feedback mechanisms related to the loading of the machines, three cases are considered: the user increases the loading to full (6 kg), loading to half of empty (4.7 kg) and to one quarter of the empty capacity (4 kg). For more details cf. 4.4.2.8.
- The changes in material composition are an estimation based on the additional components.

All percentages values are given in rounded values – the calculations are made with the exact figures

6.1.2.3 Additional costs

The assumptions regarding the price increase due to the implementation of certain design options are characterized by a level of uncertainty stemming from the following reasons:

- Usually for each design option there are several versions/models on the market (with slightly differing properties regarding reachable energy saving, durability or convenience for the consumer) which results in different manufacturing costs for this option
- A certain increase in manufacturing cost does not necessarily result in a fix increase of the retail price. As already outlined in section 5.1.3 there is no fix correlation between the recommended retail prices (RRP) and the observed retail prices (ORP). The difference between both prices depends, to a large extend on the retailer, the trade channels, the brand and also the time (e.g. seasonal sales).
- The price assumption can be derived differently either based on the manufacturing costs (bottom-up calculation) or according to the price differences which are achievable / apparent on the market.

The last two bullet points usually go hand in hand and result in higher prices for the consumers for design options at the beginning of their market introduction and lower prices after a certain time

Usually only few models are equipped with an option that is only recently introduced in the market. This can result in higher manufacturing costs, e.g. because certain manufacturing steps are done manually or with a lower degree of automation. At that moment, often only a limited number of manufacturers offer the design option that is incorporated in high-end machines (the new design option is a unique selling proposition). Additionally the new design option is often combined with other high-end features and manufacturers can follow a product differentiation strategy. Altogether this allows manufacturers to request higher purchase prices which often results in higher margins for those newly developed products. This means that at the beginning of market introduction the price is high and will depend on the price achievable on the market.

After a certain time, when the design option becomes more popular and is implemented in a larger number of models, the manufacturing costs and consequently the purchase prices tend to decrease. This is mainly due to two effects: the escalation factor and the learning curve. The first one involves the cost savings due to the production of a large number of items and the decrease in the proportional fix costs. The learning curve includes the effect of improving the production process due to the gained experience. Additionally, the new design option is no longer a unique selling proposition as other manufacturers offer products with that option as well and manufacturers tend to apply a differentiation cost strategy. Therefore the purchase price achievable on the market decreases. The price is now similar to the bottom-up calculated price (starting from the manufacturing costs).

Most design options at hand already reached a certain maturity level and it can be assumed that the additional purchase price is close to the bottom-up calculation starting from the manufacturing cost. For example, the base case washing machine has an annual energy consumption of 184.8 kWh which places it into energy efficiency class A++. To reach this class at least some design options have to be incorporated into the washing machine. This means that those design options widely integrated are mature enough to be massively manufactured and included in (almost) any average washing machine. The additional costs attributed to the design options can therefore be assumed to be competitive and approximately equal to the increase in costs calculated by means of a bottom up method that starts from the manufacturing costs.

Further cost estimations only take into account the increase of costs related to the design options due to the manufacturing cost. Other features that can raise the purchase price and which usually go together with premium models (e.g. better aesthetics, market positioning, display features, connectivity, etc.) are not taken into account. Therefore the calculated purchase price could be lower than the real market price of machines equipped with certain improvement options, as manufactures tend to equip top models with all available novelties, not necessary providing any efficiency improvement. This is especially true for the heat pump as design option as this option has been implemented only recently (in 2014) and by one manufacturer only.

The changes in material composition and the additional material costs are estimated based on the additional needed components. The assumptions on the cost increase of the design options combine both any additional material costs and any additional costs for the manufacturing process itself. Starting from the estimated manufacturing costs and following the bottom-up approach, the increase of the purchase price is calculated with the same assumptions as outlined in section 6.1.1.

Regarding the costs for repair and maintenance, it is assumed that small incremental changes in product energy efficiency produce no changes in repair and maintenance costs compared to that of the base case. However, washing machines and washer dryers having significantly higher energy efficiencies (such as those equipped with heat pumps) are more likely to incur higher repair and maintenance costs, because their increased complexity and higher part count typically increases the cumulative probability of failure. Following the same reasoning as in case of the base case (see section 6.1.2.7) where 30% of washing machines or washer dryers to be repaired once per lifetime, it is assumed that the reparation of heat pump equipped appliances will cost 200 Euros instead of 155 Euros, leading to an additional cost of 17 Euros for every appliance equipped with a heat pump (resulting in 74 euros for repair and maintenance instead of 55 Euros).

6.1.2.4 Hot-cold fills and heat-fed machines

These options would allow feeding washing machines with hot water heated up outside the machine. The inlet of hot water will decrease the demand of electricity from the machine itself at least for the most common range of temperature between 20 and 40 °C. Even if hot water systems often conduct water at 60 °C, the hot water inlet shall not be at > 40 °C if it is the only water inlet, as some textiles cannot be washed above 30°C or 40°C or they will deteriorate. Therefore, the electrical resistances of the washing machine are still necessary to increase temperatures above 40 °C if a machine programme of e.g. 60°C is selected. If two inlets are available on the machine, there is no limitation to the temperature of the hot water inlet.

These design options have a limited impact on the bill of materials and could increase the manufacturing cost by 20 € (due to the additional components needed such as a second water inlet, valves, hoses, wiring, control). However, much more relevant is the additional cost increase due to the additional components needed considering whole system:

- An extra heat-exchanger (60 / 100 €) and an external connection to a heat-water system (200 €) are needed for heat-fed machines.
- New infrastructures or considerable retrofitting of existing infrastructures may be needed in case the piping from the heater is improved, or thermal solar is used to supply hot-water, although these would be shared among the different water-using appliances of a household (where water is mainly consumed in taps and showers).

Under mostly used conditions (45 L/cycle; average maximum temperature: 55 °C), the maximum saving potential associated to this option could be 0.256 kWh/cycle (50% of the energy consumption per cycle multiplied by the share at which temperature has been estimated being below 40 °C).

As a rough estimation of the maximum potential savings for each programme are considered to be proportional to the water consumption per cycle and the temperature difference between the water inlet temperature (15 °C) and the maximum temperature (up to 40 °C). These estimations are maximum values since they have been calculated under ideal conditions: no heat losses in the pipelines, ideally isolated appliances, etc. Table 6.3 summarizes the estimations for each programme. On average, the maximum and theoretical energy saving potential would be 37%.

Table 6.3: Estimation of the energy consumption and energy saving potential of the hot-fill and heat-fed machines

Programme	Energy consumption	Energy saving potential
Standard 40 °C cotton	0.29 kWh/cycle	-38%
Standard 60 °C cotton	0.28 kWh/cycle	-29%
Normal 40 °C cotton	0.36 kWh/cycle	-39%
Normal 60 °C cotton	0.34 kWh/cycle	-29%
Superquick (20-30 min):	0.13 kWh/cycle	-64%
Normalquick (45-70 min):	0.28 kWh/cycle	-55%
Synthetic/easy care	0.28 kWh/cycle	-45%
Cotton 30 °C:	0.18 kWh/cycle	-50%
Mix	0.39 kWh/cycle	-53%
Cotton 90 °C	0.38 kWh/cycle	-17%
Cotton 20 °C	0.09 kWh/cycle	-29%

In light of the results of this study, it is questionable to encourage consumers to use hot fill in general. The saving potential of the hot fill can be very large, but also vary to a great extent. The costs of retrofitting can be very relevant (due to the extra components needed such as e.g. an extra heat-exchanger (60 / 100 €) and an external connection to a heat-water). If hot fill is to be proposed, it would have to accommodate all the installation variables described, ensuring both net energy and financial benefits.

6.1.2.5 Increase of the rated capacity from 7kg to 9kg

An increase in the rated capacity of the appliances from 7 kg to 9 kg would in theory allow the consumers to wash more laundry at a time with higher energy efficiency per kg of laundry. If a 7 kg rated capacity washing machine is considered to be fully loaded in real life with 6 kg (it is assumed that consumers would not load the 7 kg as is done in test conditions), a 9 kg rated capacity machine would be fully loaded in real life with 7.8 kg.

The water and energy consumption per cycle are thus assumed to be 71.2 l/cycle and 1 kWh/cycle. Consumption values per kg of laundry washed would be 9.18 l/kg (-5% than in case of full load for the BC) and 0.128 kWh/kg (-3% than in case of full load for the BC).

These considerations are theoretical, as full load of machines does not match with observed average loading of 3.3 kg. For the base cases, the average load would still be 3.3 kg. This would result in water and energy consumption of 46.6 l/cycle (or 14.1 L/kg, +7% than the BC) and 0.757 kWh/cycle (or 0.229 kWh/kg, +17% than the BC).

An increased rated capacity from 7 to 9 kg would have an impact also in terms of materials, because of the need of having bigger and stiffer drum, larger bearings, stronger motor, improved balancing system, and improved sensors for unbalance. This could increase manufacturing costs by 20 € and BOM by 20%.

The attractiveness of this scenario depends on the loading conditions of the machine, which must be higher than today's average.

6.1.2.6 Smart-grid ready products

As the energy system of the future is getting more and more variable due to fluctuating energy production by mainly renewable energy stations, it is necessary and helpful to have some flexibility on the demand side as well. This can be realised by appliances which offer a demand-response possibility/function. However, the demand-response function of the appliances cannot work alone, and it is needed that the distribution system operator, or an aggregator of the smart grid, offers the consumer sufficient incentives to allow the use of the demand-response enabled power capacity. Additionally, a sufficient large number of appliances need to be in the market before such a system can take off.

Due to this flexibility, this option would allow using the machine when electricity tariffs are cheaper or there is a peak of energy produced from renewable sources. In the latter case it is expected that the overall environmental impact of the consumed energy will be lower than if electricity from fossil fuels were consumed/. However, benefits are variable and difficult to quantify as they depend on the electricity grid mix of the region where the appliance is installed and on specific production and supply conditions.

Smart-grid ready products can lead to an increase of the electricity consumption for control and networked standby (0.05 kWh/cycle). Additional controls to establish connectivity are also estimated to increase manufacturing costs by 20 €. Thus, economic investment would be not recovered without political or financial instruments

6.1.2.7 Durability

6.1.2.7.1 Cycle time and life time of the washing machines

It is assumed that longer programme cycle times do not lead to significantly short life time of a washing machine. Longer operating hours of motors and other components will in real life lead to some wear and tear in case of brushless motors, which are currently the most used technology. However, in the extended time the motor, bearing and suspensions do not operate under stressing conditions, contrarily to e.g. spinning.. Also, the reached temperatures are lower, diminishing the demand to the heating systems, and the thermal wear out of components (hoses, rubber rims, etc.).

6.1.2.7.2 Lifetime and environmental impacts

The results of the base case show that the manufacturing stage contributes 14% to the overall lifecycle consumption of energy. Impacts of the manufacturing stage are embedded in materials. Thus, if a shorter product lifetime were considered, the lifecycle impacts per year due to the manufacturing stage would increase and on the contrary, if a longer product lifetime were considered, the lifecycle impact per year would decrease.

6.1.2.7.3 More durable materials/products

Durability is not included as a design option in this section, as the necessary calculations would be too complex to handle with the current version of the Ecoreport tool. A durability assessment would imply not only taking into account alterations at current washing machines but also forecasting future efficiency gains. Environmental impact benefits due to a life time extension strongly depend on the energy consumption of future washing machines. Therefore, durability is discussed in this section based on existing literature.

A LCA study carried out for Miele (Gensch and Bepp, 2015)) has pointed out that the environmental optimum lifetime is highly dependent on the environmental indicator analysed, the specific characteristics of the product analysed and on the technical development which can be expected in the future. This may result in situations with a relatively short payback period on the basis of which an early replacement may become recommendable. Considering metal resources, the payback periods can reach from 50 to 200 years which is far above a technical lifetime (20 years for this brand). The optimum lifetime for the GWP indicator is however lower. Assuming an efficiency improvement from one generation of appliances to the next one of approx. 10-20%, the assessment shows an optimal lifetime of 15 years.. In a wide context, energy efficiency improvements foreseeable for the future seem to be more limited than up to now. Conversely, product strategies aiming at increasing the durability of products would increase if impacts of production and transportation of electricity decreases, for instance as a consequence of growing shares of renewables. Indeed, this would decrease the impacts of the use phase and increase the impacts embedded in materials and components.

The study Summary of JRC study on 'Analysis of durability, reusability and reparability - Application to washing machines and dishwashers' (Tecchio et al. 2016) analysed, using LCA, some durability, reusability and reparability aspects for WM. Materials and manufacture of WM were found to have important effects on the abiotic depletion of minerals and other impact categories (such as: eco-toxicity, human toxicity, particulate matter formation, acidification, eutrophication). In particular, impacts in terms of abiotic depletion seem mainly associated to the use of copper, stainless steel and electronic components.

6.1.2.7.4 Durability

The durability analysis focused on three impact categories: climate change (measured as GWP), abiotic depletion of elements and freshwater eutrophication.

Prolonging the lifetime of the WM base case beyond 12.5 years resulted environmentally beneficial for the Climate change impact category in the large majority of the analysed scenarios. Replacement of a working WM after 12.5 years of the base case with a new product resulted environmentally convenient when the new product consumes less than 90% of energy than the base case (72% if impact variations for manufacturing are not considered).

For the ADP elements indicator, prolonging the WM base case lifetime resulted always beneficial. The environmental impact can be reduced by about 46% when the operating life is extended by 6 years and about 7% for an extension of 1 year. Percentages would increase if variation of manufacturing impacts were considered.

The environmental improvement due to an extension of the product lifetime is instead marginal for eutrophication, which mainly depends on the use of detergents.

Extending the operational lifetime of the product generally results in an environmental benefit, which however depends on the selected impact category and on the values of specific parameters (e.g. energy consumption of new and old appliance).

6.1.2.7.5 Reparability

The reparability analysis showed that there are some advanced examples of refurbishing companies which are able to give a second life to products otherwise sent to recycling process. Moreover, such companies put in force procedures to ensure high quality in refurbished products, in terms of costs, efficiency and safety.

Some barriers for the refurbishing of products have been identified, together with some potential strategies to overcome them. These include the

1) design for disassembly of certain crucial components;

2) the availability of spare parts;

3) the provision of information by manufacturers (as product’s exploded diagram with a clear list of referenced parts; disassembly information, wiring diagrams and connection diagrams; test programme and error codes); and

4) the possibility to update the software.

However, it was observed in some cases that not all the refurbished products were absorbed by the market. A first reason for this situation is the request for high quality product, in good status and reliable. However, a second reason is also a general lack of information at the consumer level about the reliability of refurbishing companies, in terms of trustfulness of their processes. Additional warranties provided by the refurbishing companies for their products could help to overcome the scepticism of some consumers. In order to promote the market of reused products among different types of clients, refurbishing companies together with associations of consumers, local authorities and NGOs should promote adequate informative campaign to let people know how refurbishing is occurring and the effective quality of reused products. The adoption of specific labelling schemes could also support the development of this market.

The potential environmental benefits due to the refurbishment of WM were also assessed. The analysis showed that there are significant benefits for all the considered impacts when the product is reused after a relatively short first life. When the product is supposed to have a full first life, the benefits of reuse are dependent on factors as the length of the second life, the potential drop of efficiency of the product and the efficiency of the replacing product. However, benefits were accounted also in this condition. Compared to DW, the reuse of WM generally implies higher environmental benefits for all the considered impact categories. This can be related to the lower energy consumption during the use phase.

The reparability analysis pointed out that a significant percentage of defects in the product are due to inappropriate use:

- unlevelled positioning without using a water level bubble leads to early wear out of shock absorbers and bearings;
- wrong loading detection and correction of textile distribution leads to imbalance and wears out the shock absorbers and ruins the bearings;
- over dosage of detergent may block the detergent hose;
- presence of foreign objects in the drain pump filter for long time may block the pumps;
- not running hot water washing cycles increases blocks in the water outlet;
- keeping closed the door between washing cycles leads to degradation of the door seal;
- lack of proper maintenance (e.g. cleaning of the filters and decalcification).

Moreover, main reasons for not repair were listed as:

- lack of spare parts;
- economic unfeasibility (for either technician or customer).

The study ''Socioeconomic impacts of increased reparability' (Deloitte. 2016) analyses the impacts associated to increasing the reparability of washing machines. The study identified the specific reparability requirements, their expected impacts and whether those impacts are positive, negative or neutral as well as the areas on which the collection of data is needed to carry out a more robust impact assessment of different options to increase reparability.

The study analyses measures to ensure availability of spare parts for at least a certain amount of years, the provision of information on the possibilities to repair the product, provision of technical information to facilitate repair to repair professionals, provision of technical information to consumers to facilitate simple self-repairs and to enable an easier dismantling of products. Some combinations of these measures were also considered.

As regards the expected impacts for washing machines, the study concluded that there will be negative economic impacts among manufacturers and positive among repairers and social enterprises. The further is expected to be limited due to the share of manufacturers located outside the EU and their possible extension to the retail services. Likely, the job market will experience some reductions on the manufacturing and supply jobs and the creation of a significant amount of jobs in the repair sector corresponds to the development of quality jobs, largely in SMEs and smaller companies.

The conclusion of the study reports that 'in terms of individual scenarios, the scenarios dealing with measures to ensure availability of spare parts for at least a certain amount of years and measures to enable an easier dismantling of products seem to provide the highest benefits, in terms of resource savings, but also impose the most significant reductions on the increase of turnover in the sectors that are impacted negatively.. Both scenarios as well as their combination require efforts from manufacturers to be implemented being the environmental and social benefits rather uncertain. Only do the scenarios that call for the provision of information seem to be easier to implement even if there are concerns on intellectual property rights or health and liability issues.' There is no a conclusion on which scenario is the most beneficial as there is a lack of data or limited geographical representativeness in certain aspects and an uncertainty on the impact coefficients due to the lack of evidence on the actual effect of reparability requirements.

6.1.2.7.6 Preliminary conclusions

Products on the market have a broad set of design strategies and characteristics, including expected durability. At this stage and with the available data, there is no general rule to handle durability aspects. The benefits of more durable products would depend, among others on:

1. Material needs, costs and frequency of failures for different product designs
2. Real time of use of products and willingness of users to purchase (usually) more expensive and durable appliances
3. Efficiency of new products on the market compared to the existing ones.

Durability is intuitively a desirable property of a product. However, the analysis of durability aspects would require the assessment of technical and the use of scenarios associated to specific products.

6.1.2.7.7 Assumptions regarding the combinations of design options for washing machines

The selection of combinations is based on the simple payback periods of the single design options, stakeholder feedback on their combinability and a market research on existing appliances. Additionally, all the combinations could include the design options discussed separately. This means an increasing rated capacity, more durable materials and hot-cold fills and heat-fed machines. These options have some limitations associated to the system conditions (hot-cold fills) or the possibility by the user to exploit such potential (increased rated capacity).

The following combinations were selected:

- WM-C1: WM-D1+WM-D6 (PM motor + improved load detection and adaptation)
- WM-C2: WM-D6+WM-D4 (improved load detection and adaptation and improved drenching)
- WM-C3: WM-D1+WM-D6+WM-D4 (PM motor, improved load detection and adaptation and improved drenching)
- WM-C4: WM-D6+WM-D2 (improved load detection and adaptation and extension of standard programme duration)
- WM-C5(a): WM-D6+WM-D8 (improved load detection and adaptation and consumer feedback on loading) (*assumption the load does not change*)
- WM-C5(b): WM-D6+WM-D8 (improved load detection and adaptation and consumer feedback on loading) (*assumption the load changes increasing 41%*)
- WM-C6(a): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C6(b): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load changes increasing 41%*)
- WM-C7: WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8+WM-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage, consumer feedback on loading and heat pump).

Additionally some of the options discussed separately were also calculated as possible combinations:

- WM-C8: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8 + hot-cold filling (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C9(a): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 + increased rated capacity (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C9(b): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 + increased rated capacity (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load changes increasing 41%)*

In this section the assumptions regarding the environmental savings potential and the additional costs are outlined.

The combination of the design options is considered as a second degree of interaction between the single design options. When implementing multiple design options in the same washing machine, the resulting environmental improvement is expected to be smaller than the sum of the environmental improvements per individual option. In other words, if a washing machine has been already improved with one design option, every consequent design option will only realize a part of its individual potential. This is one of the reasons why the energy savings are not the direct sum of the single design options that the combination consists of.

Additionally, in case of the single design option, average values for the saving potential of the different options were considered (see section 6.1.2). In case of combinations, however, where available the consumption values of existing appliances equipped with the combinations of design options, are used.

In summary, the savings of the single design options are average savings of the different variants of certain design option, whereas the savings of the combinations are mainly based on the saving of real appliances on the market that rather represent the best available variant of the respective single design option on the market.

The following specific assumptions were made:

- .
- The changes in material composition, manufacturing costs and changes in maintenance and repair are assumed to be the sum of the changes of the single design options.
- It is assumed that the combinations of options do not result in additional changes (e.g. life time).

The assumptions regarding the saving potential, the material composition, the manufacturing and the maintenance and repair costs of both single and combined design options are summarised in table 4.18.

The improved load detection and adaptation has been included in all the combinations since it presents the shortest PBT. Other options with lower PBT are extension of standard programme duration and consumer feedback on loading. Nevertheless, their effectiveness is more uncertain, as they depend, beyond technical aspects, on the acceptance/capability of users to modify their use of the product. The influence of such options has been assessed in some relevant combinations.

6.1.2.8 Summary assumptions regarding the design options and combinations for washing machines

Table 6.4: Selected design options for washing machines and estimated variations compared to the BC

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime (years)	Manufacturing costs	Repair and maintenance costs	Materials
Base case washing machines	0.84 kWh/cycle for the standard conditions 0.64 kWh/cycle for the real life conditions						
Single design options							
WM-D1: Brushless, permanent magnet synchronous DC motor (PMSM)	-0.13 kWh for a 180 min cycle at full load (calculated as average between -0.20 kWh, compared to universal motor, and -0.0.7 kWh, compared to brushless, inverter driven asynchronous DC motor). Proportionally varied depending on cycle durations. It results in -12% of the total energy consumption under real life conditions (as average of different programmes)	Not affected	Not affected	The lifetime of the motor can be longer (e.g. + 5 years) but this is not considered to affect the lifetime of the appliance	+5.5 € (improved motor and inverter, calculated as average between +10 €, compared to universal motor, and +1 €, compared to brushless, inverter driven asynchronous DC motor)	Not affected	BOM not affected significantly
WM-D 2: Extension of programme duration and lowering of washing temperature (about 4.5 hours)	Max temperature of standard programmes decreased from 40 °C to 25 °C and from 48 °C to 35 °C. Programme duration extended by 50%. Energy consumption at full load decreases by 12% for the standard 40 °C cotton programme and by 21% for the standard 60 °C cotton programme. It results in -4% of the total energy consumption under real life conditions (as average of different programmes)	Not affected	Not affected	Not affected (if not frequently used otherwise longer running time may increase wear and tear which would have material and cost implications whose quantification is seen difficult)	Not affected	Not affected	BOM not affected
WM-D 3: Heat pump technology for the washing function	Savings estimated based on the observation of the same WM model on the market with and without HP (V-ZUG operating instructions. 2014a, 2014 b):	Not affected	Not affected	Not affected	+150 € (Heat pump, circulation and drainage pumps, heat exchangers, heat storage material (e.g. phase change	Not affected	+13 kg (plastics: 2.8 kg, copper: 2.4 kg, steel: 7.7 kg) +150 / 200 g of common refrigerant R134a (175 g as average) Alternative refrigerants could

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime (years)	Manufacturing costs	Repair and maintenance costs	Materials
	• 28% for standard programmes • 33% for 20 °C cotton programme • 40% for 30 °C cotton programme • 38% for 40 °C cotton programme • 23% for 60 °C cotton programme • 27% for 90 °C cotton programme • 0% for quick programmes • 30% for synthetic/easy care and mix programmes It results in -35% of the total energy consumption under real life conditions (as average of different programmes)				material), tank, refrigerant) Costs supposed to decrease to 75 € in 5-10 years if the technology become widely available on a commercial scale.		be used in the future that has lower GWP (e.g. propane (R290), isobutene (R600a)). However, HC refrigerants have important limitations of use if the refrigerant content is above 150g, as much stricter safety conditions have to be met, resulting in additional testing and re-dimensioning of the system. According to the European Standard EN 60335-2-24 or draft IEC 60335-2-89, which must be complied with, the refrigerant charge must not exceed 150 g. In general the charge of R600a or R290 is approximately 40-50% by weight than that for HFC. Commercially available R600a and R290 must not be used because the fuel grades of these products are of a variable composition. These products may also contain impurities which could significantly reduce the reliability and performance of the system and lead to premature failure. Many commercial compressors for R600a and R290 need a base purity of 97% or better. Impurity limits shall comply with DIN 8960 of 1998 (extended version of ISO 916). All users of refrigerant R600a should refer to the chemical data safety sheets for full information on the safe handling of R600a and R290.
WM-D 4: Improved	Savings from 0 to 20% for all programmes. An average value of	Savings from 0 to 20% for all programmes. An	Not affected	Not affected	+15 / +20 € (circulation pump,	Not affected	BOM not affected significantly

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime (years)	Manufacturing costs	Repair and maintenance costs	Materials
drenching systems / improved detergent dissolution	10% is considered. Programme duration also reduced by 10%. It results in- 10% of the total energy consumption under real life conditions (as average of different programmes)	average value of 10% is considered. It results in - 10% of the total water consumption under real life conditions (as average of different programmes)			drenching / foam generator system, dissolution chamber, hoses, wiring, control)		
WM-D 5: Higher water extraction by spinning (increase of the maximum spin speed from 1,400 rpm to 1,600 rpm)	Higher spinning speeds need +0.05 kWh/cycle. These are applied for 46% of total laundry washed and only to cotton programmes. Credit for drying (per cycle) = (50%-45%) x 3.3 kg x 2.26/3.6 kWh/kg x (100%-54%) = 0.05 kWh/cycle Assumptions: - Residual moisture content of laundry decreases from 50 to 45%. - 2,260 kJ/kg (latent heat of evaporation for water) - 54% of drying does not require application of heat It results in -5% of the total energy consumption under real life conditions (as average of different programmes) Note: this option is typically associated with PM motors. In that case energy consumption would decrease by 17%.	Not affected	Not affected	Not affected if durability of components is increased	+20 € (stiffer drum, larger bearings, improved balancing system, improved sensors for unbalance, improved motor) Note: this option is typically associated with PM motors. In that case costs would increase by 25.5€	Not affected	BOM increased by 20% proportionally
WM-D 6: Improved load detection and partial load adaptation	8-10% more efficient load adaptation (9% as average). Max adaptation proportional to the 'real load' to 'rated capacity' ratio. It results in -8% of the total energy consumption under real life conditions (as average of different programmes)	8-10% more efficient load adaptation (9% as average). Max adaptation proportional to the 'real load' to 'rated capacity' ratio. It results in -8% of the total water consumption under real life conditions (as average of different	Not affected	Not affected	5 € (sensors, software)	Not affected	BOM not affected significantly

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime (years)	Manufacturing costs	Repair and maintenance costs	Materials
		programmes)					
WM-D 7: Automatic detergent dosage system	Not affected (impact of pumping negligible)	Not affected	Both overdosing and underdosing will be reduced. On average, up to 30% of detergents can be saved: -15% has been considered	Not affected	25 € (container, pump, sensors)	Not affected	BOM not affected significantly
WM-D 8: Consumer feedback mechanisms about loading	Three sub-cases are analysed: Option WM8a) this option would lead to wash always at full load (max theoretical potential). It is assumed that a 7 kg machine has an average nominal maximum load of 6 kg. Since the new average load increases from 3.3 kg to 6.0 kg (+83%), number of cycles decrease accordingly (120), as well as the energy consumption per kg of laundry washed (-32%). Option WM8b) this option would lead to increase the loading to fill up to half of the empty capacity. The new average load increases to 4.7 kg (+41%) and number of cycles decrease accordingly (155). Energy consumption per kg is also lower (-23%) Option WM8c) this option would lead to increase the loading to fill up to one quarter of the empty capacity. The new average load increases to 4.0 kg (+21%) and number of cycles decrease accordingly (182). Energy consumption per kg is also lower (-13%)	Three sub-cases are analysed: a) This option would lead to wash always at full load (max theoretical potential). Since the new average load increases from 3.3 kg to 6.0 kg (+83%), number of cycles decrease accordingly (120), as well as the water consumption per kg of laundry washed (-27%). b) This option would lead to increase the loading up to half of the empty capacity The new average load increases to 4.7 kg (+41%) and the number of cycles decreases accordingly (155). Water consumption per kg is also lower (-17%) c) This option would lead to increase the loading up to one quarter of the empty capacity The new average load increases to 4.0 kg (+21%) and the number of cycles decreases accordingly (182). Water consumption	Not affected	Not affected	5 € (sensors, display)	Not affected	BOM not affected significantly

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime (years)	Manufacturing costs	Repair and maintenance costs	Materials
		per kg is also lower (-10%)					

Table 6.5: Selected design options and estimations of alterations compared to the base case washing machines

(% vs base case)	Energy (kWh/cycle)	Water (l/cycle)	Detergent (g/cycle).	Manuf. costs (€)	ORP (€)	RRP (€)	Main material changes
Base case washing machines	0.84	43.5	75	148	414.4	577.2	
Single design options							
WM-D1: PM motor	0.8064	43.5	75	153.5	429.8	598.65	
	-4%	0%	0%	4%	4%	4%	
WM-D 2: Extension of std. programme duration	0.546	43.5	75	148	414.4	577.2	
	-35%	0%	0%	0%	0%	0%	
WM-D 3(a): Heat Pump	0.756	39.15	75	298	834.4	1162.2	
	-10%	-10%	0%	101%	101%	101%	
WM-D 3(b): Heat Pump – assuming a low cost of HP	0.798	43.5	75	165.5	463.4	645.45	
	-5%	0%	0%	12%	12%	12%	
WM-D 4: Improved drenching	0.7728	40.02	75	168	470.4	655.2	
	-8%	-8%	0%	14%	14%	14%	
WM-D 5(a): Higher spinning extraction (1600 rpm)	0.546	43.5	63.75	153	428.4	596.7	
	-35%	0%	-15%	3%	3%	3%	
WM-D 5(b): Higher spinning extraction (1600 rpm) + PM	0.546	43.5	75	173	484.4	674.7	

(% vs base case)	Energy (kWh/cycle)	Water (l/cycle)	Detergent (g/cycle).	Manuf. costs (€)	ORP (€)	RRP (€)	Main material changes
motor	-35%	0%	0%	17%	17%	17%	
WM-D 6: Improved load detection and adaptation	0.8064	43.5	75	153	428.4	596.7	
	-4%	0%	0%	3%	3%	3%	
WM-D 7: Automatic detergent dosage	0.546	43.5	75	153.5	429.8	598.65	
	-35%	0%	0%	4%	4%	4%	
WM-D 8: Consumer feedback on loading	0.756	39.15	75	148	414.4	577.2	
	-10%	-10%	0%	0%	0%	0%	

Table 6.6: Selected combinations and estimations of alterations compared to the base case washing machines

(% vs base case)	Energy (kWh/cycle)	Water (l/cycle)	Detergent (g/cycle).	Manuf. costs (€)	ORP (€)	RRP (€)	Main material changes
Base case washing machines	0.84	43.5	75	148	414.4	577.2	
Combinations							
WM-C1: WM-D1+WM-D6 PM motor + improved load detection and adaptation	0.6972	40.02	75	158.5	443.8	618.15	
	-17%	-8%	0%	7%	7%	7%	
WM-C2: WM-D6+WM-D4	0.6888	36.105	75	170.5	477.4	664.95	
improved load detection and adaptation and improved drenching	-18%	-17%	0%	15%	15%	15%	
WM-C3: WM-D1+WM-D6+WM-D4	0.63	36.105	75	176	492.8	686.4	
PM motor, improved load detection and adaptation and improved drenching	-25%	-17%	0%	19%	19%	19%	
WM-C4: WM-D6+WM-D2	0.7392	40.02	75	153	428.4	596.7	
improved load detection and adaptation and extension of standard programme duration)	-12%	-8%	0%	3%	3%	3%	
WM-C5: WM-D6+WM-D8	0.7728	40.02	75	158	442.4	616.2	
improved load detection and adaptation and consumer feedback on loading	-8%	-8%	0%	7%	7%	7%	
WM-C6:WM-D1+WM-D6+WM-D4+WM-D7+WM-D8	0.63	36.105	63.75	206	576.8	803.4	
PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading	-25%	-17%	-15%	39%	39%	39%	
WM-C7:WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WM-D3	0.4368	36.105	63.75	281	786.8	1095.9	
PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage, consumer feedback on loading and heat pump	-48%	-17%	-15%	90%	90%	90%	

6.1.3 Washer dryers

6.1.3.1 Assumptions regarding the selected design options for washer dryers

The selected design options for washer-dryers and estimated variations compared to the base case are listed in Table 6.7. Resulting variation of the EcoReport tool's input parameters are reported in Table 6.8. All options for washing machines are however taken into consideration (when relevant) for establishing the combinations of design options for washer dryers.

The following options have not been analysed:

- Parallel implementation of heat pump technologies for both washing and drying.
- Implementation of an energy storage system.
- Drying based on central/district heating.

The improvement options presented for washing machines can in principle also be applied to washer-dryers. . Additional manufacturing materials and costs are considered similar to washing machines, while estimated saving potentials would apply only to the washing process (34% share of the total for energy for washing and drying and 73% of the water).

The exception is the design option (WM-D5(b) with higher spin drying extraction, which has been re-assessed considering that:

- Residual moisture content of laundry decreases from 50 to 45%.
- 2,260 kJ/kg (latent heat of evaporation for wash)
- 54% of drying does not require application of heat for the remaining cycles.

The results show higher credits for drying (per cycle) compared to washing machines: (50%-45%) x 3.3 kg x 2.26/3.6 kWh/kg x (63% + 37% x (100%-54%) = 0.08 kWh/cycle (instead of 0.05 kWh/cycle).

6.1.3.2 Assumptions regarding the combinations of design options for washer-dryers

The selection of combinations of single options has been made in an analogous way to washing machines (see section 6.1.2.8). The combinations of design options for washer-dryers include:

- WD-C1: WM-D1+WM-D4+WM-D6+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through improved design of combined wash&dry programme)
- WD-C2: WM-D1+WM-D4+WM-D6+WD-D1+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through air condensing system and combined wash&dry programme)
- WD-C3 : WM-D1+WM-D4+WM-D6+WD-D2+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through heat pump and combined wash&dry programme)
- WD-C4: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through improved design of combined wash&dry programme)
- WD-C5: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D1+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through air condensing system and combined wash&dry programme)
- WD-C6: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D2+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through heat pump and combined wash&dry programme)

As it was done for washing machines, the following modelling assumptions have been made:

1. The savings associated to the selected combinations has been estimated by means of stakeholder feedback to questionnaires, and the models used for the assessment of base cases and single improvement options
2. The changes in material composition, the additional manufacturing costs and changes in maintenance and repair are assumed to be the sum of the changes of the single design options.
3. It is assumed that the combinations of options do not result in additional changes (e.g. life time).

Table 6.8 provides an overview of the variations estimated for the selected combinations of options for washer-dryers compared to the base case

6.1.3.3 Summary assumptions regarding the design options and combinations for washer dryers

Table 6.7: Selected design options for washer-dryers and estimated variations compared to the base case washer dryers

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime	Manufacturing costs	Repair and maintenance costs	Materials
WD-WMx: Implementation of improvement options of WM for the washing function Note: only WM5b re-assessed at this stage for WD	Variations estimated for WM would apply to 34% of energy consumption of the BC (washing quota) For higher spin drying extraction credits for drying (per cycle) are higher: (50%-45%) x 3.3 kg x 2.26/3.6 kWh/kg x (63% + 37% x (100%-54%) = 0.08 kWh/cycle (instead of 0.05 kWh/cycle). Assumptions: - Residual moisture content of laundry decreases from 50 to 45%. - 2,260 kJ/kg (latent heat of evaporation for water) - laundry dried in the WD in 63% of cycle - 54% of drying does not require application of heat for the remaining cycles.	Variations estimated for WM would apply to 73% of water consumption of the BC (washing quota)	Same as for WM	Same as for WM	Same as for WM	Same as for WM	Same as for WM
WD1: Air condensing system	Not affected	No water consumption in the drying phase, resulting in saving 27% of water compared to the BC	Not affected	Not affected	Up to +10 € (Fan, heat-exchanger)	Not affected	BOM not affected significantly
WD2: Heat-pump for the drying process	-40 / -70% of drying energy consumption (55% as average), resulting in saving 36% of the total energy consumed in the BC	No water consumption in the drying phase, resulting in saving 27% of water compared to the BC	Not affected	Not affected	Same as WM; + 150 € (Heat pump, circulation and drainage pumps, heat exchangers, heat storage material (e.g. phase change material), tank, refrigerant) Costs supposed to decrease to	Not affected	Same as WM: +13 kg (plastics: 2.8 kg, copper: 2.4 kg, steel: 7.7 kg) +150 / 200 g of common refrigerant (175 g of R-134a as average) HC refrigerants have important limitations of use if the refrigerant

Improvement options (NOTE: new numbering used)	Variations compared to BC (%)						
	Energy consumption	Water consumption	Detergent consumption	Lifetime	Manufacturing costs	Repair and maintenance costs	Materials
					75 € in 5-10 years if the technology become widely available on a commercial scale.		content is above 150 g, as much stricter safety conditions have to be met, resulting in additional testing, dimensioning of the system.
WD3: Improved design of combined wash&dry programmes	-5% of energy consumption for drying in the W&D continuous process, resulting in saving 2% of the total energy consumed in the BC	Not affected	Not affected	Not affected	Not affected	Not affected	Not affected

Table 6.8: Selected design options and combinations and estimations of alterations compared to the base case washer dryers

(% vs base case)	Energy (kWh/cycle)	Water (l/cycle)	Detergent (g/cycle).	Manuf. costs (€)	ORP (€)	RRP (€)	Main material changes
Base case washer dryers	1.93	53.5	75	296	828.8	1154.4	
Design options							
WD1: Air condensing system	1.93	39.1	75	306	856.8	1193.4	
	0%	-27%	0%	3%	3%	3%	
WD2: Heat-pump for the drying process	1.2352	39.1	75	446	1248.8	1739.4	
	-36%	-27%	0%	51%	51%	51%	
WD2: Heat-pump for the drying process – low costs	1.2352	39.1	75	371	1038.8	1446.9	
	-36%	-27%	0%	25%	25%	25%	
WD3: Improved design of combined wash&dry programmes	1.8914	53.5	75	296	828.8	1154.4	
	-2%	0%	0%	0%	0%	0%	
WD-WM5(b): Higher spinning extraction and PM motor	1.8142	53.5	75	321.5	900.2	1253.9	
	-6%	0%	0%	9%	9%	9%	
Combinations							
WD-C1: WM-D1+ WM-D4+ WM-D6+WD-D3 PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through improved design of combined wash&dry programme)	1.737	47.08	75	324	907.2	1263.6	
	-10%	-12%	0%	9%	9%	9%	
WD-C2: WM-D1+ WM-D4+ WM-D6+ WD-D1+WD-D3 PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through air condensing system and combined wash&dry programme	1.737	32.635	75	334	935.2	1302.6	
	-10%	-39%	0%	13%	13%	13%	
WD-C3: WM-D1+ WM-D4+ WM-D6+ WD-D2+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through heat pump and combined wash&dry programme)	1.0036	32.635	75	474	1327.2	1848.6	
	-48%	-39%	0%	60%	60%	60%	

(% vs base case)	Energy (kWh/cycle)	Water (l/cycle)	Detergent (g/cycle).	Manuf. costs (€)	ORP (€)	RRP (€)	Main material changes
WD-C4:WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D3 PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through improved design of combined wash&dry programme	1.737	47.08	63.75	354	991.2	1380.6	
	-10%	-12%	-15%	20%	20%	20%	
WD-C5:WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D1+WD-D3 PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through air condensing system and combined wash&dry programme	1.737	32.635	63.75	364	1019.2	1419.6	
	-10%	-39%	-15%	23%	23%	23%	
WD-C6: WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8+ WD-D2+WD-D3 PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through heat pump and combined wash&dry programme	1.0036	32.635	63.75	474	1327.2	1848.6	
	-48%	-39%	-15%	60%	60%	60%	

6.2 Best not yet available (BNAT) design options

Best not yet available technologies (BNAT) have to be identified and their potential to reduce environmental impacts has to be estimated. So far the following technological options have been identified as possible in principle but so far not yet installed in any washing machine on the market.

6.2.1 Heat pump with alternative refrigerant.

Some current heat pump (for heating water) models installed in washing machines or washer dryers work with R134a (tetrafluroroethane) as refrigerant. R134a has a high specific global warming potential (see Table 6.9). The choice of this refrigerant is because of its technical performance. However, in principle it is possible to construct heat pumps with other refrigerants with lower environmental damage potential (lower GWP) but most likely lower technical performance. This development already takes place in case of tumble dryers (to heat up air), where first appliances with R290 (propane) as refrigerant are already on the market. A challenge that has to be considered is that R290 is flammable. Therefore due to safety issues the manufacturer would probably limit the amount of R290 to 150 g per appliance due to the extra costs of additional safety measures. Table 6.9 compares the GWP of currently used refrigerant (R134a) with the possible substitute (R290).

Table 6.9: Global Warming Potential (GWP) of refrigerants used in heat pumps

	Used amount per appliance	Specific GWP (IPCC 2007; UNEP 2014)	Total GWP in case of 100% loss per appliance
	g	kg CO_2e/kg	kg CO_2e
R134a (tetrafluroroethane)	175	1 430	250
R290 (propane)	150	3.3	0.5

According to stakeholder feedback the safety limit on the amount of alternative refrigerant is supposed to lead to a lower efficiency compared to using R134a (i.e. longer cycle times and/or additional electric heating would be necessary to reach the target temperatures).

6.3 Environmental impacts (results from Ecoreport tool)

6.3.1 Environmental impacts of single design options for the base case of washing machines

Table 6.10 depicts the relative environmental impacts of the single design options compared to base case washing machines under real life conditions. Figure 6.1 shows the relative figures of the total environmental impacts of the base case (=100%) and the single design options.

Table 6.10: Life cycle impacts of washing machines design options with respect to the base case washing machine (=100%)

Indicator	WM1	WM2	WM3	WM4	WM5(a)	WM5(b)	WM6	WM7	WM8(a)	WM8(b):	WM8(c)
Total Energy (primary energy)	96%	98%	85%	95%	101%	97%	96%	95%	83%	88%	93%
Electricity (primary energy)	93%	97%	70%	91%	98%	91%	93%	100%	71%	79%	88%
Water (process)	100%	100%	100%	90%	100%	100%	92%	100%	73%	83%	90%

Water (cooling)	98%	99%	101%	98%	115%	113%	98%	100%	92%	95%	97%
Waste, non-haz./ landfill	99%	99%	108%	98%	114%	113%	99%	99%	95%	96%	98%
Waste, hazardous/ incin.	96%	98%	87%	95%	102%	98%	96%	96%	84%	88%	93%
GWP100	96%	98%	102%	95%	102%	98%	96%	95%	85%	89%	94%
Acidification, emissions	97%	98%	97%	96%	105%	101%	97%	96%	86%	90%	95%
VOC	93%	96%	68%	90%	97%	89%	92%	100%	70%	78%	88%
POP	99%	100%	119%	99%	119%	118%	99%	101%	97%	98%	99%
Heavy Metals	100%	100%	107%	99%	121%	121%	99%	102%	98%	99%	99%
PAHs	98%	99%	103%	98%	111%	109%	98%	100%	92%	95%	97%
PM, dust	100%	100%	100%	100%	104%	104%	100%	100%	99%	99%	100%
Heavy Metals	100%	100%	103%	100%	121%	121%	100%	102%	99%	99%	99%
Eutrophication	100%	100%	101%	100%	102%	102%	100%	86%	100%	100%	100%

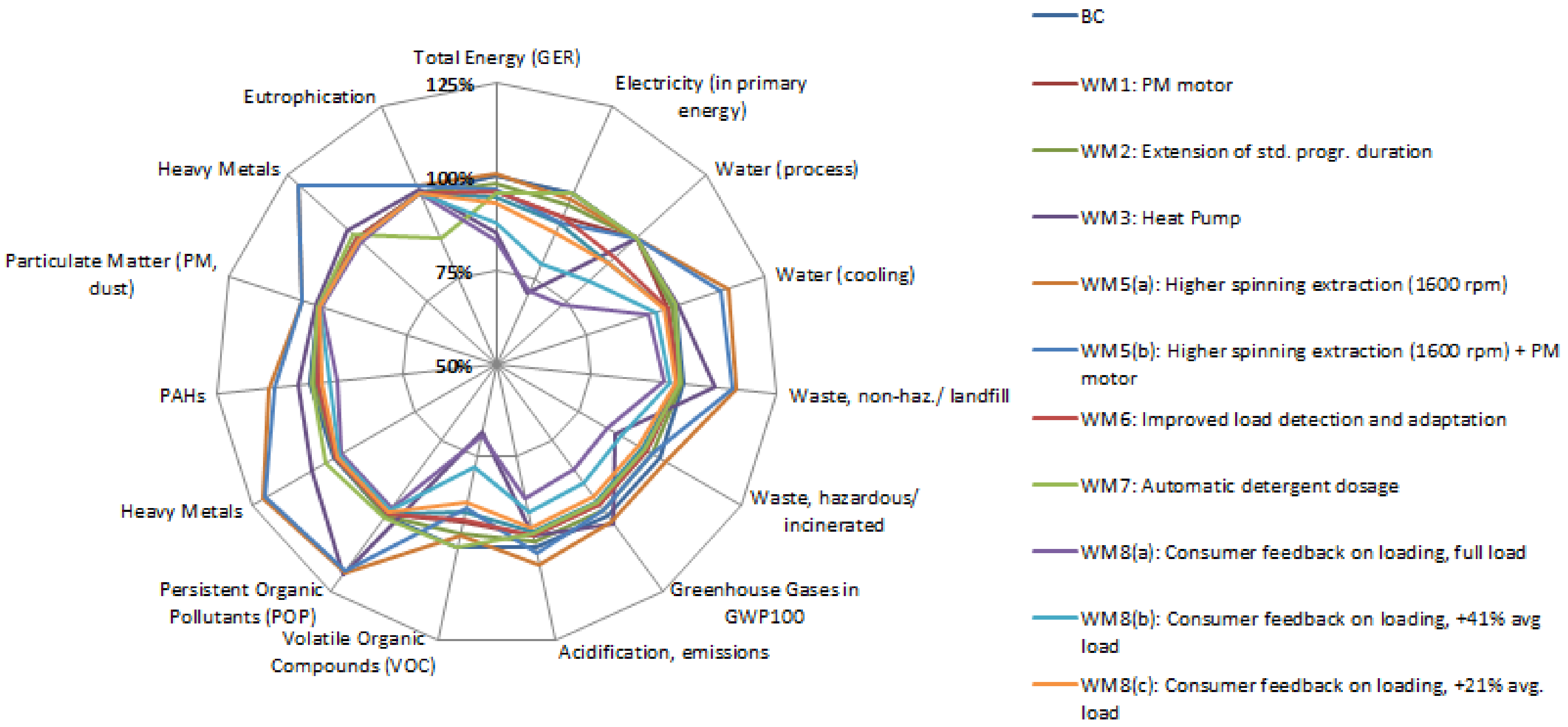


Figure 6.1: Relative environmental impacts of the single design options compared to the base case washing machines (=100%) – spider diagram

The analysis of Figure 6.1 can lead to the following issues:

- No design option is dominant in all environmental categories. Some significant trade-offs of environmental categories are registered for WM-D3 (heat pump) and WM-D5 (higher spinning extraction) mainly as a consequence of the increased demand of materials
- All assessed improvement options allow reducing impacts in some categories
- Reductions of up to -32% are estimated, but reductions depend heavily on the impact category and option considered. (VOC, WM-D3, heat pumps)

Figure 6.1 shows that the environmental profile of the options is favourable for some impact categories, but less favourable for others. Therefore, without aiming at developing some weighting mechanism (which has some inherent limitations), it would be difficult to rank options without isolating specific indicators. Some conclusions of this analysis are presented below:

- Water savings are observed in four options: WM-D6 (improved load detection and adaptation, -8%), WM-D4 (improved drenching, -10%), WM-D8 (consumer feedback on loading, variable depending on loading conditions).
- The energy demand of the design options ranges from 83% (WM-D8a – consumer feedback on loading, full load) to 101% (WM-D5a – higher spinning extraction and same motor) of the base case
- The highest energy savings figures have been estimated for WM-D8 (consumer feedback on loading), independently from the considered increase of loading. It should be observed that actual savings depend on how users will be able to load their machines.
- The energy savings due to the extension of the standard cotton programme duration (WM-D2) are limited because this design option is considered to apply only to few programmes (i.e. the cotton standard programmes). If the frequency of use of standard programmes increased, the savings associated to this option would increase. The quantification of the savings depends on the information and acceptance of consumers to use these programmes.
- Heat pump (WM-D3) can potentially provide significant energy saving. Some unexploited energy saving potential seems associated to drenching system (WM-D4), automatic detergent dosage (WM-D7), load detection, adaptation mechanisms (WM-D6) and motors (WM-D1). Option WM-D5 (higher spinning extraction) is penalised by an increased demand of materials. Some marginal saving through increasing spinning extraction is registered only when the performance of motors is improved. The use of 1600 rpm relies on climate conditions and consumers' habits among other issues
- Demand of primary energy and GWP 100 show similar results. The exception is represented by WM-D3, i.e. the machine implementing a heat-pump that works with a conventional refrigerant (R134a, with a GWP-100 of 1430 kg CO_2-eq/kg), for which it has been assumed that 64% of the whole load of refrigerant is released to the atmosphere. A similar trend is observed also for WM-D5a (higher spinning extraction and same motor) where the impact due to additional amount of materials is not totally compensated by the reduced energy needs.

The choice of R134a as refrigerant is because of its widespread use for small compressors in household appliances, and excellent technical performance. However, in principle it would be possible to construct heat pumps with other refrigerants, as is currently done for several commercial refrigeration applications. The impact for this category could be reduced by changing refrigerant (e.g. by using propane or isobutene, which have a GWP-100 of 3 kg CO_2-eq/kg). This development already took place in case of tumble dryers, where the appliances with R290 (propane) as refrigerant are already on the market. A challenge that has to be considered is that R290 is a flammable gas. Therefore, due to safety issues the amount of R290 loaded in the circuits may be limited. According to the European Standard EN 60335-2-24 or draft IEC 60335-2-89, the refrigerant charge must not exceed 150 g. In general the charge of R600a or R290 is approximately 40-50% in mass higher than that for HFC. Commercially available R600a and R290 must not be used because the fuel grades of these products are of a variable composition. These products may also contain impurities which could significantly reduce the reliability and performance of the system and lead to premature failure. Many commercial compressors for R600a and R290 need a high base purity (e.g. 97% or better). Impurity limits shall comply with DIN 8960 of 1998 (extended version of ISO 916). All users of refrigerant R600a should refer to the chemical data safety sheets for full information on the safe handling of R600a and R290.

Table 6.11: Ranking of selected improvement options for washing machines based on selected environmental indicators

Option	Total Energy (primary energy)	Water (process)	Greenhouse Gases (GWP100)
WM8(a): Consumer feedback on loading, full load	83%	73%	85%
WM3(a, b): Heat Pump	85%	100%	102%
WM8(b): Consumer feedback on loading, +41% avg load	88%	83%	89%
WM8(c): Consumer feedback on loading, +21% avg load	93%	90%	94%
WM4: Improved drenching	95%	90%	95%
WM7: Automatic detergent dosage	95%	100%	95%
WM6: Improved load detection and adaptation	96%	92%	96%
WM1: PM motor	96%	100%	96%
WM5(b): Higher spinning extraction + PM motor	97%	100%	98%
WM2: Extension of std. programme duration (moderate)	98%	100%	98%
BC	100%	100%	100%
WM5(a): Higher spinning extraction	101%	100%	102%

6.3.2 Environmental impacts of combination of design options for the base case of washing machines

Life cycle impacts of selected combinations of improvement options for washing machines, expressed per year of use with respect to the Base case WM (=100%), are shown in Table 6.12 and in Figure 6.2.

Table 6.12: Life cycle impacts of washing machines combination options with respect to the base case washing machine (=100%)

Indicator	WM-C1	WM-C2	WM-C3	WM-C4	WM-C5(a)	WM-C5(b)	WM-C6(a)	WM-C6(b)	WM-C7	WM-C8	WM-C9(a)	WM-C9(b)
Total Energy (primary energy)	91%	90%	87%	94%	96%	85%	82%	74%	73%	64%	96%	84%
Electricity (primary energy)	85%	84%	78%	89%	93%	75%	77%	64%	58%	47%	97%	77%
Water (process)	92%	83%	83%	92%	92%	78%	83%	70%	83%	83%	97%	80%
Water (cooling)	96%	96%	94%	97%	98%	93%	94%	91%	98%	87%	115%	110%
Waste, non-haz./ landfill	97%	97%	96%	98%	99%	95%	95%	92%	105%	89%	113%	109%
Waste, hazardous/ incinerated	92%	91%	87%	94%	96%	86%	83%	76%	76%	66%	97%	86%
Greenhouse Gases in GWP100	92%	91%	88%	94%	96%	87%	84%	76%	91%	68%	97%	86%
Acidification, emissions	93%	92%	89%	95%	97%	88%	86%	79%	87%	72%	100%	91%
Volatile Organic Compounds (VOC)	84%	83%	76%	89%	92%	73%	76%	62%	56%	44%	96%	75%
Persistent Organic Pollutants (POP)	99%	99%	98%	99%	99%	98%	99%	97%	119%	96%	119%	118%
Heavy Metals	99%	99%	98%	99%	99%	98%	101%	100%	108%	99%	124%	122%
PAHs	96%	96%	94%	97%	98%	93%	94%	90%	99%	86%	110%	105%
Particulate Matter (PM, dust)	99%	99%	99%	100%	100%	99%	99%	99%	100%	98%	104%	104%
Heavy Metals	99%	99%	99%	100%	100%	99%	101%	100%	104%	99%	123%	122%
Eutrophication	100%	100%	100%	100%	100%	100%	86%	86%	87%	86%	88%	88%

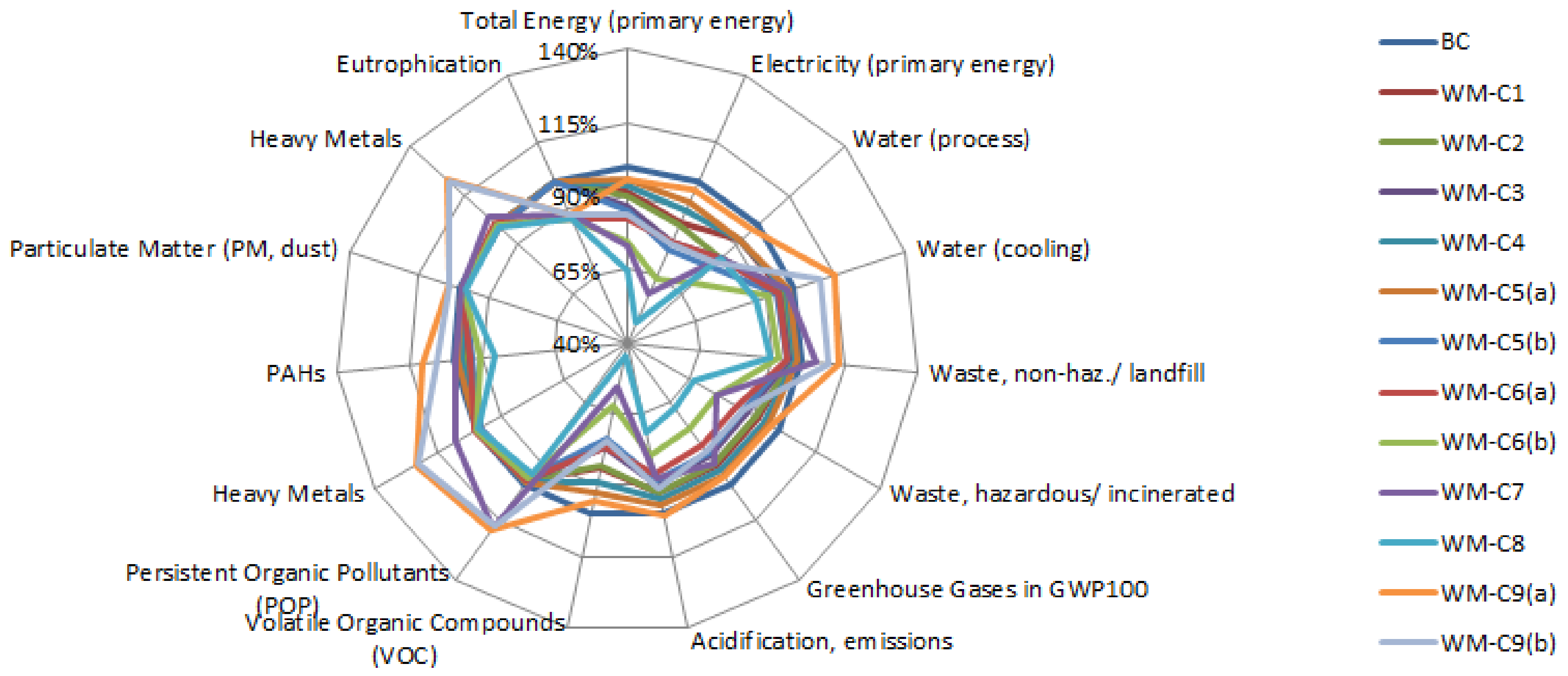


Figure 6.2: Life cycle impacts per year of combinations of improvement options selected for WM with respect to the Base case WM (=100%) – spider diagram

Figure 6.2 shows that:

- Any design option is dominant in all environmental categories. Some significant trade-offs of environmental categories are registered for WM-C7, WM-C9(a) and WM-C9(b) due to the increased demand of materials for such options (a heat pump system is implemented in WM-C5 and size of the appliance is increased for WM-C9(a, b))
- All assessed improvement options allow reducing impacts in some categories
- Reductions of up to -56% are estimated, but reductions depend heavily on the impact category and option considered. (VOC, design options WM-C8: top product with hot-cold fill and solar heating)

Without aiming at developing some weighting (which has inherent limitations), it would be difficult to rank design options without isolating specific indicators. Table ranks the combinations based on the total demand of primary energy:

- energy demand ranges from 64% to 96% of that of the base case. Potential saving of primary energy was estimated to be 13% for a product improvement combination that does not depends directly on user behaviour (WM-C3) and 18% for a combination with a broader range of options (WM-C6(a)). The estimated savings could increase in case of increased loading conditions (WM-C6(b), WM-C9(b) and WM-C5(b)), application of a heat pump (WM-C7) or hot-cold fill connections (WM-C8).
- The maximum energy saving potential relies on the implementation of hot-cold fill connections (WM-C8). This option also scored very well regarding GWP if all heating energy comes for free (solar heating) and without considering additional system aspects (i.e. heating system, alternative supply of energy, water supply network, losses of energy). In case of hot-fill and average mix of electricity, natural gas and oil for water heating, estimated energy saving for WM-C8 would be comparable to that of WM-C7
- The second highest energy savings is achieved by a washing machine equipped with a heat pump (WM-C7). Washing machines with heat pumps are currently a niche market. This is thus to be considered as the maximum theoretical potential achievable for this option.
- Significant savings can be achieved, without changing current behaviour practices, through the application of relatively simple technical solutions: WMC1 (-9% energy, -8% water), WMC2 (-10% energy, -7% water), WMC3 (-13% energy, -17% water), WM-C5(a) (-4% energy, -8% water), WM-C6(a) ((-18% energy, -17% water), WM-C9(a) ((-4% energy, -3% water).
- Savings could be higher even if longer standard cotton programmes were accepted by consumers (WM-C4) or, more in general, if use of standard cotton programmes increases.
- Possibility to increase loading conditions (options WM-Cx(a) vs WM-Cx(b)) can lead to significant extra saving. Net savings are however estimated for all the combinations, no matter the loading conditions, as a result of the implementation of other improvement options. Overall savings are penalised depending on the extent of the under-loading conditions (see WM-C6(a) vs. WM-C9(a) and WM-C6(b) vs. WM-C9(b)).
- A similar ranking is generally observed also for GWP100. The exception is represented by WM-C7, i.e. an appliance implementing a heat-pump that works with a conventional refrigerant. The use of alternative refrigerants may add benefits in terms of GWP.

Table 6.13: Ranking of combinations of improvement options for WM based on selected environmental indicators

Design option	Total Energy (GER)	Water (process)	Greenhouse Gases in GWP100
WM-C8	64% (*)	83%	68% (**)
WM-C7	73%	83%	91%
WM-C6(b)	74%	70%	76%
WM-C6(a)	82%	83%	84%
WM-C9(b)	84%	80%	86%
WM-C5(b)	85%	78%	87%

WM-C3	87%	83%	88%
WM-C2	90%	83%	91%
WM-C1	91%	92%	92%
WM-C4	94%	92%	94%
WM-C5(a)	96%	92%	96%
WM-C9 (a)	96%	97%	97%
BC	100%	100%	100%

(*) Estimated considering solar heating and no system aspects (i.e. only savings of electricity for heating due to hot-fill). The indicator could increase to 76% considering average mix of electricity, natural gas and oil for water heating(**) Estimated considering solar heating and no system aspects (i.e. only savings of electricity for heating due to hot-fill). The indicator could increase to 78% considering average mix of electricity, natural gas and oil for water heating

6.3.3 Environmental impacts of single design options for washer dryers

Life cycle impacts of washer-dryers single design options are shown in Table 6.14 and in Figure 6.3. The results are expressed with respect to the base case washer dryer (=100%),

Table 6.14: Life cycle environmental impacts of a standard household washer dryer (base case) and its single design options

Indicator	WD1	WD2(a, b)	WD3	WD-WM5(b)
Total Energy (primary energy)	100%	74%	98%	97%
Electricity (primary energy)	100%	66%	98%	95%
Water (process)	73%	73%	100%	100%
Water (cooling)	100%	92%	99%	108%
Waste, non-haz./ landfill	100%	98%	99%	110%
Waste, hazardous/ incin.	100%	76%	99%	98%
GWP100	100%	85%	99%	98%
Acidification, emissions	100%	82%	99%	100%
VOC	99%	65%	98%	94%
POP	100%	111%	100%	116%
Heavy Metals	100%	102%	100%	118%
PAHs	100%	91%	99%	106%
PM, dust	100%	98%	100%	104%
Heavy Metals	100%	100%	100%	119%
Eutrophication	100%	101%	100%	102%

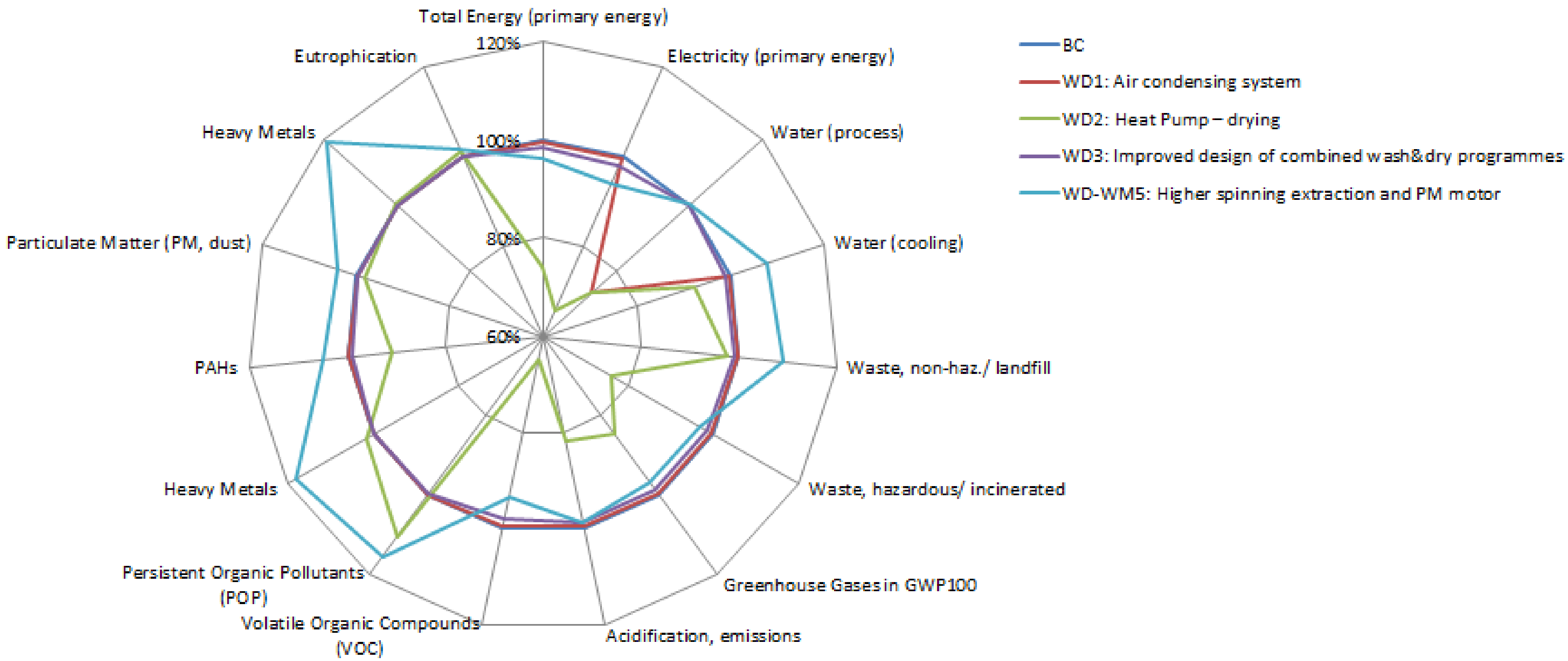


Figure 6.3: Relative environmental impacts of the single design options compared to the standard base case – spider diagram

The analysis of Figure 6.3 leads to the following issues:

- Any design option is beneficial on all categories. Trade-offs are registered for WD-D2 (heat pump) and WD-WM5 (higher spinning extraction) mainly as a consequence of the increased demand of materials
- Reductions of up -35% are estimated, but reductions depend heavily on the impact category and option considered. (VOC, WD-D3, heat pumps)

The assumptions made for the design options of the base case washing machine can be generally extended to the washing function of washer dryers. This is not the case for the drying function of a washer-dryer that has larger energy consumption and related environmental impacts than washing function.

Without aiming at developing a weighting mechanism (which has inherent limitations), it would be difficult to rank options without isolating specific indicators. Table 6.15 ranks options based on the total demand of primary energy and the conclusions drawn are presented below:

- Primary energy demand ranges from 74% to 100% of the base case. The maximum saving potential is achieved with WD-D2 (heat pump for drying). No energy saving is associated to WD-D1 (air conditioning system), while some saving is achieved with WD-WM5b (Higher spinning extraction and PM motor, 3%) and WD-D3 (Improved design of combined wash&dry programmes2%). Energy saving potential of WD-D3 depends on the frequency of use of combined wash&dry programmes and on the optimisation of the related wash cycle.
- Results of primary energy demand and GWP100 are very close, although the difference between base case and WD-D2 (heat-pump for drying) when reported as GWP100 is reduced because of the use of refrigerants in such option.
- 27% water saving is observed both for WD-D1 (air condensing system for drying) and WD-D2 (heat pump for drying).
- Similar considerations made for the design options of the base case washing machines apply here for the design options of washer dryers, although saving figures would be proportional to the weight of the washing process in the two functions of the machine.

Table 6.15: Ranking of selected improvement options for the base case washer dryers based on selected environmental indicators

Improvement option	Total Energy (primary energy)	Water (process)	GHG in GWP100
WD-D2(a,b): Heat Pump – drying	74%	73%	85%
WD-WM5(b): Higher spinning extraction and PM motor	97%	100%	98%
WD-D3: Improved design of combined wash&dry programmes	98%	100%	99%
WD-D1: Air condensing system	100%	73%	100%
Base case washer dryers	100%	100%	100%

6.3.4 Environmental impacts of combination of design options for the base case of washer dryers

Life cycle impacts of selected combinations of improvement options for washer-dryers, expressed per year of use with respect to the base case washer dryers (=100%), are shown in Table 6.16 and in Figure 6.4.

Table 6.16: Life cycle environmental impacts of a standard household washer dryer (base case) and the combination of the design options

	WD-C1	WD-C2	WD-C3	WD-C4	WD-C5	WD-C6
Total Energy (primary energy)	92%	92%	65%	90%	90%	63%
Electricity (primary energy)	90%	90%	54%	90%	90%	54%
Water (process)	88%	61%	61%	88%	61%	61%
Water (cooling)	95%	95%	87%	96%	95%	87%
Waste, non-haz./ landfill	96%	96%	93%	96%	95%	92%
Waste, hazardous/ incinerated	93%	92%	67%	90%	90%	65%
Greenhouse Gases in GWP100	93%	92%	76%	90%	90%	73%
Acidification, emissions	93%	93%	74%	91%	91%	72%
Volatile Organic Compounds (VOC)	90%	90%	53%	90%	90%	53%
Persistent Organic Pollutants (POP)	98%	98%	108%	99%	98%	109%
Heavy Metals	98%	98%	100%	100%	100%	101%
PAHs	95%	95%	85%	95%	95%	85%
Particulate Matter (PM, dust)	99%	99%	97%	99%	99%	97%
Heavy Metals	99%	99%	99%	100%	100%	100%
Eutrophication	100%	100%	101%	86%	86%	87%

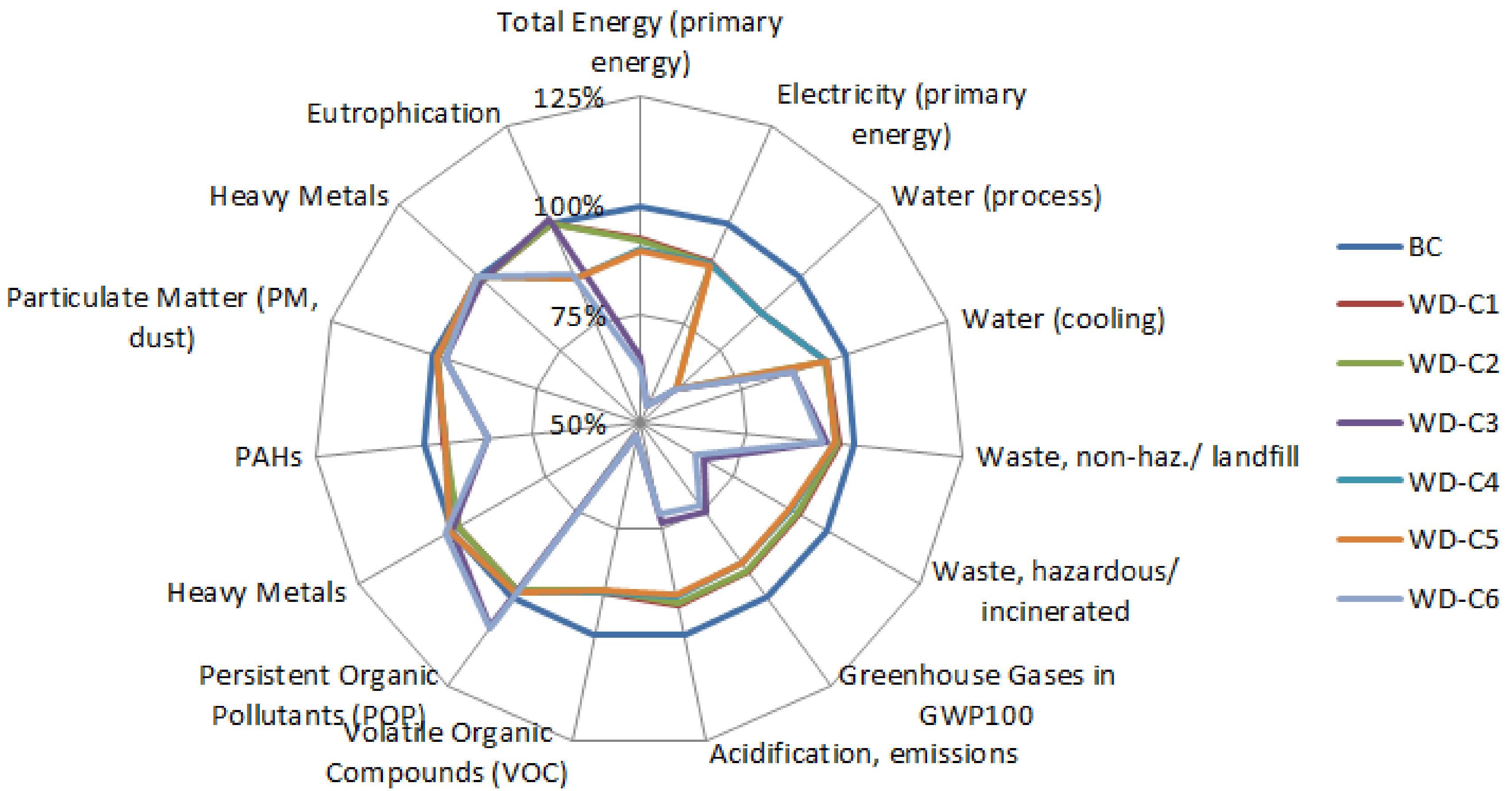


Figure 6.4: Life cycle impacts per year of combinations of improvement options selected for WD with respect to the Base case WD (=100%) – spider diagram

Figure 6.4 shows that:

- Any design option is beneficial on all categories. Trade-offs are registered for WD-C3 and WD-C6 that can save energy but they present an increase in POP, mainly as a consequence of the increased demand of materials
- Reductions of up -35% are estimated, but reductions depend heavily on the impact category and option considered. (VOC, WD-C3 and WD-D6, heat pumps)

Without aiming at developing a weighting mechanism (which has inherent limitations), it would be difficult to rank options without isolating specific indicators. Table 6.17 ranks options based on the total demand of primary energy. The main conclusions drawn are below:

- Primary energy demand ranges from 63% (WD-C6) to 92% (WD-C1 and WD-C2) of the base case. The highest energy saving potentials are obtained with the two design options implementing heat pump for the drying process (37% in case of WD-C6: heat pump for the drying process + extensive improvement of the washing function; 35% in case of WD-C3: heat pump for the drying process + basic improvement of the washing function). One could top-up the observed savings if technological options from the compatible washing machine are added, e.g. dosage (WM-D7 with -5% of energy consumption) and user behaviour information.
- A similar ranking is observed for GWP100, although the difference between heat-pump based (WD-C3 and WD-C6) and heat-pump free (WD-C1, WD-C2, WD-C4, WD-C5) options is reduced because of the use of refrigerants.
- Water saving is significant since the base case was assumed to use water for the wet-air condensing process: from -12% for WD-C1 and WD-C4 (improvement of the washing phase and of the wash and dry process only) to -39% for other combinations considering improvements in the washing phase and no demand of water for the drying process.

Table 6.17: Ranking of combinations of improvement options for WD based on selected environmental indicators

	Total Energy (primary energy)	Water (process)	Greenhouse Gases in GWP100
WD-C6	63%	61%	73%
WD-C3	65%	61%	76%
WD-C5	90%	61%	90%
WD-C4	90%	88%	90%
WD-C2	92%	61%	92%
WD-C1	92%	88%	93%
BC washer-dryers	100%	100%	100%

6.4 Costs (results from Ecoreport tool)

6.4.1 LCC of the design options for the base case washing machines

LCC parameters and calculations for each design options of design options are reported in this section.

Table 6.18 shows the life cycle costs for the single design options compared to the life cycle costs of the base case for washing machines with reference to a unit of product and the considered lifetime 12.5 years.

The life cycle costs for all the single design options except for the heat pump options are very similar. They range from -1% to +1% of the LCC of the base case (both in the case of the RRP and the ORP).

Taking into account the uncertainties especially of the cost data, the differences are not considered to be significant.

The single design option with the highest LCC is WM-D3 (heat pump), which mainly results from the high purchase price (12 to 52% higher than the base case). The LCC are increased by 4 to 22% (depending on the assumption regarding the purchase price). The high purchase price is to some extent compensated for by the savings in the electricity costs (electricity costs are reduced by 35%).

It should be noted, that this simplified approach does not internalise by means of monetisation any environmental externality. For instance, the single design option WM-D7 is approximately 70 euro including taxes. The potential saving for the consumers for this single design option is, if a reduction of 15% of detergent consumption is achieved, of about 75 euros over the life time of the machine. However, in this case the cost for the society due to the environmental loss (or the cost of an alternative mitigation measure in a wastewater treatment plant) is not included and internalised.

Table 6.18: LCC of single design options to a unit of product over its lifetime and compared to the base case washing machines.

Option	RRP (€)	OC (€/yr.)	MRC (€)	Total LCC RRP (€)	% diff to BC	ORP (€)	Total LCC ORP (€)	% diff to BC
Base case washing machines	577	112	45	2017		414	1855	
WM-D1: PM motor	599	109	45	2009	-0.40%	430	1840	-0.81%
WM-D2: Extension of std. programme duration	577	110	45	2003	-0.69%	414	1840	-0.81%
WM-D3(a): Heat Pump	1162	101	45	2473	22.61%	834	2146	15.69%
WM-D3(b): Heat Pump - assuming low cost of HP technology.	870	101	45	2181	8.13%	624	1936	4.37%
WM-D 4: Improved drenching	645	105	45	2001	-0.79%	463	1819	-1.94%
WM-D5(a): Higher spinning extraction (1600 rpm)	655	110	45	2081	-0.79%	470	1896	-1.94%
WM-D5(b): Higher spinning extraction (1600 rpm) + PM motor	677	108	45	2073	-0.79%	486	1882	-1.94%
WM-D6: Improved load detection and adaptation	597	106	45	1969	-0.79%	428	1801	-1.94%
WM-D7: Automatic detergent dosage	675	105	45	2032	0.74%	484	1842	0.7%
WM-D8(a): Consumer feedback on loading, full load	597	92	45	1790	-0.69%	428	1622	-1.94%
WM-D8(b): Consumer feedback on loading, +41% load	597	98	45	1871	-0.69%	428	1703	-1.94%
WM-D8(c): Consumer feedback on loading, +21% load	597	104	45	1941	-0.69%	428	1773	-1.94%

6.4.2 LCC of the combinations of the design options for the base case washing machines

Table 6.19 shows the life cycle costs of the combination of the design options compared to the lie cycle costs of the base case washing machines with reference to a unit of product and the considered lifetime of 12.5 years.

The life cycle costs of all combinations are very similar. They range from 1848 to 2206 euros (RRP), representing a cost saving compared to the base case of -8 to 9%. When taking into account the ORP instead of he RRP the cost savings are slightly higher, i.e. from -11% to 2%.

An interesting case is the LCC of the combination WM-C7 which are, depending on the assumption regarding the purchase price, 9 or 2% higher than the base case. This can be attributed to eh high purchase price due to the inclusion of a heat pump. The purchase price of WM-C7 is almost twice as high as that of the base case. In contrast the electricity costs are reduced by approximately 35% which results in an overall increase of the LCC in only 9 and 2%.

The life cycle of the combinations WM-C1 to WM-C5(a) are nearly the same: they vary only between -1% and -3% (RRP) and -2% to -5% (ORP). From WM-C1 to WM-C5(a) the purchase price is more or less increasing whereas the electricity costs are decreasing by basically the same amount, resulting in similar LCC.

Table 6.19: LCC of the combination of single design options to a unit of product over its lifetime and compared to the base case washing machines.

Option	RRP (€)	OC (€/yr.)	MRC (€)	Total LCC RRP (€)	% diff to BC	ORP (€)	Total LCC ORP (€)	% diff to BC
Base case washing machines	577	112	45	2017		414	1855	
WM-C1	618	104	45	1958	-2.93%	444	1783	-3.88%
WM-C2	665	100	45	1958	-2.93%	477	1770	-4.58%
WM-C3	686	98	45	1954	-3.12%	493	1760	-5.12%
WM-C4	597	105	45	1955	-3.07%	428	1786	-3.72%
WM-C5(a)	616	106	45	1989	-1.39%	442	1815	-2.16%
WM-C5(b)	616	95	45	1848	-8.38%	442	1675	-9.70%
WM-C6(a)	803	91	45	1988	-1.44%	577	1761	-5.07%
WM-C6(b)	803	82	45	1871	-7.24%	577	1644	-11.37%
WM-C7	109 6	84	45	2196	8.87%	787	1887	1.73%
WM-C8 (solar heating)	881	81	45	1937	-3.97%	633	1688	-9.00%
WM-C8 (avg mix of electricity, NG, oil for water heating)	881	88	45	2022	0.25%	633	1773	-4.42%
WM-C9(a)	881	102	45	2206	9.37%	633	1958	5.55%
WM-C9(b)	881	89	45	2044	1.34%	633	1796	-3.18%

6.4.3 Best available and Least LCC options for washing machines

6.4.3.1 Selection of the combination of design options for washing machines

To select the combination, first the single design options have been ranked according to their Simple Payback Period (SPP) (see COWI and VHK (2011b)). The SPP has been calculated as follows:

$$SPP= \Delta PP / \Delta OE$$

With

ΔPP: extra investment in purchase price (both RRP and ORP) of the design option compared to the base case

ΔOE: reduction in annual operating expense of the design option compared to the base case

The SPP was calculated only when the ΔOC is negative, this means when the improvement option allows reducing the operating costs.

Table 6.20 shows the simple payback period for the design options of the base case washing machines (calculated both with the recommended and the observed retail price)) in increasing order. It can be seen that when calculating with the ORP the simple payback periods are shorter, however the resulting order of the options is the same. The SPP allows clustering options in different groups:

- Group I includes improvement options that comes with no added costs (i.e. WM-D2) and that consequently are recovered in zero years
- Group II includes improvement options in which the additional investment is recovered in less than half of the product's lifetime (i.e. WM-D8, WM-D6)
- Group III includes the improvement options in which the additional investment is recovered between half and one product's lifetime (i.e. WM-D4, WM-D1)
- Group IV includes the improvement options in which the additional investment recovered in about one product's lifetime (i.e. WM-D7), before or after one product's lifetime depending on the reference purchase price
- Group V includes the improvement options in which the additional investment would require more than the product's lifetime to be recovered (i.e. WM-D5, WM-D3)

Table 6.20: Simple Payback Periods (SPP) of the design options for washing machines

	SPP (years) (by ORP)	SPP (years) (by RRP)	Group
WM2: Extension of std. progr. duration	0.0	0.0	Group I: No added costs
WM8(a): Consumer feedback on loading, full load	0.7	1.0	Group II Economic investment is recovered in less than half of the product's lifetime
WM8(b): Consumer feedback on loading, +41% avg load	1.1	1.5	
WM8(c): Consumer feedback on loading, +21% avg load	1.8	2.6	
WM6: Improved load detection and adaptation	2.6	3.6	
WM1: PM motor	6.5	9.1	Group III Economic investment recovered between half and one product's lifetime
WM4: Improved drenching	7.3	10.1	
WM7: Automatic detergent dosage	10.6	14.8	Group IV Economic investment recovered in about one product's lifetime (before or after one product's lifetime depending on the reference purchase price)
WM5(b): Higher spinning extraction (1600 rpm) + PM motor	20.2	28.1	Group V Economic investment recovered only extending the product's lifetime
WM3(b): Heat Pump - lower cost of techn.	20.4	28.4	
WM3(a): Heat Pump	40.7	56.7	
WM5(a): Higher spinning extraction (1600 rpm)	47.5	66.2	

One interesting design option is the WM-D8 (consumer feedback on loading). Table 6.20 and Table 6.21 present a comparison of the SPP depending on the loading of the machine. This sensitivity analysis was carried out due to the uncertainties to estimate the improvements that this design option can bring, as they are heavily dependent of the user aptitude. According to the results, it can be concluded that:

- If the users would increase the average load by at least 21% as a consequence of the implementation of this option, the SPP would be shorter than half of the product's lifetime
- If the users would increase the average load by 4-8%, the additional investment will be recovered within the lifetime, but.
- If the users would increase the average load less than 4-8%, the additional investment will not be recovered within the lifetime.

A second step in this study is to consider the combination of single design options for the washing machine. Obviously the combinations of single design options have better performance form the efficiency point of view than the implementation of single design options. However, as commented in section 6.3, the improvements of the combinations of single options are not the direct sum of the single design options since it depends on the interaction among the design options.

Therefore, taking into account

- The ranking of SPP of single design options,
- Stakeholder input on possible or impossible combinations and
- Market research on existing appliances and the respective implemented design options.

The following combinations were selected:

- WM-C1: WM-D1+WM-D6 (PM motor + improved load detection and adaptation)
- WM-C2: WM-D6+WM-D4 (improved load detection and adaptation and improved drenching)
- WM-C3: WM-D1+WM-D6+WM-D4 (PM motor, improved load detection and adaptation and improved drenching)

  WM-C4: WM-D6+WM-D2 (improved load detection and adaptation and extension of standard programme duration)

  WM-C5(a): WM-D6+WM-D8 (improved load detection and adaptation and consumer feedback on loading) (*assumption the load does not change*)

  WM-C5(b): WM-D6+WM-D8 (improved load detection and adaptation and consumer feedback on loading) (*assumption the load changes increasing 41%*)
- WM-C6(a): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C6(b): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load changes increasing 41%*)
- WM-C7: WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8+WM-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage, consumer feedback on loading and heat pump)

Additionally some of the options discussed separately were also calculated as possible combinations

- WM-C8: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8 + hot-cold filling (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C9(a): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 + increased rated capacity (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load does not change*)
- WM-C9(b): WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8 + increased rated capacity (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading) (*assumption the load changes increasing 41%*

The assumptions regarding the saving potential and additional costs of these combinations of options can be found in section 6.1.2.8.

Table 6.21 shows the SPP of the combinations of design options. In accordance to the life cycle cost results (see section 6.4.2), it can be seen that only the combination WM-C7 and WM-C9(a) have a payback time which is longer than the assumed life time of washing machines of 12.5 years (both the RRP and the ORP). In case of the combinations WM-C8 and WM-C9(b) it depends if the RRP or the ORP is regarded if the SPP is shorter or around the assumed life time of washing machines. All other combinations have shorter SPP which correspond to lower life cycle costs than the base case.

Table 6.21: Simple Payback periods (SPP) of the combination of design options for washing machines

	SPP (years) (ORP)	SPP (years) (RRP)
WM-C5(b)	1.7	2.3
WM-C4	2.1	3
WM-C1	3.6	5.1
WM-C5(a)	5.2	7.2
WM-C2	5.3	7.4
WM-C6(b)	5.4	7.6
WM-C3	5.7	7.9
WM-C8 (solar heating)	7.1	9.9
WM-C6 (a)	7.9	11.1
WM-C8 (avg mix of electricity, NG and oil for water heating)	9.1	12.7
WM-C9(b)	9.8	13.7
WM-C7	13.7	19
WM-C9(a)	23.7	33

6.4.3.2 Least Life Cycle costs calculations for washing machines

The life cycle costs and the environmental impacts of the single design options are plotted in one graph to give the least life cycle curve. Figure 6.5 and Figure 6.6 show these graphs for base case washing machines taking into account the recommended retail price (RRP) and the observed retail price (ORP). As environmental impact indicator the total energy consumption (MJ) over the lifecycle is chosen. The only difference between the two graphs of the base case washing machine is on the LCC results, the environmental impacts are identical.

From the figures it can be seen that the shape of the LCC is basically the same for the RRP and the ORP case: the life cycle costs of combinations WM-C1 to WM-C5 of the base case washing machines is slightly decreasing. When taking into account the RRP, the LCC decreases smoother than when considering the ORP. The LCC curve calculated with the RRP is obviously higher than that calculated with the ORP. It has to be considered however, that all differences between the life cycle costs of combinations WM-C1 and WM-C5 are not significant. Note that the left vertical axes in Figure 6.5 and Figure 6.6 do not start from zero.

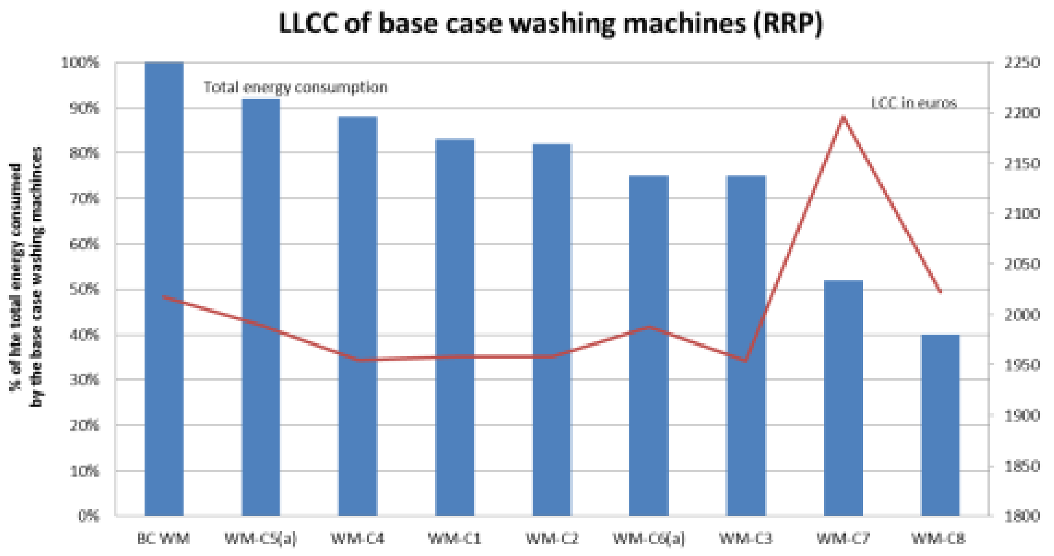


Figure 6.5: LCC for the combination of the design options together with the total energy consumption over the lifetime for base case washing machines taking into account the recommended retail price (RRP)

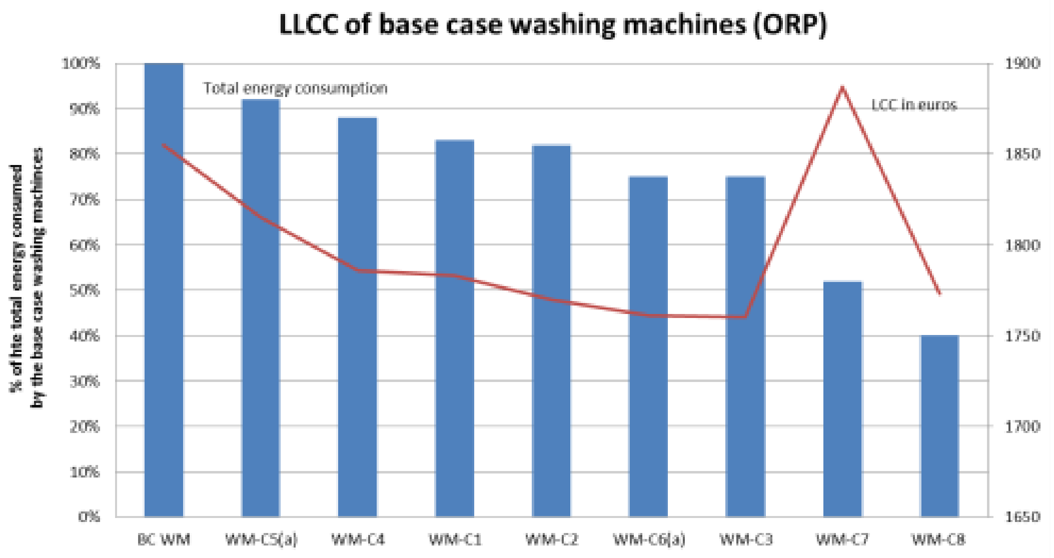


Figure 6.6: LCC for the combination of the design options together with the total energy consumption over the lifetime for base case washing machines taking into account the observed retail price (ORP)

6.4.4 LCC of the design options for the base case washer dryers

LCC parameters and calculations for each design options are reported in this section. The methodology replicates the method followed in section 6.4.1

Table 6.22 shows the life cycle costs for the single design options compared to the life cycle costs of the base case for washer dryers with reference to a unit of product and the considered lifetime 12.5 years.

The life cycle costs for all the single design options except for the heat pump options are very similar. They range from -11% to 1% of the LCC of the base case (both in the case of the RRP and the ORP). Taking into account the uncertainties especially of the cost data, the differences are not considered to be significant.

The single design option with the highest total LCC is WD2b or WD-WM5(b) depending on the purchase price considered, which mainly results from the high purchase price and the poor energy saving, respectively.

Table 6.22: LCC of single design options to a unit of product over its lifetime and compared to the base case washer dryers.

Option	RRP (€)	OC (€)	MRC (€)	Total LCC RRP (€)	% diff to BC	ORP (€)	Total LCC ORP (€)	% diff to BC
Base case washer driers	1154	2237.5	45	3436.5		829	3111.5	
WD1: Air condensing system	1193	2087.5	45	3325.5	-3%	857	2989.5	-4%
WD2a: Heat Pump – drying	1739	1687.5	45	3471.5	1%	1249	2981.5	-4%
WD2b: Heat Pump - drying, lower cost of techn.	1447	1387.5	45	3179.5	-7%	1039	2771.5	-11%
WD3: Improved design of combined wash&dry programmes	1154	2212.5	45	3411.5	-1%	829	3086.5	-1%
WD-WM5(b): Higher spinning extraction + PM motor	1254	2175	45	3474	1%	900	3120	0%

6.4.5 LCC of the combinations of design options for the base case washer dryers

Table 6.23 shows the life cycle costs of the combination of the design options compared to the lie cycle costs of the base case washer dryers with reference to a unit of product and the considered lifetime of 12.5 years.

The life cycle costs of all combinations are very similar. If the analysis considered the RRP, all combinations show a higher LCC than the base case. The decrease ranges from -11% to -1% of the base case. If the analysis considered the ORP, all combinations show a lower LCC than the base case. The decrease ranges from -3% to -11%. This is an interesting observation that points out the importance of the purchase price of this appliance on the overall LCC.

Table 6.23: LCC of single design options to a unit of product over its lifetime and compared to the base case washer dryers.

Option	RRP (€)	OC (€)	MRC (€)	Total LCC RRP (€)	% diff to BC	ORP (€)	Total LCC ORP (€)	% diff to BC
Base case washer driers	1154	2237.5	45	3436.5		829	3111.5	
WD-C1	1264	2062.5	45	3371.5	-2%	907	3014.5	-3%
WD-C2	1303	1900	45	3248	-5%	935	2880	-7%
WD-C3	1849	1487.5	45	3381.5	-2%	1327	2859.5	-8%
WD-C4	1381	1975	45	3401	-1%	991	3011	-3%
WD-C5	1420	1825	45	3290	-4%	1019	2889	-7%
WD-C6	1849	1400	45	3294	-4%	1327	2772	-11%

6.4.6 Best available and Least LCC options

6.4.6.1 Selection of the combination of design options for washer dryers

Table 6.24 shows the simple payback period for the design options of the base case washer dryers (calculated both with the recommended and the observed retail price) in increasing order. The options have also been aggregated depending on the number of years of SPP and their lifetime as done in section

6.4.3. It can be seen that when calculating with the ORP the simple payback periods are shorter, however the resulting order of the options is the same.

Table 6.24: Simple Payback Periods (SPP) of the design options for washer dryers

	SPP (years) (by ORP)	SPP (years) (by RRP)	Group
WD-D3: Improved design of combined wash&dry programmes	0	0	Group I: No added costs
WD-D1: Air condensing system	2.2	3.1	Group II Economic investment is recovered in less than half of the product's lifetime
WD-D2b: Heat Pump - drying, lower cost of techn.	4.7	6.6	
WD-D2a: Heat Pump – drying	9.5	13.2	Group IV Economic investment recovered in about one product's lifetime (before or after one product's lifetime depending on the reference purchase price)
WD-WM5(b): Higher spinning extraction + PM motor	13.2	18.4	Group V Economic investment recovered only extending the product's lifetime

According to the information of the Table 6.24, the design options WD-D3, WD-D1 and WD-D2 are interesting improvements as the investments needed are recovered in less than half the lifetime of the product. The design option WD-WM5(b), however, is not recovered with the period of the technical lifetime of the washer dryer.

As done for the base case of washing machines, the study progresses towards the combination of the single design options for the washer dryer. As before, the combinations of single design options have better performance from the efficiency point of view than the implementation of single design options, but the combinations of single options are not the direct sum of the single design options. The same assumptions and limitations regarding the no possible combinations have been considered.

The following combinations were selected:

- WD-C1: WM-D1+WM-D4+WM-D6+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through improved design of combined wash&dry programme)
- WD-C2: WM-D1+WM-D4+ WM-D6+WD-D1+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through air condensing system and combined wash&dry programme)
- WD-C3 : WM-D1+WM-D4+ WM-D6+WD-D2+WD-D3 (PM motor, improved load detection and adaptation and improved drenching, improvement of the drying phase through heat pump and combined wash&dry programme)
- WD-C4: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through improved design of combined wash&dry programme)
- WD-C5: WM-D1+WM-D6+WM-D4+WM-D7+WM-D8+ WD-D1+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through air condensing system and combined wash&dry programme)
- WD-C6: WM-D1+WM-D6+WM-D4+ WM-D7+WM-D8+ WD-D2+WD-D3 (PM motor, improved load detection and adaptation, improved drenching, automatic detergent dosage and consumer feedback on loading, improvement of the drying phase through heat pump and combined wash&dry programme)

The assumptions regarding the saving potential and additional costs of these combinations of options can be found in section 6.1.3.3

Table 6.25 shows the SPP of the combinations of design options. In accordance to the life cycle cost results (see section 6.4.4)), it can be seen that all the combinations recover the additional investment within the 12.5 year lifetime of the appliance (both the RRP and the ORP). In case of the combinations WD-C2, WD-C1 and WD-C5, the additional investment is recovered within the first half lifetime or just above it, depending if the RRP or the ORP is regarded. This makes the combinations more attractive.

Table 6.25: Simple Payback periods (SPP) of the combination of design options for washer dryers

	SPP (years) (ORP)	SPP (years) (RRP)
WD-C2	3.9	5.5
WD-C1	5.4	7.6
WD-C5	5.6	7.9
WD-C6	7.4	10.3
WD-C4	7.7	10.7
WD-C3	8.2	11.4

6.4.6.2 Least Life Cycle costs calculations for washer dryers

The life cycle costs and the environmental impacts of the single design options are plotted in one graph to give the least life cycle curve. Figure 6.7 and Figure 6.8show these graphs for base case washer dryers taking into account the recommended retail price (RRP) and the observed retail price (ORP). As environmental impact indicator the percentage of the total energy consumption compared to the base case over the lifecycle is chosen. The only difference between the two graphs of the base case washer dryers is on the LCC results, the environmental impacts are identical.

From the figures it can be seen that the shape of the LCC is basically the same for the RRP and the ORP case: the life cycle costs of all combinations apart from WM-C3 of WM-C6 of the base case washer dryers is decreasing. When taking into account the ORP, the LCC decreases smoother than when considering the RRP. The LCC curve calculated with the RRP is obviously higher than that calculated with the ORP. It has to be considered however, that the differences between the life cycle costs of these combinations and the combinations WM-C3 and WM-C6 are not significant. Note that the vertical axes in Figure 6.7 and Figure 6.8 do not start from zero.

WD-C6 is considered the LLCC option. This is a combination that includes among other improvements options a heat-pump for drying process, improved design of the wash and dry process, consumer feedback mechanism on loading and automatic detergent dosing. WD-C3 implements heat pump for the drying process, improved design of the wash and dry process and a more limited set of improvements for the washing phase (improved loading detection and adaptation, PM motor and improved drenching)

Energy and economic saving as can be achieved through all the design options analysed and without the need of increasing loading conditions. Further benefits would be achieved if the laundry process were carried out with higher loads as explained in the previous section. This could be realized in combinations WD-D4, WD-D5 and WD-D6.

The presence of an air-based condensing system seems to be convenient from a LCC perspective than a water-based condensing system (WD-C2 vs WD-D1).

Finally comparing washing machines with washer dryers, it can be observed that the implementation of a heat pump for the washing process would increase the LCC and would allow lower energy savings than the application of the same technology to the drying process. The parallel implementation of heat pump technologies to both washing and drying processes is considered as a BNAT in this study.

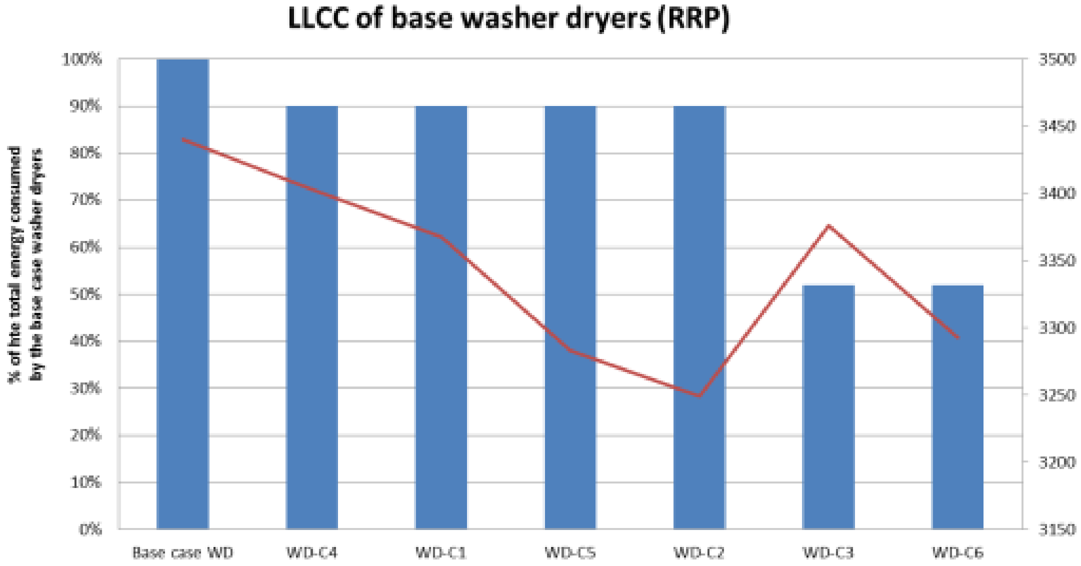


Figure 6.7: LCC for the combination of the design options together with the total energy consumption over the lifetime for base case washer dryers taking into account the recommended retail price (RRP)

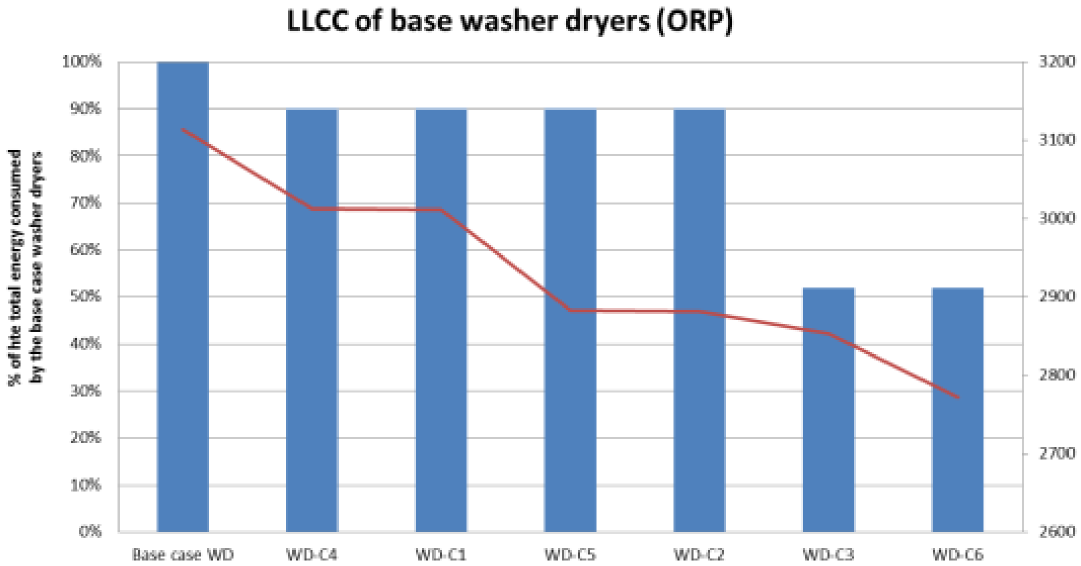


Figure 6.8: LCC for the combination of the design options together with the total energy consumption over the lifetime for base case washer dryers taking into account the observed retail price (ORP)

6.5 Level of integration of specific technologies

The assessment of technologies indicated the maximum potential energy and water saving achievable by implementing one or more technologies to the base case. Some of these technologies are widely implemented in the models that are currently on the shelves, while some are rare. The base case used in the assessment could be considered as a basic model where one or more design options have been already implemented. Therefore the saving potential that could still be exploited in the coming years is estimated as the difference between the maximum energy saving potential of the specific technology and the current energy consumption of the base case (which already considered some of these technologies).

With feedback from some manufacturers, the integration of the design options in the currently available models has been roughly estimated.

An attempt has also been made to estimate the possible use of these technologies in the next 10-15 years. Due to the high uncertainty associated with such quantifications, the figures have not been used to refine saving figures. This information is provided in Annex 8.6

7 Task 7: Policy analysis and scenarios

Building on the information gathered and produced in the previous sections, this task aims at describing policy measures which could be proposed for household washing machines and washer-dryers. These measures relate to generic and specific ecodesign requirements, the energy label and other communication requirements, and/or possible resource efficiency requirements, which have implications for standards and measurement methods. More widely, these measures also affect consumer information and education.

Self-regulation or voluntary agreements by industry (as set out in the Ecodesign Directive 2009/125/EC) have been explored in previous regulation work on washing machines and washer dryers, and are not seen as alternative to the existing Ecodesign measures, however they might be supportive for example in terms of consumer information campaigns. This is of particular interest for issues like maximising the machine loading, and machine maintenance good practice.

A full list of potential policy options is provided in Annex 8.5 and Annex 8.6. After discussion with stakeholders a short-list of selected policy measures has been discussed more in detail. The expected benefits and costs of these measures, possible drawbacks for the environment as well as for the consumers industry and other stakeholders are quantified and/or described.

7.1 Stakeholder consultation and policy options

During the preparatory work a continuous and transparent stakeholder consultation has taken place. Apart from bilateral contacts with stakeholders for information exchange, two technical working group (TWG) meetings have been organised. The TWG is composed of experts from Member States' administration, industry, NGOs and academia. The first TWG meeting, focusing on Tasks 1-4, took place in Seville on 24th June 2015, the second TWG meeting, focusing on Tasks 5-7, in Brussels on 18th November 2015. An additional meeting in form of a webinar took place on 7th October 2016, specifically dedicated to material efficiency.

Additionally, the project team has visited different manufacturers, test labs, recyclers and trade fairs to investigate the products in detail and to stay up to date with the latest developments. Two questionnaires have been distributed to the stakeholders along the process, addressing information and data updates, and gathering the opinions on scope, definitions, and performance parameter specifications like electricity and water consumption, programme duration, etc. an online communication system BATIS has been set-up for easy exchange of documents between registered stakeholders. A website was made available to have the final working documents in the public domain.

Regarding policy options, a comprehensive list of potential policy options including expected benefits and potential disadvantages, challenges and / or drawbacks was compiled and circulated to stakeholders during summer 2015 (see Annex 8.5 for washing machines and Annex 8.6 for washer-dryers and Annex 8.5 for material efficiency of both appliances).

Stakeholders were asked for additional feedback: during spring 2016 for policy options related to energy and water consumption of washing machines and washer-dryers, and during autumn 2016 for those related to end-of-life, durability and material efficiency. These are described in more detail in the following sections.

7.2 Current status of household washing machines and washer-dryers in the policy landscape of Ecodesign and Energy labelling

Household washing machines and washer-dryers already have a long history when it comes to ecodesign and energy label. The first energy labels for these product groups were based on the Directive 92/75/EEC (European Council 1992).

Commission Directive 95/12/EC established the first energy label for household washing machines. A first revision resulted in Commission Regulation 1061/2010 with requirements reaching into 2016 (European Commission 2010a). Moreover, in 2010 also ecodesign requirements came into effect for household washing machines (not including washer-dryers), by Commission Regulation 1015/2010 (European Commission 2010b). Table 7.1 shows that only three label classes (i.e. A+, A++ and A+++) are allowed on the market for washing machines ≥ 4 kg since December 2013.

According to the CECED database, all 36 models of 4 or 4.5 kg on the European market are labelled as A+. In 2014 about 43% of the washing machines that were sold on the European market were A+++ (Michel et al. 2015). In terms of number of models labelled as A+++, these were about 50% in 2013, about 60% in 2014, and about 65% in 2015 (CECED 2014, 2015, 2016).

The label class A could be in theory allowed only for washing machines with rated capacity < 4 kg. According to the feedback of a manufacturer, compact machines have a niche market (<< 1%) and have limitations in reaching energy classes higher than A. No products of this type were listed in the last CECED database. This type of machines are demanded for instance by consumers living in very small apartments.

Table 7.1: Overview of the current Ecodesign requirements for household washing machines, which classes are phased out

Class	EEI	Tier Dec 2011	Tier II Dec 2013
A+++	EEI < 46		
A++	46 ≤ EEI < 52		
A+	52 ≤ EEI < 59		
A	59 ≤ EEI < 68		Banned for all machines ≥ 4 kg
B	68 ≤ EEI < 77	Banned for all machines	
C	77 ≤ EEI < 87		
D	EEI ≥ 87		

The energy label for washer-dryers was published in Commission Directive 96/60/EC in 1996 (European Commission 1996), and is still valid today. In 2013, around 50% of all washer-dryer models were labelled in Energy Efficiency class A, around 45% in class B (CECED 2014). A larger number of A-labelled models of about 65% were found in 2015 (CECED 2016).

Altogether, this called for a revision of the energy label classes for washing machines, together with an update of the 1996 Energy label for washer-dryers, especially in view the upcoming revision of the Energy labelling Directive 2010/30/EU.

A sample of washing machines models sold in the EU in 2014 (CECED database) with a rated capacity ≥ 5 kg is shown in Figure 7.1 together with the current labelling classes and ecodesign requirements. It shows that a large share of washing machines already far exceeds Energy Efficiency class A+++, especially for appliances with larger rated capacity. On the other hand, smaller machines below than 5 kg hardly achieve Energy Efficiency Classes better than A+++. Please note that the figure shows the yearly consumption under standard conditions, i.e. under standard cotton 40 °C and standard cotton 60 °C at full and half loads, and is not a direct representation of real life operation of the machines.

The market of washing machines is strongly influenced by the energy label, since this plays as a powerful marketing instrument. At first glance, it seems necessary to refresh the scale and revise the MEPS since some of the declared performance values are achieved by prolonged duration of the standard programmes. For instance, the appliance marked with a red square in Figure 7.1 consumes only 89 kWh/year but the programme lasts for 300 minutes, i.e. five hours in the standard 60 °C cotton programme. In comparison, a current heat pump washing machine on the market consumes 98 kWh/year, and the programme lasts 230 minutes.

According to the assessment of Task 6, combinations of design options could allow reducing the energy consumption values below A+++ -10% and -20%. However, without extending the programme duration beyond 3hrs, A+++ -50% could be achieved through the simultaneous application of a set of technical improvement options (e.g. improved load detection and adaptation, PM motor, improved drenching, consumer feedback on loading) and either efficient hot-cold fill connections, ideally with solar heating, or a heat pump. Both solutions have technical or financial limitations, as described in Task 6.

Task 6 revealed additionally that there is a high potential for energy savings by the implementation of design options that influence the user behaviour, such as increasing the loading. These measures are less expensive, but in practice more difficult to make effective, and monitor.

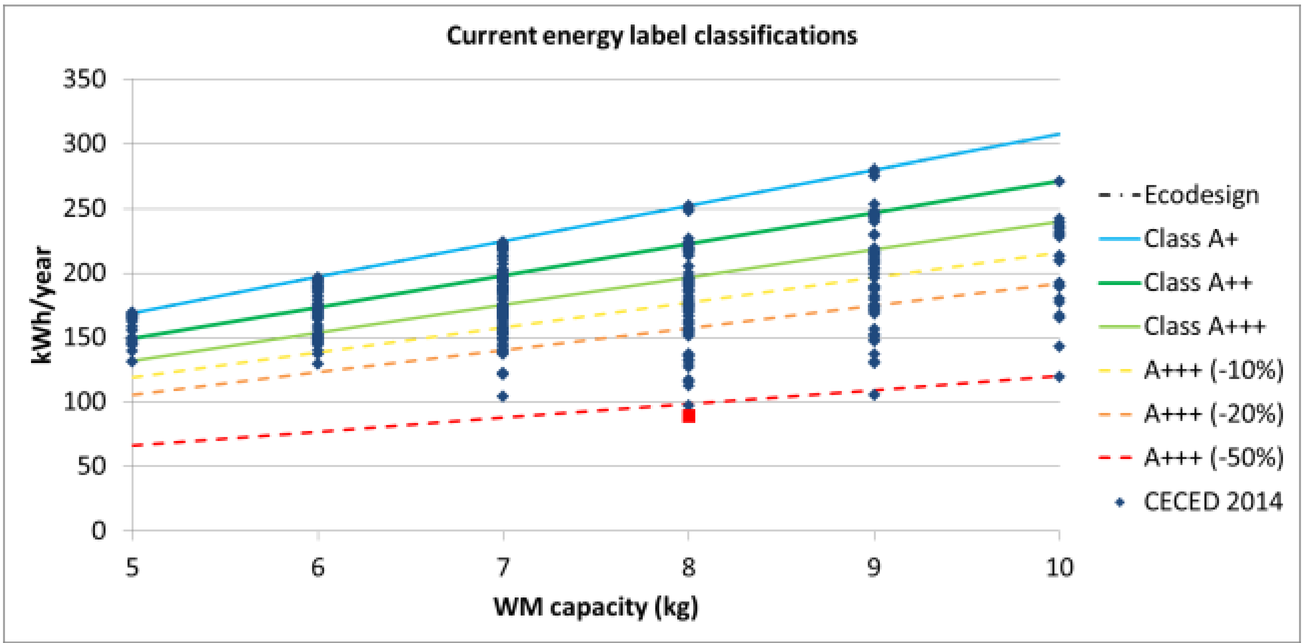


Figure 7.1 Yearly energy consumption of washing machine models on the market in 2014 in function of their rated capacity c (for 5 kg ≤ c ≤ 10 kg) together with the current labelling classes and ecodesign requirement.

7.3 Policy options related to energy and water consumption for washing machines.

Table 7.2 shows an overview of selected policy issues and options for further discussion related to water and energy consumption. The options are discussed more in detail in the sections below.

Table 7.2: Overview of the selected policy options for washing machines

Issue	Possible policy options	Expected benefits	Possible drawbacks and risks
TIME (programme duration reduction)	Adding the programme time of the tested cotton programme(s) on the Energy label	Manufacturers may reduce the time of the programmes if they see consumers pay attention to this and respond to the labelling	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested cotton programmes, e.g. 3 h	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway (Sinner circle). Most appliances will cluster on few classes, reducing the influence of the label on purchase
TEMPERATURE (more transparent communication to users)	1) Consumer information (e.g. in the user manual) about the temperature reached by programmes 2) Adding a requirement for a minimum temperature and time to be reached, at least in the 60 °C cotton programme	1, 2) Knowledge of the temperature for the consumers that know its effects (e.g. hygiene, odours) and choose the programme deliberately for this reason. 2) Overall average hygiene of the machine's wet areas improves. Imposing this condition makes the testing be sufficiently demanding on the machine's heating system performance.	1,2) Testing protocol needed. Measurement method for the temperature inside the textile load needs to be defined or adapted from professional WMs. Testing burdens increase. 2) Manufacturers reduce their leeway (Sinner circle). Most appliances will cluster on few classes, reducing the influence of the label on purchase If not introduced, the offer of cotton programmes where the actual temperature is not the declared may continue and further spread. The exact temperature and duration may be difficult to justify, an option can be a consensus over a minimum common denominator (e.g. 55 °C for 2 seconds) Depending on the conditions set, energy saving may be limited

Issue	Possible policy options	Expected benefits	Possible drawbacks and risks
	Requirement of presence of a separate programme for hygienisation of textiles by means of high temperature	Clear indication for consumers; no need to increase the energy consumption of the standard programmes as hygienic needs only occur seldom; increasing transparency for consumers	Consumers might choose the hygiene programme more often as really needed, i.e. energy consumption might increase compared to today's choice of standard 60° cotton programme for hygienic needs A method for assessing the hygiene performance may be needed.
LOAD (increase of average loading)	Test cycles: 1) Full / half loads 2) Full load and fixed load (s) (between 2-4 kg, e.g. 3.4 kg, or two loads of 2kg and 4 kg) 3) Full and partial loads (e.g. 1/3 and 2/3) 4) Partial loads (e.g. 1/3 and 2/3)	Machines should be subject to a demanding test that rewards those that better adapt their energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not be enough.	Ensure that the testing procedure does not become overly complex and costly (e.g. a max amount of laundry equivalent to 5 full load cycles) Fixed loads (e.g. 2kg, 4kg would allow comparability across machines, regardless of capacity). Stakeholders indicate that partial loads of a full load (e.g. ½., 1/3, 2/3) may in practical terms be easier (cheaper) to implement for testing than fixed loads (e.g. 3.4kg)
WASHING PERFORMANCE	Keep as currently: >1.03	Continuity	One shall ensure that the measurement of performance on average or on sub-cycles (e.g. after full load, and after partial load) is designed to avoid playing with average performance, as this may be against the objective of rewarding load adaptation
PROGRAMME RESTRICTION for certain programmes to avoid undermining the use of energy-saving programmes	1) allow the use of names such as 'eco', 'super saver' (lower temperature, long duration) 2) avoid names that can be associated with the testing cotton programmes	1) None 2) Avoid other programmes names that consumers can associate to testing or to the 'normal' or 'daily' use	1) There is no reason for restriction of low consuming programmes. If consumers are willing to use them, this should not be hindered. Some rules may be needed for the declarations of 'eco' or 'super saver', e.g. only if the programmes are more efficient than the normal cotton.

Issue	Possible policy options	Expected benefits	Possible drawbacks and risks
			2) Enforcement can be challenging
PROGRAMME INDICATION AND SELECTION to promote use of energy-saving programmes	Programme indication on the display: ‘Standard cotton programme’ / arrow symbol	Continuity	People might not understand the underlying design of the programme and thus not choose it
	Default programme selection (when available in the appliance)	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are two standard programmes; consumers might easily overcome such default selection

7.3.1.1 Differences between real life use of the appliances and the current ecodesign and energy label regulations

The information gathered in previous tasks indicates that significant improvement potential for the energy efficiency of household washing machines could be realised if consumers were willing to use more often the most energy-efficient programmes and to increase the loading conditions. Additional energy savings would result from the implementation of technical innovation, which would be most effective if loading conditions increased

There are several aspects that indicate a need for revising the regulations and to align appliance testing with real-life use, while stimulating competitiveness by keeping incentives to manufacturers to continue improving their appliances. The aspects identified are as follows:

- Broad programme range: Washing machines are characterised by offering a broad range of programmes, besides the standard cotton 40 °/60 °C programmes which are the basis for the energy label declarations. In comparison to the standard programmes, the other programmes are not optimised from the energy efficiency point of view to the same extent as the standard programmes. However, the 2015 user survey indicates that 90% of respondents expect or understand that the label represents the performance of the washing machine in all programmes, and not only in some of them.
- Minor use of standard programmes / other programmes for the same purpose: The standard cotton 40 °/60 °C programmes are not often used by consumers (17% on average, and 5% for the programmes lasting more than 3 hours). Moreover, there are other programmes for the same purpose (i.e. the 'normal' cotton 40 °/ 60 °C programmes) which are more often used (26% on average). These 'normal cotton' programmes consume more energy and water than the standard programmes, but have normally a shorter duration. In some appliances, consumers can alter the standard cotton 40 °/60 °C programme by adding options such as ‘short’ or different temperatures. These alterations have an influence on the energy and water efficiency of the programme, and thus differ from the measurements that are the basis for the label declaration.
- Long programme duration: The standard cotton 40 °/60 °C programmes are designed with an improved energy efficiency but at the expense of reducing the washing temperature and increasing mechanical action by prolonging the programme duration –Time extension is however a characteristic not convenient to many consumers. The 2015 user survey revealed a high reluctance by the consumers to use long programmes beyond 3 hours.

- Underloading combined with an increasing rated capacity of machines: consumer research shows that the average amount of loading is only 3.3 kilogram per cycle for the cotton programmes, which is far away from full load conditions of most machines on the market. It is also lower than the average of 5 kg load used for measurement under standard conditions for a 7 kg capacity machine. Additionally, there is a trend towards increasing rated capacities of machines, since they are in general better-rated according to the current EEI calculation formula.
  A lower energy and water consumption per kilogram of laundry is only obtained if the machines are fully loaded, therefore measures aiming at making aware consumers of the savings resulting from larger loading could help to reduce the overall energy consumption of this product group.

- Limitations on the technical innovation: Manufacturers of appliances often mention that there is a relatively small improvement potential with current technologies regarding the energy performance of the washing machines. They however confirmed that there is still improvement potential for the drying phase of washer dryers.

The revised regulations need therefore to address the mismatches listed above between the real life use and the reference washing machine operation used for label declarations and ecodesign requirements, and exploit the remaining technical development potential. The revision will require that the current testing standard is also thoroughly revised.

7.3.1.2 Programmes for the declarations on the energy label and ecodesign requirements of washing machines

The current requirements, in place since 2010, introduced two so called 'standard' programmes, used for the calculation of the energy consumption, and other parameters declared for household washing machines. The regulation text indicates that the standard programmes shall be:

- designed to wash cotton normally soiled at 40°C and at 60°C.
- tested at full load and half load.
- the most efficient programmes in terms of their combined energy and water consumption for cotton (not including the 20°C programmes).

The definition of these programmes makes them suitable for cotton laundry normally soiled at full or half load.

As discussed in previous sections, these aspects are not fully representative of the usage conditions under real-life conditions, where more kinds of textiles are loaded into the machine, the soling level is usually not so high, and the loading is on average lower.

The revision of the standard testing conditions is therefore needed to ensure that the programme selected is sufficiently representative of both:

- the use by the consumers, and
- the operation of the appliance (in terms of e.g. mechanical stress and temperature conditions)

Ideally, the testing of all the programmes in a machine would be desirable. However, this would imply excessive costs for the manufacturers and market surveillance authorities

Different options can be hypothesized with regard to the programme that has to be measured and the measurement conditions:

1. Keep the standard cotton programmes 40°C and 60°C, refining some parameters such as temperature declarations, time declarations or rinsing performance.

This proposal would keep the standard programmes as the basis for energy label and ecodesign requirements.

2. Use normal 40°C cotton programme as standard programme.

This option would go back in time to the conditions before the last revision, with some modifications (e.g. measurement of 40°C instead of 60°C), and temperature declarations (and perhaps requirements), time declarations, and minimum rinsing performance.

3. Introduction of additional programmes or test conditions (i.e. include short programmes, or programmes for lightly soiled textiles).

This option would create a totally new reference programme, designed for washing as high loads as possible of lightly soiled clothes, with the ambition that the capacity of machines is better used.

7.3.1.3 Cycle time

Most stakeholders have agreed on a more transparent indication of the programme time on:

- the label ,
- the booklet of instructions,
- the display, when this feature is present on the machine.

Programme duration would be mandatorily indicated on the label, and also on the booklet of instructions. User surveys indicate that the duration shall be preferably expressed in hh:mm and not only in minutes. This declaration would in theory create competitive conditions for machines with similar technology, some with shorter programmes but higher energy consumption, and others with lower energy consumption but using more time.

In addition, it remains to be decided if a time limitation shall be introduced. The ideal competition conditions of time-energy described above are theoretical, but some stakeholders have indicated that they do not believe that the market will behave ideally, and suggest that a time cap of e.g. 2h 30m to 3h is necessary to ensure that competition takes place within a time range that is acceptable to consumers. This would, however, restrict the differentiation of machines, although the real dimension of this restriction is to be seen once real test values with the new standard measurement protocol are available. In the extreme, if the range is too restricted and most machines on the market are clustered around one-two classes, the strength of the label as communication instrument is weakened until technology development stretches the time range.

The introduction of time as additional parameter in the energy index (EEI) calculation formula has been considered. This would be done introducing an additive coefficient to the formula that provides a bonus to programmes shorter than 180 minutes and a malus to programmes exceeding 180 minutes. This would disincentive manufacturers to pursue test programmes with long duration, as these would not obtain better energy indices, and would incentivise development of energy-saving programmes that are also shorter than 3 hours. On the one hand, this strategy is less transparent than the plain declaration of the programme time on the label, and takes away from the consumer the decision of going for a 1) short but less efficient programme or 2) long but efficient programme. On the other hand, it is a pragmatic approach that addresses the repeatedly observed and reported results that indicate that consumers do not understand how longer programmes can be energy-saving. This approach somehow helps consumers not to have to decide on this trade-off, which is well-known to washing machine experts, but not the layman.

7.3.1.4 Water consumption

As explained in the report, water is scarce only locally in Europe. Water is also necessary in some areas to ensure minimum sewage flows. In washing machines, in particular fresh water is necessary to achieve appropriate rinsing. It is thus necessary to limit any unnecessary spillage of water, but its use shall not be as strict as to compromise the rinsing needs outlined above (see also 7.3.1.8 below).

7.3.1.5 Temperature

Stakeholder discussions concluded that temperature shall be communicated more transparently. The bottom-line agreed by stakeholders is that manufacturers shall declare the temperature reached in the laundry (inside the drum) in the main programmes, be it on the appliance booklet of instructions, data sheets, product fiche, operation manuals, or manufacturer's internet site.

In addition, one may propose ecodesign requirements of temperature. There are two distinct cases: (1) hygienistation temperatures, and (2) textile protection temperatures.

Regarding hygienisation temperatures, Honisch et al (2014) have reviewed the combinations of chemistry, temperature and time of washing that are able to remove an array of different pathogens from laundry. A key finding of this review was the lack of standardization of test conditions and the inconsistency in the published data, which makes it extremely difficult to propose with confidence performance standards for home laundering. The study finds that most pathogens are deactivated without bleaching if the temperature is >52°C for >15 mins, or >47 °C for >90 mins. With bleaching agents the temperatures or washing times can be lower.

It has been discussed with stakeholders if it shall be mandatory that washing machines have hygienisation programmes. User surveys indicate a relatively frequent (17%, not including standard cotton 60 °C) use in Europe of programmes with high temperature (≥ 60°C), which one can interpret as programmes deliberately selected for the purpose of hygienisation (e.g. bed linen, towels, textile nappies). In other regions of the world, similar hygienisation results are achieved at low temperatures (<30 °C) by means of chemistry (e.g. activated bleaching agents). The decision of whether hygienisation shall ideally be by means of temperature or chemistry is of political character. Most stakeholders have reported preference for the use of temperature, especially as the sources of energy in Europe have gradually less and less environmental impacts.

Based on this discussion, and in the absence of any harmonised method that quantifies the degree of hygienisation, one may propose that as a minimum, machines have efficient hygienisation programmes for cotton in which a temperature of at least 52 °C is reached for 15 minutes, or any other combination of temperature and time resulting in equivalent pathogen removal. In practice, this would be achieved by cotton 60 °C and 90 °C programmes. A minimum energy efficiency requirement can be proposed for the energy consumption of these hygienisation programmes.

Regarding textile protection temperatures, the main concern for users is to not damage the clothes by exposing them to excessively high temperatures, and thus follow the instructions indicated in clothes' labels. The appropriate ecodesign requirement would thus be that the maximum temperature reached by clothes in the main programmes is declared and is accessible to consumers, e.g. in the booklet of instructions and on the machine's display (when available).

7.3.1.6 Loading conditions

A new standard shall specify a new testing protocol which is represents current loading conditions (3.3 kg/load on average) and tests the capacity of appliances to adapt to the load , e.g. by testing different loading conditions (partial, e.g. ¼, and ½ or 1/3 and 2/3, and full loads).

Hybrid approaches mixing fixed (e.g. 2.5 or 3 kg), with partial and full loads have been also proposed. Fixed loads (e.g. 2 kg, 4 kg) would allow in the future comparability across machines, regardless of their capacity, and a better monitoring of the fitness of machines to adapt to small loads and thus real-life laundry behaviour.

Partial loads (1/4, 1/3 etc.) of a full load may in practical terms be somehow easier (cheaper) to implement for testing than fixed loads (e.g. 3.4 kg), as they better enable to optimise the use of a split full load.

In any case, it has to be ensured that the testing procedure does not become overly complex and costly (e.g. a max amount of laundry equivalent to 5 full load cycles), and shall not be much higher than what is done today (7 runs, effectively 5 days = 1 week).

7.3.1.7 Washing performance

Washing performance is currently measured as a comparison to the soiling removal of a reference machine. The current minimum value is 1.03. Stakeholder discussions have taken place, some suggesting lowering this value, as clothes washed in Europe tend to be progressively less soiled. However, there is currently little scientific evidence supporting to what alternative value this reference shall be changed.

7.3.1.8 Rinsing performance

There is no current method for measuring rinsing performance that is sufficiently reproducible and replicable. As discussed in the report, rinsing is an issue that deserves being regulated, as insufficient rinsing (sometimes caused by the intention of manufacturers to reduce programme time and energy consumption) is the source of cases of allergic reaction. Thus, standard methods currently explored are expected to soon become available, and requirements shall ideally be introduced in the revision. This parameter is furthermore important if any type of time restriction is introduced, as shortening the programme time shall not be done at the expense of insufficient rinsing.

7.3.1.9 Low power modes

Currently, to evaluate the annual energy consumption (AEC) of a washing machine, the energy consumption of a combination of cycles is multiplied by an aggregated number of washing cycles (220 cycles/year) and the energy consumption of low-power modes is added.

These kinds of low power modes are in general regulated by the Standby Regulation (EC) No 1275/2008. A review study of this regulation was launched in June 2015 (see http://www.ecostandbyreview.eu).

The stand-by mode is, based on the Standby Regulation, a condition where the equipment is connected to the main power source, depends on energy input from the mains power source to work as intended and provides only the following functions, which may persist for indefinite time:

- Reactivation function and only an indication of enabled reactivation function (being the maximum power consumption 0.5 W), and/or
- Information or status display or combination of reactivation function and information and status display (being the maximum energy consumption 1.00 W)

Additionally, the standby regulation requires that when an equipment is not providing the main function, or when other energy-using products are not dependent on its function, equipment shall, unless inappropriate for the intended use, offer a power management function that switches equipment after the shortest possible period for the intended use of the equipment, automatically into standby mode or off mode or another conditions which does not exceed the applicable power consumption requirements of the off mode and/or standby mode when the equipment is connected to the mains power sources.

The left-on mode is, according to the Regulation (EC) No 1016/2010, the lowest power consumption mode that may persist for an indefinite time after completion of the programme and unloading of the machine without any further intervention of the end-user. Since January 2013, a power management system is mandatory for all household washing machines according to the Standby Regulation. When a power management system is implemented, the left-on mode reverts to off mode "*after the shortest possible period of time appropriate for the intended use of the equipment*" (cf. section 1.2.1.1). The exact time meant by "*after the shortest possible period of time appropriate for the intended use of the equipment*" is not clearly defined for washing machines. Manufacturers state that in general washing machines revert to off mode after a maximum of 30 minutes.

The off-mode is, according to the Standby Regulation, a condition in which the equipment is connected to the main power source and is not providing any function. The off-mode is regulated by the regulation and shall not exceed 0.50 W.

Specifically in the washing machines, the off-mode means a condition where the household washing machine is switched off using appliance controls or switches accessible to and intended for the operation by the end-user during normal use, or attain the lowest power consumption that may persist for an indefinite time while the household washing machine is connected to a power source and used in accordance with the manufacturer's instructions. Where there is no control or switch accessible to the end-user, off-mode means the conditions reached after the household washing machine reverts to steady-state power consumption on its own.

Other low power modes are for the time being not included in the AEC formula, but are present or start being common in this type of machines, such as the delay start mode and the smart connectivity/smart ready mode.

Smart connectivity of appliances to the internet is seen as an upcoming trend. It could help for better communication between manufacturers, consumers, and appliances. Appliances with this function have been presented at the last IFA fairs 2015/16 in Berlin. This kind of smart connectivity/smart ready mode might fall under networked standby as defined in Regulation (EU) No 801/2013 amending the Standby Regulation. If not, however, a specific cap on the energy consumption of this mode could be introduced.

The delay start mode is similar to the standby mode regarding its function but, according to Regulation (EC) No 1275/2008, it is not considered as a standby mode because it has a limited duration. Currently, the delay start mode can last up to 24h having an energy consumption that varies between 0.3W and 3.0W per hour (Stifung Warentest, personal communication 2015). In practice, these kinds of modes normally do not exceed 8h and are not used for every cycle.

Assuming the highest or lowest power consumption (3W representing current worst case and 0.3W representing the best case), an average duration of 8 h or 24 h and the use of this function either in all cycles or only in half of the cycles, the annual consumption of the delay start mode for the base case would amount between 0.26 kWh or 15.84 kWh per year which equals a contribution from 0 % to 11% of the overall real-life energy consumption, respectively (see Table 7.3)

Table 7.3: Annual energy consumption of delay start mode

	W	Time (h)	Wh	Cycles/y	kWh/y	% BC real-life energy consumption
Option 1	3	8	24	110	2.64	1.86%
Option 2	3	24	72	110	7.92	5.59%
Option 3	3	8	24	220	5.28	3.73%
Option 4	3	24	72	220	15.84	11.18%
Option 5	0.3	8	2.4	110	0.264	0.19%
Option 6	0.3	24	7.2	110	0.792	0.56%
Option 7	0.3	8	2.4	220	0.528	0.37%
Option 8	0.3	24	7.2	220	1.584	1.12%

Most of the options showed in Table 7.3 represents worse case scenarios on a per appliance basis. According to the consumer survey (Albozi et al 2015) consumers do not use the delay start that often (9% use it often, 13% use it sometime) and for a lower duration (43% less than 3h, 10% between 3 and 6h, 7% more than 6h, 10% for varying times) resulting as CECED provided in a detailed calculation included in the Preparatory Study for household dishwashers, in an average consumption of the appliance of 0.84kWh/a. This consumption represents 0.59% of the annual energy consumption of the base case.

On this basis, the policy options to regulate the low power modes could be:

- Keep on calculating AEC as it is done in the current regulation and add additional low power modes, e.g. the delay start function.
  This option would leave the calculation as it is currently, and add further low power modes which are actually not included, like the delay start function.
  It has to be noted however that the currently included low power modes (left-on and off-mode) were introduced in the AEC calculation before the Standby Regulation (EC) No 1275/2008 entered into force. The mandatory prescriptions for standby, in place since 2013, seem to have made obsolete the testing of some of the low power modes conditions in performance tests of washing machines. Testing of low power modes may thus be excluded from the calculation of the EEI used for eco-design and the energy label.
- Introduce a specific cap on the energy consumption of the delay start and/or the smart connectivity mode
  Some stakeholders support an eco-design requirement on the energy used by the "delay start" function. Although the impact of this function on the energy bill on individual households might not be significant, they pointed out that washing machines are broadly used in the EU and that the energy that could be saved cumulatively by restriction the energy use of this setting could become significant. Additionally, this function might become even more relevant in the future when smart appliances become more common.
  The smart connectivity mode is supposed to fall under networked standby as defined by Regulation (EU) No 801/2013 amending the Standby Regulation. If not, however, a specific cap on the energy consumption of this mode could be introduced.
  As these functions exist in various household appliances a horizontal approach might be appropriate or at least a certain degree of harmonization among the requirements included in each specific product regulation
- Delete the energy consumption of the low power modes from the AEC calculation
  Given that the low power modes generally contribute little to the overall energy consumption, most stakeholders have expressed that they would like to see these modes taken out of the AEC calculation to account for more simplicity and reduce the complexity in testing and the associated market surveillance.
  In Australia, New Zealand and the US, the delay start mode is left out from the calculation to avoid penalization of this mode which was recognized to have an overall positive impact by allowing the delay of the washing cycle to off-peak hours.
  Keeping the low power modes outside of the EEI calculation makes the formula simpler and more transparent. Therefore, an alternative to the existing EEI formulae would be to define a new one considering only the product's primary function, i.e. washing laundry.

7.3.1.10 Communicating the consumption (energy and water) per cycle or per year.

The information regarding the energy and water consumption is provided to the consumers to allow them to compare among the different models in the market. One question is if this information should be provided on a per cycle basis, or on an annual basis. In the first case, the information is more transparent, but the displayed numbers could be too low and using decimals and thus apparently close to each other, making the comparison more challenging for the consumer. In the annual basis option, 220 cycles/year are assumed as basis for the calculation. This assumption does not reflect each specific consumer situation. During this revision study, it has also been mentioned that not all consumers understand the expression “per annum”, as also reported in Dünnhoff & Palm (2014).

Stakeholder feedback regarding the question if the consumption shall be given per cycle or per year is somehow split.

Some stakeholders are in favour of “per cycle” as

- Recent user surveys show that more than 70% of interviewees did not understand correctly or did not understand at all the meaning of “per annum” on the energy label,
- The consumer survey that has been conducted under this study reveals consumers prefer an indication per cycle
- the 220 cycles which are currently the basis for the calculation of the annual energy consumption does not correspond to the user pattern of all households

Other stakeholders are in favour of an annual indication, as

- this would be more coherent with the energy labels of other products, and
- The per cycles values are very small, use decimal figures, and thus apparently reflect insignificant differences between appliances. Yearly consumption values deliver greater numbers, so differences between appliances become more obvious and easier to quantify by users (in favour of energy efficient appliances).

A third alternative could be to provide the consumption per a certain number of cycles, e.g. 100 cycles, which does not necessarily represent annual consumption but increases the value of the displayed numbers.

7.3.2 Policy options related to energy and water consumption for washer dryers

7.3.2.1 Differences between the real life use of the washer dryers and the current energy label criteria for washer dryers

The existing European Directive on energy labelling of washer-dryers (96/60/EC from 19 September 1996) is based on the use of the washer-dryer to wash and subsequently dry a full load of laundry (as discontinuous processes). Because the rated washing capacity of the machines is currently higher than the rated drying capacity, this testing requires more than one drying cycles.

The standard measure mentioned above is described in the basic standard for measuring the energy consumption and performance of washer-dryers (EN 50229) which is aligned to the measurement standards for washing-machines (EN 60456) and for tumble-dryers (EN 61121).

EN 50229 for washer-dryers was first published in 1997 and subjected to regular updates to adjust it to the modifications carried out in EN 60456 and EN 61121.

However, not all the elements included in the standards have been fully harmonized. For example, the washer-dryer's standard checks the washing performance throughout 5 cycles at 60 °C full-load, whereas washing machine standard checks it throughout a 3:2:2 combination of full and half loads at 40 °C and 60 °C. Also for the drying testing, half loads are used only.

The test methods specified in EN 50229 with regard to the energy labelling are based on:

- Energy and water consumption of the washing cycle based on the ‘Cotton 60 °C’ wash programme at the rated washing capacity, as specified in EN 60456, and
- Energy and water consumption of the drying cycle based on the ‘Dry cotton programme’ at the rated drying capacity, as specified in EN 61121.

As the rated washing capacity is normally higher than the rated drying capacity, the use of this standard requires the load to be divided into two or more parts. Water and energy consumption are calculated by adding up the consumption value from the wash cycle and the subsequent drying cycles (2 or more, when the rated washing capacity is more than twice the rated drying capacity).

The revision of the standard EN 50229:2007 is currently in a formal voting process (draft standard prEN 50229 finalised in March 2015 by CENELEC TC 59X), as shown in Figure 7.2.

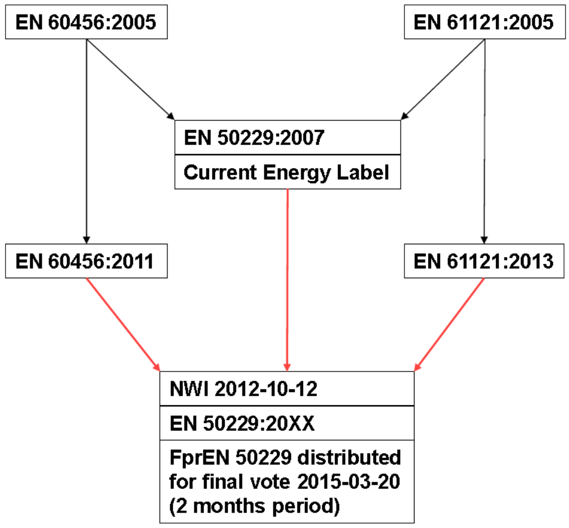


Figure 7.2: Relationship between the washing-machine standard, EN 60456, and the standard for measuring tumble-dryers, EN 61211, with the measurement standard for washer-dryers, EN 50229. Timeline is from top to bottom of the graph. No current relationship exists to IEC 62512, which describes a method for continuous wash and dry.

New designs of washer-dryers allow washing and drying loads of laundry in a continuous cycle (called 'wash&dry' cycle). Additionally, the current trend of producing machines with higher drum volumes (>7 kg for washing machines and ~3.5 kg for washer-dryers) makes that nowadays the rated capacity of drying in the washer-dryers is already exceeding the average wash load in the EU (3.4 kg). This means that the washing and drying functions can be used without interruption, load splitting nor reloading of the parts of the washed load that exceeded the drying capacity. This new feature is what distinguishes a washer-dryer from the equivalent set of two separate appliances (a washing machine and a tumble-dryer). It is also one of the main reasons why washer-dryers are reportedly well accepted by consumers, especially by those that have room limitations at home. However, as described previously, this feature is not considered neither in the Energy Label Directive 96/60/EC for washer-dryers nor in the measurement standard EN 50229.

At international level, the first edition of IEC 62512 'Electric clothes washer-dryers for household use – Methods for measuring the performance' was prepared specifying the conditions needed to test the combined function of washing and drying in a washer-dryer. The standard defines in detail the procedures of how an interrupted operation cycle (i.e. a complete operation cycle where the operator's action is required to continue the process) and a continuous operation cycle (i.e. a complete operation cycle without interruption of the process or additional action by an operator) of a washer-dryer have to be tested.

As described in section 3.1.22, the consumer survey 2015 on washer-dryers (Stamminger, R. et al. 2015) shows that the dominant use of a washer-dryer is as a washing-machine. Washer-dryer appliances are mostly used for washing (EU average number of wash cycles per week is 4.6) and to a less extent for drying (EU average number of drying cycles per week is 2.9). Thus, these numbers indicate that about 1.5 cycles/week is done in a continuous wash&dry cycle and that approximately 1.4 cycles/week is drying of a washed load that was previously split.

Consumers are keen to compare the washing and drying performance of washer-dryers with that of washing machines and tumble-dryers. Around 78% of the consumer survey respondents categorise comparability of the energy label values for a washer-dryer with a washing machine as very important or important. Almost identical results are delivered for the comparability of a washer-dryer energy label with that of a tumble-dryer.

7.3.2.2 Proposals for the declaration the energy label and ecodesign requirements for washer-dryers

Based on the current situation and the fact that washer-dryers are used for the functions of washing only, drying only and wash&dry three basic proposals for updating the measurement of the performance of this appliance have been circulated to stakeholders for detailed feedback during summer 2015 (details including expected benefits and potential disadvantages, challenges and / or drawbacks are detailed in below).

The three proposals were:

1. Including the washer-dryers into the revised ecodesign and energy label regulations for washing machines

Including the washer-dryers into the revised ecodesign and energy label regulations for washing machines will imply that the same or similar requirements as for washing machines for the washing function of the washer-dryers and requirements for drying only cycle and/or continuous wash&dry cycle for the drying function.

This proposal will imply two different label scales for the washing and for the wash&dry function into a combined label as it is done for air conditioners and information of potential interest for the washer-dryer's users such as absolute energy and eater consumption, cycle time, rated capacity for wash&dry, noise for drying, etc.

This proposal allows a fair performance comparison with washing machines and tumbles dryers and will bring less regulatory work compared to two separate regulations. As challenges, it was identified that the wash&dry procedures differ from the single wash procedures of a washing machine (e.g. thermos-spin ability) or the simple drying process of a tumble dryer and therefore washer-dryers will come up always with worse values that separate washing machines and tumble dryers. Also two different label scales may confuse the consumers.

2. Totally separating ED/EL regulations for washing machines and washer-dryers

This proposal includes values for interrupted and continuous wash&dry process and washing function to be assessed for Energy label and Ecodesign. The proposal allows each machine (washing machine and washer-dryer) to be rated according to its specific function, i.e. it highlights better the character of a washer-dryer. On the other hand, according to this proposal the consumptions values for washer-dryers will show relative higher absolute values and if both regulations are not aligned, consumer will not be able to compare the washing function of washer-dryers and washing machines. Finally, it is expected a not proportional regulatory work for the small market share of this kind of appliances. A separate regulation for this product group might be dropped at all at some point in time, i.e. no further revisions.

3. Splitting the wash and dry functions of the washer-dryers and including them separately into the regulations for washing machines and tumble dryers, respectively.

This proposal means that the washing function will be subject of the requirements included in the revised regulations for washing machines and that the drying function will be subject of the requirements of the revised regulations for tumble dryers (EU Regulations 932/2012 and 392/2012). The advantages of this proposal are the transparency for consumers and the direct comparability of the wash function with a washing machine and the dry function with a tumble dryer. The main disadvantages are that this proposal does not highlight the characteristics of the washer-dryer, that the information on the label may be confusing to consumers due to the double label scale for washer-dryers, that the continuous wash-dry cycle (which is often used) is not covered and that the handling and maintenance of regulations in the future might have different timelines.

Two key discussion issues were raised in the revision, one formal and one of content:

a) from a formal/administrative process point of view, dealing with washing machines and washer-dryers together would avoid any delay in the washing dryers revision
b) from a content point of view, dealing with washing machines and washer-dryers together would facilitate alignment of the common elements (washing cycle) and reduce the efforts testing it.

According to stakeholder feedback, the most preferred option is including the washer-dryers into the revised ecodesign and energy label regulation for washing machines. The same or similar requirements as for washing machines shall be applied for the washing function of the washer-dryers with regard to the performance testing. This will enhance the comparability of washing processes for consumers between washer-dryers and washing machines.

Based on the comments above, the requirements of the ecodesign and energy label will be based on two main aspects:

1. The washing function of washer-dryers will be subjected to the same requirements as for washing machines (cf. sections 0). This fact will align both product groups as much as possible, simplify the performance testing and enhance comparability of the washing processes. Stakeholders generally agreed on this proposal.
2. The drying function(s) of washer-dryers, i.e. for the drying-only function and for the continuous wash&dry function will need the development of further requirements or policy options that complement the current regulation.

7.3.2.3 Proposals for the declaration of the drying function requirements for washer-dryers

As commented in the previous section, the preferred option of the stakeholders is to include the washer-dryers into the revised ecodesign and energy label regulations for washing machines. This means that the same or similar requirements as for washing machines shall be applied for the washing function of the washer-dryers but that new requirements should be developed for the drying function.

For the drying function(s) of washer-dryers, the alternatives showed in Table 7.4 were identified.

Table 7.4: Alternative policies for the drying process of washer-dryers.

Alternative	Sub-alternatives	Pros/Cons
1. Dry-only function		- good basis for comparison to tumble dryers - all washer-dryers can be tested - does not reflect real-life conditions, as washer-dryers are often used in wash&dry cycles
2. Dry function as part of a wash and dry cycle	Rated washing capacity as basis	- continuity of the current test procedure
		- does not reflect the usual consumer practice - energy and water consumption values are far beyond the consumption of a washer-dryer in a real life - Large number of testing cycles required by the EN 50229.
	Rated drying capacity as basis	- specific rated capacities for each drying and washing process are separately determined: better reflection of the real-life consumer behaviour - measurement uncertainties and room for circumvention

Alternative	Sub-alternatives	Pros/Cons
	Rated wash&dry capacity as basis (in a continuous cycle)	- the key feature of washer-dryers is tested - certain performance parameters of the washing cycle cannot be tested - consumption values of the wash are not comparable to a washing machine according to EN 60456
	Rated wash&dry capacity as basis (in an interrupted cycle)	- reflects better the real-life user behaviour - certain performance parameters of the washing cycle cannot be tested - consumption values of the wash are not comparable to a washing machine according to EN 60456 - IEC 62512 specifies a testing procedure for this cycle - If this testing cycle is added to the washing performance the overall testing costs and time will be approx. double.

- Dry-only function, i.e. testing the drying function following or adapting the tumble dryer test standard EN 61121.

Ecodesign and energy label requirements for tumble-dryers included in the (Regulation EU 932/2012) can be applied for the dry-only function of washer-dryers. This alternative will allow comparability, e.g. for a consumer doubting to buy a washing machine and a tumble-dryers separately or a washer-dryer.

To be able to compare the dry-only function of washer dryers to that of tumble dryers, the same starting conditions as defined for tumble-dryers in EN 61121:2013 should be reached in the washer dryer, including a starting with a 60% humidity of the laundry (as average output humidity of laundry out of washing machines), an equilibrium temperature of the washer-dryer with the laboratory environment and a specific rated drying capacity. These conditions are, however, not representative of the real-life conditions of use of the appliance. In general the washing process takes place in the washer-dryer just before the drying cycle starts, meaning that the humidity of the laundry at that point is different from 60% (The value will vary depending on the model) and that result of the test of the drying-only function of the washer-dryer would not reflect the real-life performance of the washer-dryer. If the test procedure is aligned to EN 61121:2013, i.e. testing all washer-dryers with the same initial humidity, relevant differences between the washer-dryers models would be neglected.

From a consumer perspective, the main reported reasons for purchasing a washer-dryer are the lack of room to have two appliances and the possibility of washing and drying without intermediate intervention. According to the EU consumer survey 2015 on washer-dryers, washer-dryers are rarely used as a tumble dryer for drying only, as this would practically imply washing the laundry by other means (e.g. another separate washing machine).

Summing up, we can conclude that a comparison to tumble dryers, while in principle desirable does not fully reflect the functionality and real-life use of washer-dryers. Stakeholder feedback received supports this conclusion, and therefore it is proposed NOT to include the dry-only function of washer-dryers in a future test procedure and in future ecodesign and energy label measures for household washer-dryers.

- Dry function as part of a wash&dry cycle, i.e. first, a certain load is washed in the washer-dryer. Subsequently, this load is dried in the same appliance.

The key feature of a washer-dryer is the ability for washing and drying the clothes in the same appliance. Washing machines can only wash and tumble dryers can only dry. As reflected in the purpose of Directive 96/60/EC, the washer-dryer is able to wash and dry the entire tested load. The drying process takes place after the wash cycle, with or without interruption and following intervention of the consumer. As the rated load capacities of the washing, drying, and wash and dry functions within a washer-dryer often differs, the dry function after washing can be executed in different ways:

a) Rated washing capacity as basis (WD SPLIT):

In accordance with the current test standard EN 50229:2015, the rated washing load would be taken as basis for testing the drying cycle. The washed load will be split for drying into the usually smaller rated drying capacity. The standard defines how the wash load needs to be taken out and split after the washing process into two or more partial loads which are dried one after the other.

The advantages of this option is the continuity of the current test procedure and the disadvantages are that this procedure does not reflect the usual consumer practice, that the energy and water consumption values do not reflect well the consumption of a washer-dryer in real life, and the large number of testing cycles required by the EN 50229.

According to the consumer survey 2015 (Stamminger et al. 2015), on average from 4.6 wash cycles per week, only 2.9 cycles per week are undergoing a drying process, whereof 1.5 cycles per week are done in the continuous wash&dry cycle (see below, c/i), and 1.4 cycles per week in an interrupted wash and dry cycle (see below, c/ii). This means that about one third of the load is not dried in the washer-dryer (but in a line, tumble-dryer or other methods

Table 7.5: Overview of the advantages and disadvantages of the WD SPLIT option

Policy options for WD SPLIT scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
STANDARD PROGRAMME FOR WASHING	Alignment to the standard programme(s) of WM is not relevant for the scenario 'WD SPLIT', as wash and dry cycles are tested independently of each other.	---	---
STANDARD PROGRAMME FOR DRYING	1) Iron dry 2) Cupboard dry Mix of both programmes in a series of test cycles, cf. further explanation below the table* 3) For machines without final humidity sensor, the drying can only be regulated by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.

Policy options for WD SPLIT scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
	measurement standard).	organisations	
	Common consumer information (e.g. in the user manual) about the optimal application of different drying programmes and their specific energy consumption	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and environmentally friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	Standardised text may be complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated washing capacity of the WD. Split rated washing capacity into 2 equal shares. Split rated washing capacity into a) rated drying capacity of the WD plus b) the "rest" Mix of full load and partial loads with regard to the machine's drying capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes,	Restriction of the playing field to areas that are known to be	Manufacturers reduce their leeway. Most appliances will cluster on few classes,

Policy options for WD SPLIT scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
	e.g. 3 hrs.	acceptable for consumers. As a consequence the use of such programmes may increase	reducing the influence of the label on purchase
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 'Standard dry programme' / arrow symbol No explicit indication at all	Alignment to WM	People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection, when the appliance allows it	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are several standard programmes (1 or more for each washing and drying); consumers might easily overcome such default selection

b) Rated drying capacity as basis (WD REMOVE)

In this scenario, the wash cycle is run at full load but the rated drying capacity would be taken as basis for testing the drying cycle. This alternative is thus closer to the real-life conditions. As the rated washing capacity usually is higher than the drying capacity, after washing the cycle should be interrupted and certain laundry items should be taken out until the (lower) rated drying capacity is reached. The removed load is discarded for the drying test.

The main advantages are that the specific rated capacities for each washing and drying are used for testing, that the specific testing parameters can be separately determined and that it reflects better the real-life consumer behaviour.

For each of the sub-cycles (wash and dry) the specific rated capacity is used and every testing parameter can be separately determined, e.g. the remaining moisture content (RMC) after washing/spinning. This procedure may save additional testing efforts for testing solely the washing function of the washer-dryer. Additionally, this approach reflects better the real-life consumer behaviour. According to the EU consumer survey 2015 on washer-dryers, consumers often remove certain laundry items from the wash load due to several reasons such as hanging them up separately, removing delicate fabrics or getting better drying results or preventing creasing by drying smaller loads.

The measurement uncertainties and room for circumvention are the main disadvantages of this alternative. Although for testing purposes in principle one could define in the measurement standard the kind and amount of laundry to be removed for ulterior drying, the different laundry items do not have the same humidity after finishing the washing cycle. This might introduce large variations in the measurement when taking out certain items as the starting humidity for the drying cycle will not be well defined. There may be room for circumvention created by selecting those items for drying which are better spun.

Table 7.6: Overview of the advantages and disadvantages of the WD REMOVE option

Policy options for WD REMOVE scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**	**Preference / Comment of the stakeholder**
STANDARD PROGRAMME FOR WASHING	Alignment to the standard programme(s) of WM is not relevant for the scenario 'WD REMOVE' as wash and dry cycles are tested independently of each other.	---	---	---
STANDARD PROGRAMME FOR DRYING	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles, cf. further explanation below the table for the 'WD SPLIT' scenario* For machines without final humidity sensor, the drying can only be regulated by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the measurement standard).	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.	
	Common consumer information (e.g. in the user manual) about the optimal application of different drying	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and	Standardised text may be complicated when designed for all countries and languages	

Policy options for WD REMOVE scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**	**Preference / Comment of the stakeholder**
	programmes and their specific energy consumption	environmentally friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.		
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated drying capacity of the WD. 1. Mix of full load and partial loads with regard to the machine's drying capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensuring a fair selection of laundry items to test in the drying process. Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)	
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.	

Policy options for WD REMOVE scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**	**Preference / Comment of the stakeholder**
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase	
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 1) 'Standard dry programme' / arrow symbol 2) No explicit indication at all	1) Alignment to WM	1) People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing	
	Default programme selection, when the appliance allows it	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are several standard programmes (1 or more for each washing and drying); consumers might easily overcome such default selection	

c) Rated wash&dry capacity as basis (WD COMBI)

a. Continuous cycle

In a continuous wash&dry cycle the laundry will automatically be dried after washing without any interruption of the process. In this alternative, the rated capacity for the wash&dry cycle would be taken as basis for testing, which is usually lower than the rated washing capacity, but normally equal to the drying capacity.

The advantage of this alternative is that the key feature of washer-dryer, namely the continuous wash&dry cycle, is tested. The wash load does not need to be split or removed after the washing.

However, certain performance parameters of the washing cycle cannot be tested in a continuous wash&dry cycle, e.g. spin drying or rinsing performance directly after washing. Moreover, due to different capacities of the wash cycle and the wash and dry cycle, the washing performance and related consumption values of the wash would not be compared to a washing machine result test according to the EN 60456 for the partial loads. As the drying capacity of a wash&dry cycle usually is lower than the washing capacity of washer-dryer, the washing takes place “underloaded” compared to the full rated washing capacity. This underloading will be normally used by manufacturers to reduce the washing time and/or temperature compared to a full load wash-only cycle. This will make the 'wash' part of the washer-dryer cycle not comparable to cycle tested in accordance with EN 60456. The washing cycle would have to be tested separately

This aspect can be positive in the real-life for the consumer and the energy consumption, but has to be adequately communicated in the context of labelling (two different washing values may be given – one for full load washing according to EN 60456 and one for washing at the rated wash&dry capacity in the washer-dryer testing). Finally, most but not all WD currently on the market provide such a continuous wash&dry function (this may change though in future models). These other machines would need to be tested in an interrupted wash and dry cycle.

Table 7.7: Overview of the advantages and disadvantages of the WD COMBI continuous option

Policy options for ‘WD COMBI – Continuous’ scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
STANDARD PROGRAMME FOR WASHING in the wash&dry cycle	Programme selection based on the final decision of a policy scenario for WM, i.e. one or more programmes (wash temperatures), probably combing full and partial loads, see below.	Could allow potential testing synergies with WM	The currently applied combination of different WM standard programmes with different load capacities (e.g. 40/60 ° cycles at full and partial loads) would be even more complex when adding the testing of drying cycles. Some information from the wash cycle would not be comparable/measurable with the wash&dry testing.
STANDARD PROGRAMME FOR DRYING in the wash&dry cycle	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles, cf. example below the table * For machines without final humidity sensing, the drying time can only be selected by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the standard).	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.
	Consumer information	Provision of information in	Standardised text may be

Policy options for 'WD COMBI – Continuous' scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
	(e.g. in the user manual) about the optimum application of different drying programmes and their specific energy consumption	a clear and homogeneous form can facilitate education of consumers on the most correct and environmentally friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated wash&dry capacity of the WD. 1) Mix of full load and partial loads with regard to the machine's wash&dry capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy-use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMME INDICATION	Programme indication on the display:	1) Alignment to WM	1) People might not understand the underlying

Policy options for 'WD COMBI – Continuous' scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
AND SELECTION	1) 'Standard dry programme' / arrow symbol 2) No explicit indication at all		design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection (when possible) 1) Standard wash programme (aligned to WM) 2) Iron-dry for the drying programme 3) None	Introduced already for dishwashers. A default selection of the iron-dry programme for the wash&dry cycle could be an option to save energy compared to cupboard dry condition.	A default selection of a wash&dry standard programme when starting the WD seems not appropriate, as consumers often use their washer-dryer for washing the laundry only. Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are several standard programmes (1 or more for each washing and drying). Consumers might easily overcome such default selection

b. Interrupted cycle

In an interrupted wash and dry cycle, the machine stops after washing before starting the drying cycle. IEC59D has agreed in IEC60512 to have a time gap between washing and drying of 30 minutes to consider the time gap between washing and separate drying operation in consumers' homes.

This approach also reflects the real-life of 30% of the consumer behaviour as already described in 'WD REMOVE' above. As consumers would not stay next to the washer-dryer waiting until the wash cycle is finished to immediately start the drying, the load will be exchange temperature with the environment before the drying starts. Thus, this defined interrupted time gap avoids non-realistic accounting the heat transfer from the washing to the drying part, Also, for testing purposes stain strips can be removed / replaced and the RMC of the laundry and the rinsing efficiency can be measured after the wash cycle. Finally, also washer-dryers not providing a continuous wash&dry function could be tested.

Similarly to the continuous cycle, due to different capacities of the wash cycle and the wash and dry cycle, the washing performance and related consumption values of the wash phase would not be comparable to a washing machine tested according to EN 60456 for the partial loads. Consequently, all performance and consumption values would need to be assessed for the wash and dry process independently of the pure washing process.

A continuous and interrupted wash&dry process is specified in IEC 62512 'Electric clothes washer-dryers for household use – Methods for measuring the performance', which has been prepared by the International Electrotechnical Commission (IEC) subcommittee '59D: Home laundry appliances', of IEC 'Technical Committee 59: Performance of household electrical appliances'. This standard could form the basis for the testing of washer-dryers in future. This means also in practical terms that the testing of a washer dryer may need firstly a fully-fledged test as a washing machine followed by a complete test as a washer-dryer with little options for synergic use of the test results between the two. The overall testing time and cost may roughly duplicate that of a washing machine

Table 7.8: Overview of the advantages and disadvantages of the WD COMBI continuous option

Policy options for 'WD COMBI – Interrupted' scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
STANDARD PROGRAMME FOR WASHING in the wash&dry cycle	Programme selection based on the final decision of a policy scenario for WM, i.e. one or more programmes (wash temperatures), probably combing full and partial loads, see below.	Could allow potential testing synergies with WM. It would be possible to measure all parameters of interest for the wash cycle	The currently applied combination of different WM standard programmes with different load capacities (e.g. 40/60 ° cycles at full and partial loads) would be even more complex when adding the testing of drying cycles. Some information from the wash cycle could not be comparable with the wash&dry testing.
STANDARD PROGRAMME FOR DRYING in the wash&dry cycle	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles, cf. example below the table for the 'WD COMBI - continuous' scenario* For machines without final humidity sensing, the drying time can only be selected by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the standard).	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.
	Consumer information (e.g. in the user manual) about the optimum application of different drying programmes and their	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and	Standardised text may be complicated when designed for all countries and languages

Policy options for 'WD COMBI – Interrupted' scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
	specific energy consumption	environmentally friendly use of the appliance. There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated wash&dry capacity of the WD. 1) Mix of full load and partial loads with regard to the machine's wash&dry capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy-use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMME INDICATION AND	Programme indication on the display:	1) Alignment to WM	1) People might not understand the

Policy options for 'WD COMBI – Interrupted' scenario	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
SELECTION	1) 'Standard dry programme' / arrow symbol 2) No explicit indication at all		underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection (when possible) 1) Standard wash programme (aligned to WM) 2) Iron-dry for the drying programme 3) None	Introduced already for dishwashers. A default selection of the iron-dry programme for the wash&dry cycle could be an option to save energy compared to cupboard dry condition.	A default selection of a wash&dry standard programme when starting the WD seems not appropriate, as consumers often use their washer-dryer for washing the laundry only. Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are several standard programmes (1 or more for each washing and drying). Consumers might easily overcome such default selection

7.3.2.4 Proposals for the declaration of the performance of washer-dryers in ecodesign and energy label

The information presented on the current label for washer-dryers includes:

- energy consumption per cycle: washing only and washing + drying
- washing performance – with a class from A to G
- maximum spin speed
- total cotton capacity (washing and drying separately)
- total water consumption for a full load continuous or interrupted washed and dried (note that water-based condenser washer-dryers may use significant amounts of water on the drying cycle)
- noise in dB (A) (separately for washing, spinning and drying)

Possible information to report on the future washer-dryer label:

- Rated capacity for the wash&dry process,
- Average total energy consumption for the drying and/or for the wash&dry processes,
- Energy label class for the drying and/or for the wash&dry processes,
- Average total water consumption per cycle for the drying and/or for the wash&dry process,
- Average time for the drying and/or for the wash&dry processes
- Noise for washing, spinning and drying during the wash&dry process.

The following specific ecodesign requirements may be also considered for washer-dryers:

- Washing performance > 1,03 for the wash&dry process to ensure a reference for the washing process in the continuous wash&dry process

- Minimum Energy Efficiency Index for the drying and/or wash&dry processes
- Maximum total water consumption (cap) for the drying and/or wash&dry processes

And regarding the lay-out the following possible options could be

- 1 label with 1 scale based on WM label, with additional information for washer-dryers
- 1 combined label with 2 scales as already applied e.g. for air conditioners
- one for the (wash and) dry cycle, depending on the policy scenario chosen as introduced above.
- 2 or 3 separate labels (washing machine label, tumble dryer label, Wash&Dry label)

7.3.2.5 Stakeholder feedback on washer-dryer policy options

Input on washer-dryers declaration options was provided by nine stakeholders and summarised in this section.

All stakeholders supported not including the dry-only function of washer-dryers into the future ecodesign and energy label measures for household washer-dryers, as it covers only small percentage of the normal use of the appliances. Additionally, it would have to handle, among others, the drawbacks dumbed in terms of residual moisture content from the wash cycle.

Any of the stakeholders preferred the alternative WD SPLIT. This is not perceived to reflect real life behaviour but it might be the simplest scenario in terms of testing effort (since there would not be the need of additional washing cycles).

A majority of stakeholders expressed their preference for the WD COMBI alternative while some stakeholders went for the WD REMOVE alternative. Another stakeholder proposed to test according to WD REMOVE (both rated capacity drying and the remaining load), and include WD COMBI continuous into the programme portfolio to determine the declaration values and the efficiency calculation.

Those stakeholders in favour of the alternative WD REMOVE argued that it makes possible to test the washing in the same way as for washing machines. This fact makes easier to use results of the washing process in a washer-dryer with normal washing machines (e.g. same scale for label etc.). This is practical as the washer-dryer should be first tested for washing (full load) and then a certain amount of laundry should be removed to test the drying. Furthermore, the testing of the remaining load would show the performance of the appliance depending on the amount of load. Regarding the testing, one stakeholder believed it will be easier and faster. Some soiled strips will be indeed removed after the wash cycle (to adapt the load from the washing capacity to the lower drying capacity) and the test of the drying process would take place immediately after that. With the current standard method, the total wash load has been dried in two drying cycles. it was commented that even if the process of testing in the WD REMOVE alternative is good, the removal of certain laundry items will be problematic, especially for the market surveillance authorities.

Those stakeholders in favour of the scenario WD COMBI argued that the main purpose and key feature of a washer-dryer is the combination of washing and drying which seems to be the closest to real life usage. The continuous wash&dry cycle is the unique function of washer-dryers opposed to washing machines and tumble dryers, and it is one of the major reasons for consumers to buy a washer-dryer. Then, the continuous wash-dry function would be used to compare washer-dryers among each other (both washing and drying performance). Testing the washer-dryer with an interruption (with a time gap up to 30 minutes) seems a good option as it can be used for all models. With the interrupted option it would be possible to test wash and dry cycles altogether or separately, thus allowing measuring also parameters of the wash cycle such as the washing performance and the spin drying efficiency of the wash cycle.

However, the WD COMBI alternative would require additional test cycles to those needed for testing the wash only function (based on the washing rated capacity). The WD COMBI alternative should be tested at the specific wash&dry capacity (possibly coincident with the drying rated capacity) for the reference it would be reasonable to curve that most parameters agreed for washing machine testing (e.g. washing performance, temperature declarations, etc.) would also be applied to the washing part of the washer dryer cycle.

7.3.2.5.1.1 *Cycles and loads of the testing portfolio*

Most stakeholders explicitly mentioned the need of including full and partial loads in the washer-dryers testing, with the load composition defined according to the standard (i.e. mixed and not sorted). The combination should be aligned as much as possible to the programme portfolio for washing machines to avoid additional loads and workload.

For the WD COMBI alternative one stakeholder specified that the machine should be tested at the rated capacity for wash&dry. If the appliance does not offer a continuous cycle, a time gap of 30 minutes between the end of the washing sub-cycle and the start of the drying sub-cycle could be tolerated. In this case the sub-cycle with the lowest rated capacity would determine the load that is washed and dried (usually the drying load).

Other stakeholders instead proposed that in order to save testing cycles the load should be derived from the washing machine programme portfolio. If more than one partial load is used for the continuous wash and dry, the partial load that is the closest to the rated drying capacity should be chosen.

Another stakeholder suggested testing the maximum drying load (e.g. 2-3 times) and the half maximum drying load (e.g. 3 times). One possible deviation proposed could be maximum drying load and maximum washing load minus maximum drying load, and this load amount to be tested in the wash & dry function.

There is general agreement over the fact that the testing of the wash cycle should resemble that used for washing machines. It has been proposed to test only a specific 40 °C cotton programme to minimise the testing efforts.

As reference for testing the drying cycle, stakeholders have explicitly suggested to take the cotton “cupboard dry” condition, which has fewer issues of uncertainties and tolerance than the "iron drying" condition.

7.3.2.5.1.2 *Energy label*

Stakeholders suggested having one label divided in two parts (as in Regulation (EU) No 811/2013 for combination heaters, which combines two energy efficiency scales for space heating and water heating in one label):

- One part would be aligned with the energy label for washing machines
- The other part would provide information either on the wash & dry or on the drying function.

However, some stakeholders see two labels as most adequate, one for the washing function, equal to washing machines, and one for the drying part or WD COMBI of the appliance.

One stakeholder instead proposed to use only one label with one scale for the washer-dryer function (similar to the current layout) to avoid confusion. Two scales would be an option if results of WD COMBI interrupted could not be combined in a single value.

It was also pointed out that, in line with the proposal made for washing machines, information about consumption and duration of the tested cycle should be provided, possibly for different conditions of load.

With regard to the indication of the energy consumption, a stakeholder proposed to express it in kWh/kg instead of in kWh/cycle for the washer-dryers arguing that the capacity differs from a washing machine and the values declared therein. Condensing efficiency might not be needed on the label but in the booklet if a minimum ecodesign requirement is set.

Finally, label programmes should be indicated with an arrow and selected by default (if this function is available).

7.3.2.5.1.3 *Further requirements*

Requirements set for washing machines should be applied to the extent possible to the wash function of washer-dryers. In particular, for the wash & dry cycle, the same washing performances and rinse efficiency (to be defined as in the washing machine reference programme should be ensured). Restrictions on water consumption should take into account any requirements on rinsing performance.

A minimum ecodesign requirement on condensation efficiency was also proposed, in analogy with tumble dryers. However, no measurement standardised method is available for the moment.

Consumer information (e.g. in user manual) about the optimal application of different drying programmes and their specific energy consumption are also supported, in line with the approved presented for washing machines. As explained by one stakeholder, the actual energy consumption is not depending on the selected drying programme but on the amount of water to evaporate and the energy efficiency of the appliance. Energy consumption can be improved working in full drying load conditions and through the application of higher spin speeds.

7.3.2.5.1.4 *Standardisation issues*

As for washing machines, some stakeholders indicated that the changes to the washer-dryers standard necessary for the policy implementation will require some time (e.g. 2 years as minimum). The development of common modifications to describe the special test programme portfolio should be feasible within the given time frame if the future test approach is covered by existing international standards (IEC 60456 ed. 5, IEC 61121 ed.4 and IEC 62512 ed.1).

The standardisation process should be initiated by issuing a related mandate towards CENELEC as soon as the washer-dryer requirements are agreed upon. Some points raised by stakeholders are:

- IEC62512 will become EN 62512 with all necessary common modifications.
- Since the current test of a washer dryer is limited to the subsequent run of wash with dry cycles, a formal act is necessary to define and test the use of the washer dryer as a washing machine (i.e. according to EN 60456).
- Ensuring the same washing performances and rinse efficiency for wash&dry cycle and reference programmes of the washing machine.
- The rinsing performance measurement method is under development. A round robin test at international level (IEC) has the target to be finished by mid of 2017 and be included in a next edition of IEC 60456 together with uncertainty figures.
- Measurement of the washing performance and the applicability of the rinsing performance measurement method are key issues for the continuous wash&dry process
- A temperature measurement method is already discussed within CENELEC WG1 SWG 1.6.
- Description of the procedures to test the closest to the real-life washer-dryer testing alternative (SPLIT, REMOVE, WD COMBI Continuous or WD COMBI) is to be included. Additionally, the testing of partial loads (drying) has to be developed for continuous and interrupted wash&dry cycles.
- Up to now no low power modes are defined for a washer-dryer. These should be aligned with the washing machines
- Condensation efficiency measurement for WD needs to be developed. This is not a trivial testing and its development would need time. Different to a conventional condensation dryer, a washer-dryer has no compartment to collect the condensed water. A washer-dryer uses customarily the drain pump of the washing machine part to get rid of the water (condensed water plus cold water used for condensation).

7.3.3 Policy options regarding for information requirements

The energy label is a powerful communication tool among producers and consumers. Moreover, it helps manufacturers differentiate their products from competitors.

7.3.3.1 Additional information on the energy label

Information provided on the energy label should be clear and should allow consumers to make informed purchase decisions. Several aspects have been highlighted as candidates to be included in a revised energy label for washing machines and washer-dryers.

For washing machines the proposals are;

- *Inclusion of the energy efficiency class, energy consumption values, water consumption values, and noise during washing and spinning. One can opt for reporting a single value (weighted average of different loadings) or to report all values of all different loadings*. The advantage of a single value is simplicity. The advantage of reporting all values is full transparency. If all values are reported, (e.g. for full, half load and a quarter load or full, 2 kg, and 4 kg, depending on the decision finally made), the label may be very crowded with information. The communication of data for all loads will provide an idea of the increase in the efficiency of the appliance in relation to the increase in the loading, and make aware the educated consumer that full loads are much more efficient that half loads or quarter loads, but it is very difficult to communicate such large amount of information in a simple manner. A compromise to the above can be to present an average value on the label, and report the load-specific values in the product fiche and/or booklet of instructions and internet sites.
- *Cycle time of the standard programmes*. This will provide the idea of the cycle duration. However, it has to be discussed which value is included in the energy label as there are several programmes that can be used as standard programmes at different temperatures and loadings. One may again opt for presenting all values, or a weighted average duration, or the longest of all durations.
- *Other information of the label that it is proposed to be kept is the maximum loading capacity of the machine, and the spin dry efficiency.*
- *In addition to the above, it has been proposed by some stakeholders to include the rinsing performance. However, others are in favour, for the sake of simplicity, of leaving this parameter as part of ecodesign requirements, and not present the information on the label*

For washer-dryers the proposals are

- *Rated capacity for the wash&dry process in kg*. The rated capacity for the washing process is different to that of the drying process alone and also that for the wash&dry process. As the continuous wash&dry function is the most characteristic of this appliance, it was proposed to introduce this rated capacity into the energy label. In the absence of a continuous wash-and-dry function, the drying capacity would be labelled, but indicating this clearly.
- *Average total energy and water consumption for the* continuous *wash&dry (and in its absence interrupted washing and drying) process in kWh/cycle or Wh/cycle*. The average total energy consumption for the washing process plus the drying process or for the wash&dry process alone will be the closest value to the real life energy consumption of this appliance. It will be measured at the rated capacity for the continuous wash&dry, and if not available, the capacity of drying–only.
- *Average specific energy and water consumption for the continuous wash&dry (and in its absence interrupted washing and drying) process in kWh/cycle/kg or Wh/cycle/kg.*
- *Energy label class for the continuous (if not available, interrupted) wash&dry processes*. This is in contrast to the current washer dryer EU Regulation 96/60/EC where the energy labelling is based on using the washer-dryer to wash a complete load and to subsequently dry the whole load, which means, in most cases, to have two subsequent drying cycles (as the whole washing load is too much to be dried in one go). This proposal will make more relevant the drying function with respect to the washing process and likely trigger some improvements on this function
- *Average time for the drying and/or for the wash&dry processes in minutes/cycle.* The inclusion of this information will provide an idea of the cycle duration of this cycle. It should be clearly stated that the duration belongs to the continuous wash&dry cycle. If continuous wash and dry is not available, the sum of the duration of the washing and drying cycles will be reported.

- *Noise for drying during the wash&dry process*. This information complements the information about washing and spinning already available on the washing label.

7.3.3.2 Consumption values of the main programmes

The information that consumers get about energy and water consumption values at the point of sale via the energy label is based on specific programmes tested. To help consumers make better informed purchase decisions and, once the appliance is bought, make better programme selections, it is recommended that the manufacturer provides additional information on the consumption values of the main programmes. Currently, the ecodesign regulation for washing machines requires that the booklet of instructions includes *'indicative information on the programme time, energy and water consumption for the main washing programmes at full or partial load, or both'.* This requirement shall not be indicative but representative of the programmes, and be at full load. Only the information relative to the programmes used for the label shall also report the consumption values at partial load.

Regarding the provision of information related to the energy and water consumption for programmes in the washing machines or the washer dryers, some points were commented by stakeholders:

- One possibility is that the user manual contains, besides the information of the main programmes, also detailed information on energy, water consumption, programme time, maximum temperature reached, and the recommended usage and consumption consequence for each individual add-on option (e.g. selection of longer rinsing, shorter duration etc.).
  Similarly, the functioning of options could be described visually, e.g. diagrams showing how much more or less energy is used when activating certain functions.
- When the appliance has a display, or a function indicating the consumption (e.g. a stripe of LED lights where the number of lights lit is proportional to the energy used in a given programme) a possibility is to convey the information on the machine display, either (and ideally) before it starts the programme, and/or once the programme has finished. In doing this, the consumer has easy access to the information at any time the machine is used. This would encourage consumers to choose the most suitable programme for their needs. This option requires a display on the machine which could increase the purchase price. The limitation of this option is that not all machines have currently a display. The requirement could however be made conditional: whenever the machine has a display, the information of consumption shall be included.

7.3.3.3 Additional information in the user manual

Some stakeholders are in favour of including advice on how to use the washing machines or the washer-dryers while ensuring low environmental impacts. Some stakeholders propose to obligatory include the following information in the user manual:

- *Advice that helps decrease the energy and water consumption*, as for example: use full load whenever possible; programs at lower temperatures save energy, longer programmes can save energy.
- *Advice on the installation procedure* as for example how to correctly install the appliance in order to minimise unbalance and the noise emitted or whether the machine can be operated with hot-fill water and under which circumstances this leads to lower environmental impacts
- *Advice on how to operate the washing machine or the washer dryer*. A recent analysis by the Austrian repair and service centre RUSZ (as reported by Tecchio et al. 2016) indicate that a significant percentage of breakdowns of washing machines are related to the miss-operation of the appliance by the users. Provided that users make the effort of reading the instructions supplied, a longer life of the appliances can be achieved if consumers are informed on how to properly use, install and maintain the machine. The provision in the manual of advice on how and

how often to clean filters or how often perform washes at high temperature to clean the inner piping is thus proposed.

Many of these points are already included in the user manual, even though they are not obligatory. It is thus proposed to streamline the minimum contents of the manual regarding the items above, and to harmonise the sequence of presentation of these items.

7.3.4 Tolerances

In the current Regulation 1015/2010 and for the purposes of checking conformity with the requirements, authorities shall test a single household washing machine. If the measured parameters do not meet the values declared in the technical documentation file by the manufacturer within the ranges of the tolerances, the measurements shall be carried out on three more household washing machines. The arithmetic mean of the measured values of these three household washing machines shall meet the requirements within the ranges of the tolerances, except for the energy consumption, where the measured value shall not be greater than the rated value of the E_t by more than 6%.

It is proposed to keep the current tolerances for verification purposes as a starting point. However, these values may have to be revised when the expanded uncertainty of the new measurement procedure will be known.

In order to get the new expanded uncertainty of a measurement procedure, in most cases, it will be necessary to perform a RRT, after the agreement to a final text of the measurement standard, for evaluating the expand uncertainty, which will naturally take time. Unless this evaluation is carried out, the expanded measurement uncertainty will not be known. Therefore as soon as an expanded uncertainty is determined, respective regulatory action should incorporate this new finding into the verification tolerance (a revision of these values will be needed).

7.3.5 Demand-response enable appliances

As the energy system of the future is getting more and more variable due to fluctuating energy production by mainly renewable energy stations, it is necessary and helpful to have some flexibility on the demand as well. This can be realised by appliances which offer a demand-response possibility/function. However, the demand-response function of the appliances cannot work alone, and it is needed that the distribution system operator, or an aggregator of the smart-grid, offers the consumer sufficient incentives to allow the use of the demand-response enabled power capacity. A sufficient large number of appliances need to be in the market before such a system can take off.

It could therefore be useful to support the introduction of demand-response enabled appliances. Requirements to the demand-response function itself can be set up either by standardisation or be introduced in the ecodesign or energy label regulation.

Therefore, it was discussed if support to the demand-response enabled appliances should be introduced, and what would be the best tool to set up the general requirements, e.g. user settings, information and capabilities.

Both industry and consumer organizations do not support using the EU energy label as a marketing tool to promote the use of smart appliances. Also the EU ecodesign regulation is not seen as suitable instrument for such requirements.

7.3.6 Policy options related to material efficiency

Since 2009, EU ecodesign and energy labelling are gradually introducing requirements on material efficiency, initially of informational character only (water consumption, noise level, etc.), but lately also including specific thresholds (e.g. durability of lighting, durability of two components in vacuum cleaners).

Material efficiency requirements are also present in a number of examples of voluntary agreements (e.g. imaging equipment) and labels such as EU Ecolabel, German Blue Angel or the Nordic Swan.

This development has been accompanied by increasing importance of research on the feasibility of implementing resource efficiency aspects into product policies, as reflected in at least six European research studies published since 2013 (Ardente & Talens Peirò 2015; Benton et al. 2015; Bobba et al. 2015; Deloitte 2016; Prakash et al. 2016; Ricardo-AEA 2015).

A recent study (Tecchio et al. 2016) reviewed a database regarding the frequent failure modes, diagnosis and repairs of dishwashers and washing machines. Data were collected by Reparatur- und Service-Zentrum (RUSZ) in Vienna, Austria. The database contains approximately 3 500 records collected from 2009 to 2015. According to these data, most of the failure modes identified concerned the circulation and drain pumps (approximately 1 100) and electronics (control electronics, relays, sensors, programme selectors and control panels, approximately 750).

There are various causes for the slower uptake of requirements in mandatory policies, including for instance the lack of enforceable and relevant metrics, the lack of proper standards to measure the requirements, and the lack of data demonstrating the benefits of minimum material efficiency requirements, to justify the thresholds.

It is widely accepted that any new resource efficiency requirement should be measurable, enforceable, and relevant and should not hinder innovation and competitiveness. Additionally, any new requirements should have a proven environmental benefit and thus be based on robust data, methodologies and widely recognised standards that confirm this. Standards should be built on a solid foundation to ensure they reflect the technical reality (state-of-the-art). However, for the time being, the absence of proper standards for testing and measuring resource-related criteria seems to have hindered a practicable implementation of the criteria, including procedures for verification and market surveillance. Solid evidence for feasibility, proper measurability and environmental benefit should be taken into account when developing such standards.

Manufacturers have also stressed the need to make sure that ecodesign product measures do not overlap with other existing regulations that are already imposing end-of-life provisions and material/resource provisions, such as REACH, RoHS, WEEE and F-Gas.

Regarding currently existing standards, there are a number of harmonised EU standards that include material efficiency aspects (e.g. safety standards for durability, recycling standards for end-of-life management), but they are primarily developed for other purposes (product safety, management at recycling operations) and are not directly transferrable for increasing resource efficiency in the design phase. For example, the EN 50625 standard series covers various aspects of the treatment of electronic waste (including collection, treatment requirements, de-pollution and preparing for re-use). However, it only deals with the handling of existing (waste) products entering the recycling stream and not with the products that are currently being manufactured.

National standards on durability and reparability do exist. An example is the Austrian "sustainability label for electric and electronic appliances designed for easy repair (white and brown goods)'' of 2006, followed by the 2014 "label of excellence for durable, repair-friendly designated electrical and electronic appliances" (ONR 192102).

The "*Sustainability label for electric and electronic appliances designed for easy repair (white and brown goods) 2006*'' is a combination of mandatory and optional criteria (from which a minimum number of points should be reached) related to general criteria and service documents. Examples of criteria are the accessibility of sub-assemblies for the purpose of repair, resource savings, ensuring long product life, keeping repair periods to a minimum, simplification of repair and broader range of spare parts, ensuring faultless production, etc. After fulfilment of the conditions the product may be ranked and marked with one of the labels that show the level of satisfaction of the criteria

The "*label of excellence for durable, repair-friendly designated electrical and electronic appliances (2014)*" includes, following the same structure as described before, two lists of requirements: one for white goods and another for brown goods. The lists focus on those aspects that guarantee the ability of the appliance to be repaired as for example the accessibility of the parts to be repaired, the reduction of the repair time, the reduction of the repair costs and the enhancement of the durability of the appliances (see also section 1.3.4.).

Following M/543 (2015) from the European Commission, EU standardisation bodies (CEN and CENELEC) begun in September 2016 to develop generic standards for resource efficiency metrics for use in energy labelling and ecodesign requirements.

The section below describes an array of policy options for extending the durability of appliances and facilitating reparability, as well as a proper management of the appliance during the end-of-life stage, and the outcome of the discussions with stakeholders.

7.3.6.1 Durability and reparability

The improvement of energy efficiency in the future years is expectedly limited for washing machines, with current technologies. More technical improvement potential can be expected from the drying cycles of washer-dryers, as the integration and optimisation of drying functions in the constraints of a washing machine drum are still recent. In the context of ecodesign, durability and reparability measures might become more relevant, compared to measures to improve further energy efficiency. Improved durability can be understood as an extension of the lifetime of the machine under the same performance conditions. Such an extension of lifetime can be established either by increasing the technical lifetime of the product (during design), or by extending the real lifetime of products, e.g. through repair activities.

However, while lifetime and durability tests are undertaken on a systematic basis by many manufacturers, standardisation of these procedures or methods is neither yet in place, nor harmonised.

The following reasons that decrease the durability of products or the use time by the consumer have been identified:

- Unsatisfactory mechanical robustness or durability of certain components and/or the whole appliance, which lead to early failure rates
- Wrong user behaviour leading to defects of appliances (e.g. incorrect use, insufficient maintenance).

The Austrian repair and service centre RUSZ (as reported in Tecchio et al. (2016)) observed that inappropriate use by the customers leads to a large number of early device failures. The repair centre listed a series of behaviour patterns that should be avoided, in order not to compromise the proper functioning of a device:

- The extensive use of low temperature programs, as well as the insufficient use/no use of detergents, leading to fat deposition;
- Lack of proper maintenance by the users (e.g. regular cleaning of the filters, an operation of high temperature programmes and decalcification).
- Early replacement of appliances due to changes in consumer preferences and needs (e.g. larger or newer products, modern design, etc.).

RUSZ indicates additionally that better communication to consumers and preventive measures in this context may help prolonging the lifetime of a device.

- The overall number of repairs (per inhabitant) is decreasing. In case of a defect, appliances are increasingly discarded although a repair might have increased the real lifetime. Reasons for discarding the products might be e.g. intrinsic product design impeding repairs, missing and/or no access to spare parts, or high costs for repairs compared to purchase of a new product.

Tecchio et al. (2016) classified the reasons for not repairing a device into three groups: *too expensive for consumers* (the repair is technically possible but considered too expensive by the consumer), *not viable* (the repair is technically possible but considered economically not feasible by the technician) and *technically not feasible* (the repair is technically not possible, mainly because the spare parts are not available or the cause of failure is not identifiable).

The distribution of the cases into these three categories varies depending on the failure. For example, for the most frequent failure types (failures in the pumps or electronics), the main reason for not repairing a washing machine or a dishwasher is that the repair was considered too expensive by the consumer. This reason accounts for approximately 76% of the cases of dishwashers. The second most important reason was that it was technically not feasible (17.5%), while '*economically not viable (by the repairer*)' only accounted for 6.5%. one should expect similar percentages for washing machines.

Tecchio et al. (2016) provides additionally some data regarding the early replacement of the appliances because the consumers by mistake consider that the appliance fails. The study reported that approximately 10% of the machines that reached the repair services had no failures or no failure was found. However, these machines did not perform well likely due to blocked drainage (outside the device/in the wall), the water tap was closed or defect, the power plug off, activated child safety lock, electronics that became wet and dried out in the meantime, or other reasons.

A list of policy options on durability and reparability has been shared with the stakeholders. The stakeholder feedback received reflects the divergent opinions between environmental / consumer NGOs, Member States representatives, and industry. There is however general agreement on the need for requirements that improve durability, such as information about the technical lifetime of the products, of spare part availability, or of design for upgrades and repairs. The lack of practicability of some of these approaches is often mentioned as an obstacle, due to missing definitions and standardised metrics or the cost and duration of the required measurements. Table 7.9 presents the options seen as least feasible according to stakeholder feedback.

The policy options are seen as most feasible by stakeholders deal with reparability of products, and are presented in Table 7.9 . The full list of policy options can be found in Annex 8.7.

Table 7.9: Durability and reparability policy options seen by stakeholders as least feasible

Op-tion	Policy option	Reasons for the option to be less feasible
Component level		
1a	Requirement on performing durability tests of certain components which are known to be prone to early failures	• No standard / test available for all components; existing safety standards cannot be taken to measure durability • Such requirements have been proposed for vacuum cleaners, essentially consisting of 2 components. DW are more complex appliances and there is a large group of 5-10 components that fail most often, effective measures would have to be set to all these main components (defining "main"). • Definition of components difficult due to different designs – a too wide definition would make consistency checks complicated; a too narrow definition would be easy to circumvent

Op-tion	Policy option	Reasons for the option to be less feasible
		• urable components do not lead to durable products automatically, especially in complex appliances. • High effort / costs for testing, also for market surveillance , long-time needed for tests or accelerated tests
1b	- e.g. by means of Requirements on minimum operational lifetime of certain components	• No standard / test available; no definition of “operational lifetime” against different usage patterns in EU
1c	- e.g. by providing consumer information about the operational lifetime of certain components (motor, pumps, electronic components, other)	• The lifetime of single components is not always equal to the lifetime of the product as a whole
Whole product level		
2a	Requirement on performing durability tests of the whole product (e.g. endurance tests, accelerated tests under extreme conditions), where manufacturers declare the durability values.	• Market surveillance issues: endurance tests take long, for WM and DW about 9-12 months, and are expensive (~minimum 50 000 EUR/test). The results of non-compliance would only be available 1 year after the product is on the market, making the removal conflicting. The mechanism would work more on the brand reputation, if several cases of non-compliance are found.
2b	Requirements on minimum operational lifetime of the whole appliance (e.g. machines to run a certain minimum number of cycles). Several sub options are possible: lifetime set by the manufacturer (see option 2a and option 2c in table 7-6), or by the regulator. If by the regulator also sub options are possible, such as fixed minimum values (5 years, or fixed fractions of the average lifetime (e.g. 50%, 75%), or flexible: e.g. 50% of the value declared by the manufacturer.	• For long-living products such as DW a minimum operational lifetime must be quite high to be meaningful. Even if it would be set at 50% of the Average Expected Product Lifetime (AEPL), it is more crucial that it can be repaired if it fails after the minimum operational lifetime has expired. • Alternatives exist that are less burdensome to producers and to MSAs, like regulation of spare part availability, or guarantee systems.
General information of consumers		
3b	Compulsory direct feedback on necessary maintenance intervals via the machine’s display	• If the feedback mechanism is compulsory, this forces producers to install displays or LED mechanisms, increasing appliance costs, especially for low-price machines without display so far. The requirement can however be made conditional to the presence of a display, but this would not ensure market uptake.

Op-tion	Policy option	Reasons for the option to be less feasible
3c	Consumer information about the environmental (and economic) benefits of prolonged product use	• Long lasting DW are usually rather not replaced due to fashion and design • Possibly better option: proper information on disposal and more efficient WEEE collection / recycling • Information on appropriate use (loading) and maintenance can extend the lifetime of the product • Educational effects might be limited • Work with second hand market might be more effective
Reparability		
4d	Information requirements on reparability (e.g. repair label); indicating if the machine can be repaired or not; indicating which components are not repairable	• Many stakeholders considered the idea of a reparability scoring attractive, but reparability and after-sales services are market differentiation / competition issues, and therefore self-declared claims are prone to market distortion, unless clearly ruled • May require a standard similar to ONR 192102, and broad agreement on any internal weighting mechanisms, which are better addressed at a horizontal level • No certainty that repairs will be done/commissioned by consumers in the end (e.g. depending on the costs for repairs compared to the purchase price for a new product) • Needs investigation of consumer acceptance and understanding
4e	Consumer information about access to professional repairs	• Common practice of most (all?) manufacturers, although a standard format might help the enforcement of such requirements • It might be better that such requirements are not set on a product by product case, but on a horizontal, and widely accepted level • Reparability and after-sales services are market differentiation / competition issues, and therefore the ruling must also be clear and transparent, and shall ensure the operation of independent repairers
4j	Mandatory provision of information to consumers about commercial guarantees, i.e. the number of months/years the producer guarantees the full functioning of the appliance on top of the legal 2yr warranty, without passing the burden of proof to the consumer	• Cf. arguments under option 4i • Needs investigation of consumer acceptance and understanding • Requires broad agreement on any internal weighting mechanisms, which are better addressed at a horizontal level

Table 7.10: Durability and reparability policy options for follow-up

	Policy option	Pros	Cons/Challenges / drawbacks
Component level			
No feasible requirements were identified on specific components			
Whole product level			
2c	Consumer information about the expected operational lifetime of the whole product (e.g.	• When buying new appliances, consumers are not informed about the lifetime expectancy of the product, if used and maintained properly. With	• While still controversial and generally opposed, the most supported sub option would be one where, based on a harmonised standard, manufacturers declare the durability of their

	Policy option	Pros	Cons/Challenges / drawbacks
	label, manual)	such information, consumers are enabled to favour manufacturers who produce long-lasting and/or repairable goods. Some consumer surveys indicate a certain willingness to pay for more durable and repairable products, if this information is clearly conveyed.	appliances. • Liability declarations and implications would have to be clarified in detail • No existing definition / standard yet (work is in progress on a horizontal level in CEN/CENELEC TC10) • Market surveillance authorities may need additional guidance. Surveillance effect would work out via brand reputation, rather than affecting/leaving out specific models on the market.
General information of consumers			
3a	Consumer information about correct use and maintenance of appliances, to ensure durability	• Often available in the documentation from manufacturers, this information should additionally be promoted to extend it to the manufacturers not currently including it • Use of further dissemination possibilities, e.g. NGOs and test institutes	• A standard format needs agreement and could help enforcement of such requirements • better enforced as a consumer information campaigns than as an ecodesign / energy label requirement
Reparability			
4a	Design for upgrades and repairs: components being prone to early failures should not be designed in a manner prohibiting repairs (e.g. high integration of different components)	• Independent repairers and consumer organisations see this as very important • The market of repair shall be as transparent and as open as possible to reduce the cost of repair for the consumers	• Information on which components usually fail is needed. • The formulation of how design for disassembly has to be agreed (e.g. avoidance of permanent fastening not using gluing, soldering or welding) • Trade-offs are not excluded (e.g. it is reported that certain designs might favour energy efficiency and durability at the expense of reparability (by keeping reduced overall costs)
4b	Design for upgrades and repairs: components prone to early failures should be easily accessible and exchangeable using universal tools	• Seen as very important by stakeholders, including independent repairers and consumer organisations • Already applied by some manufacturers	• Cf. arguments under option 4a • Early failures are covered by the warranty and defects liability regulation, but not covered after 2 years • In exceptional cases, the use of non-universal tools can save time in repairing. However, affordable access to such tools should be mandatory.
4c	Provision of Repair and Maintenance Information Appliance internal failure diagnosis systems to report error specific messages to the user.	• Seen as very important by stakeholders, including independent repairers and consumer organisations • Already applied by some manufacturers, but not by others • Particular relevant for	• Some manufacturers make it difficult and/or expensive to provide diagnostic tools to independent repairers.

	Policy option	Pros	Cons/Challenges / drawbacks
	Diagnostic tools should also be made available to independent repair operators to make them understand the error codes.	electronic failures, for which identification of defects is difficult for repairers	
4f	Information about the availability (and price) of spare parts (current practice: from 0 to 10-15 years after production) and maximum delivery time	• Seen as very important by stakeholders • Already applied by some manufacturers, which have open access websites for purchase of spare parts • Cf. French decree 2014-1482 about the time for which spare parts will be available	• Potential difficulties in market surveillance authorities that may need harmonized guidance. • It shall be clarified if other legislation (e.g. REACH, RoHS, ecodesign on certain components being integrated in appliances such as motors or fans) would ex post restrict the availability of spare parts, and deploy special exemptions where appropriate
4g	Guarantee of public availability of spare parts for a certain period following the end of the production of the model; ensure original and backwardly compatible spare parts	• Seen as very important by some stakeholders • Already applied by some manufacturers	• For DW and WM, the array of components that fail may be broad • A time provision guarantee bears the risk of oversupply of spare parts that become WEEE at a later point in time • Research on costs and impacts assessment will be needed. • Verification will be supported if there is a guidance document to surveillance authorities. Market surveiliance is relevant only if it takes place some months or years after the appliance has been on the market, and not when the product is placed on the market for the first time

	Policy option	Pros	Cons/Challenges / drawbacks
4h	Provision of Repair and Maintenance Information Repair manuals shall be available for free or at reasonable fees at least to independent repairers, including clear disassembly and repair instructions to enable non-destructive disassembly of product for the purpose of replacing key components or parts for upgrades or repairs. Information shall be publicly available or by entering the product serial number on a webpage to facilitate access for recognized / independent repair centres. Wiring and connection diagrams showing the location of the components shall be available online for at least 5 years (ideally for the length of availability of the spare parts)	• Seen as very important and prerequisite for reparability by some stakeholders • Repair manuals and wiring and connection diagrams are already in place for approved service providers which undergo specific in-house training / qualification programmes, and pay fees to manufacturers	• Having access to electronic repair software is becoming even more relevant to repairers as appliances become electronically more complex • Public availability of repair manuals bears the risk of abuse by non-professional repairers, potentially causing damage to manufacturers brand image • Making repair manuals available publicly is straightforward. Making restricted access would require a multi-brand tailored system of access to repairers, similar to the system in place for automotive repair. • Reparability and after-sales services are currently seen as market differentiation / competition issues, however the restriction of market competition is not in the benefit of consumers
4i	Manufacturers shall mandatorily offer to the customer a commercial guarantee, that extends the 2-year warranty (legal guarantee) currently applicable, and ensure that the goods are in conformity with the contract of sale, without passing the burden of proof to the consumer. It includes service agreement with a pick-up and return option. A commercial guarantee would rule in addition to the current legal obligation relating to the guarantee of conformity. The duration of the commercial guarantee, however, would be defined by the	• This requirement would have the advantage that the manufacturer guarantees the proper functioning of the product e.g. for a certain number of cycles or years (whichever occurs first), i.e. that the manufacturer has to prove misuse by the consumer, and not the other way around that the consumer has to prove that the failure was due to a manufacturing fault). This approach might facilitate reducing early failures. An extension of the guarantee would also mean that manufacturers will pay attention to the availability of spare parts. • The guarantee should include a take back requirement by the manufacturer, so that it	• The actors involved (manufacturer or seller) shall be defined, not to confuse the customer. • The Guarantee Directive would prescribe the minimum conditions to be met by the commercial guarantee. • Ideally, commercial guarantee yearly primes could better reflect the expected durability of the appliances, but it may take long before the market is transparent enough to reflect this. • This initiative shall better be addressed horizontally, and not only to dishwashers or washing machines.

	Policy option	Pros	Cons/Challenges / drawbacks
	manufacturer.	can be properly recycled or components be reused if the product cannot be repaired.	

Regarding the option 4 on reparability, some stakeholders have proposed to combine some of the options outlined, which are initially conceived as ecodesign criteria (i.e. mandatory minimum criteria), into a more flexible 'scoring system' that could be communicated to the consumer by means of the product fiche, or even the energy label.

Two proposals have been tabled by stakeholders:

(1) a simplified scoring of three categories (green-yellow-red) or 'basic reparability grades':

- RED: No repair service by the manufacturer or authorized repair companies and no availability of spare parts for at least 10 years or no repair manual publicly available. The product information sheet and the information on the website of the manufacturer shall contain a warning on that.
- YELLOW: Repair service by the manufacturer or authorized repair companies for at least 10 years (could be variable per product, e.g. differ for WM/WD) after production.
- GREEN: Availability of spare parts for at least 10 years (variable) and repair manuals made publicly available by the manufacturer.

(2) a more elaborated, 5-classes system, where the 5-classes are awarded to services (e.g. provision of the dishwashing service or clothes washing service per year/per month, including any necessary repair or appliance replacement), and no stars are awarded where no repair, spare parts or instructions are available.

This system is more flexible than mandatory ecodesign requirements, as the manufacturer shall communicate the choice to the consumer, but at the same time manufacturer has a choice to:

a) do nothing (when the product is too cheap to afford this),

b) keep the repair service in its own hands (repair manual need not be available publicly) or to the restricted circle to registered and authorised repair services.

c) have spare parts available and make the repair manual public, including private customers and/or independent repairers.

While this idea is very attractive and could have potentially a high impact, its practical implementation needs to be further analysed. Two important aspects to consider are

(1) that it shall not only be suited to dishwashers and washing machines, currently under revision, but ideally be suited for all appliances, in a horizontal manner, and

(2) that a central element of its success is that consumers understand the message of the 'reparability scoring'. To this aim, an intuitive, well-designed pictogram and symbols shall be used, including equally clear distinction between the different grades or classes of reparability.

In addition to the feedback above, an important source of information for the development of a scoring system is the comprehensive scoring and labelling system of the Austrian standard ONR 192102 mentioned in the sections above

On the drawback side, it is easy to see that no matter how simple the system is designed with additional colours or icons (e.g. red/yellow/green, smileys or pluses/minuses), it will work for well-established manufacturers (which normally keep an eye on each other's declarations), but will not be on the way for deliberate wrong declarations and illegal commercialisation or import of products. A key point of these proposals is the extent to which swift market surveillance can hinder that e.g. smaller parties of DWs declared as very repairable have no actual system for spare part provision, repair, etc.

Underlying this discussion, and the requirements listed in Table 7-6, is the purpose of ensuring a transparent market for repair, the best conditions for access to that market for independent repairers and the interested consumers, as well as transparent communication to consumers of reparability characteristics of appliances, ideally before an appliance is purchased.

Given the arguments above, within the scope of this preparatory study it has not been discussed in-depth with the stakeholders how the reparability scoring could look like. The European Commission is thus encouraged to undertake a horizontal analysis of this option, including all appliances potentially included, and ensuring a thorough user behaviour survey that ensures that consumers understand clearly the scoring.

7.3.6.2 Recyclability

Similarly to durability and reparability, policy options on recyclability have been discussed with stakeholders. Specific requirements in the product design could be put forward that would enhance the effectiveness of end of life efforts by facilitating

- Proper collection, sorting and treatment of appliances after use; or
- More efficient de-pollution of hazardous components, enabling recyclers to comply with the WEEE Directive
- More efficient recycling of the materials that have a positive market value (i.e. with prices based on international trade and markets, and not subject to subsidies or tariffs.

Some stakeholders brought forward general comments to this approach, indicating that the proposed action is interesting from a theoretical point of view, but is superfluous to recyclers that currently use recycling practices or technologies where the proposals are inapplicable, and therefore of no real benefit. They also indicate that some of the proposals are very dependent on time and are only financially feasible under certain market conditions (e.g. certain price ranges for metals) that are not always met, due to the volatility of metal prices in the international market.

Table 7.11 below includes the proposals that have been generally supported. Other non-supported measures are discussed further below.

Table 7.11: Recycling policy options for follow-up

Proposed options	Rationale

Mandatory marking of Annex VII WEEE (2012/19/EU) **components** that are not always present, and are **not visible from the outside**: (1) F-gas – Back panel marking following an agreed pictogram (2) Electrolytic capacitor containing substances of concern - marking of component (3) Printed circuits >10cm2	WEEE contains in Annex VII a list of components in EEE that may contain hazardous substances. If so, those components need to be treated separately. The identification and removal of these components can be difficult if they are dispersed throughout the inside of the appliance, and furthermore if they are permanently fixed by e.g. soldering or gluing. Simple and cost-effective marking requirements in the frame of ecodesign could significantly facilitate compliance with WEEE. For the appliances of concern, three components have been identified (1) F-gases in heat pumps, (2) certain electrolytic capacitors, and (3) large printed circuits. A marking in the back plate indicating the presence and location of these components would be sufficient. Standardisation bodies are to define the adequate material characteristics, size, shape, etc. for the purpose described. For illustration, the marking shall be readable for recycling plant operators in the direct visual inspection of the appliances, as well as in control for surveillance purposes. The back panel F-gas marking shall be identifiable from any distance and readable from a distance of approx. 2m, while the capacitor marking shall be identifiable from approx. 1m. The marking must be indelible and durable for at least the technical lifetime of the appliance. For the back panel marking, tentatively a minimum size of 300cm^2, letter fonts (if present) of minimum 40mm tall, and contrasting colours (Black-white, black-yellow) could be appropriate. Pictograms are also possible and recommendable to avoid language translation issues.
Dismantlability for depollution in recycling operations: **Access to and extraction of the components of concern** (WEEE Annex VII, 2012/19/EU) **must not encounter fixings that require proprietary or not commonly available tools.**	Even if the majority of recycling currently takes place mechanically, there are still niche recyclers that operate business models based on quality of the recovered components. These recyclers need to comply with WEEE too, and therefore it is essential for them that the components in appliances that contain hazardous substances are easy to remove. This criterion addresses the concern above. The criterion reflects current practice in most manufacturers, and therefore should not imply any significant burden. In addition, it aligns objectives related to easier access and removal for the purpose of repair, which is also for the benefit of manufacturers that wish to project an image of repair-friendliness.

The marking of the F-gas (marked (1) on table 7.11) has been widely supported by stakeholders, and will enable operators to detect when a heat pump is present in the appliance (normally not visible from the outside), and therefore requires special treatment for removal of the refrigerant gas and compressor oil, much in the same manner that is currently undertaken for refrigeration appliances.

Currently, standard IEC 60335-2-89:2012 describes the marking of flammable insulation blowing agent used in appliances, in particular:

- The marking shall declare the chemical name of the principal component of the insulation blowing agent
- The height of the letter used for the marking of the flammable insulation blowing agent shall be at least 40 mm

The marking shall include the symbol ISO 7010 W021:"Warning; Risk of fire/ flammable materials"

- the height of the triangle in the symbol "Warning; Risk of fire" shall be at least 15 mm

The other two markings discussed have less clear benefits. The marking of the electrolytic capacitor (marked (2) on Table 7.11) would allow to distinguish if it contains or not substances of concern, and therefore if it needs separate collection for hazardous waste treatment.

Electrolytic capacitors are used to accumulate charge and kick-start mechanical components such as motors. They have a liquid (electrolyte) sandwiched in an aluminium spiralled plate and have two poles, and two pins, positive and negative. The negative/positive pin is indicated like in batteries, with a "-" [minus] or "+" [plus] marking, and/or a coloured strip. Big capacitors are usually electrolytic, with no indication of the presence of substances of concern. There are other types of capacitors (non-electrolytic) which are also polarised and thus have pole markings.

Stakeholders interviewed for this purpose[2] indicate that currently, all large electrolytic capacitors in dishwashers, washing machines and washer dryers do all contain substances of very high concern, and therefore there is no current system for identification of electrolytic capacitors NOT containing substances of concern. Additionally, the producers of these components stated for the time being that they do not see chances for substitution. Therefore, there is potential for the development of non-hazardous capacitors, but these are not yet on the market.

Regarding printed circuit boards (marked (3) on Table 7.11), these have traditionally been placed behind the controls of the appliance, in the top frame (for free standard appliances) or in the door top (for integrated appliances). However, some appliances can have printed circuit boards elsewhere, making it less intuitive for recyclers to find and remove (especially if manual removal is used). In case of mechanical treatment (the vast majority of treatment in the EU), there is little difference to the placement, as the shredding process will tear the appliance into pieces from the outset and then the pieces of EEE will be separated. According to stakeholders, marking is not as important as a non-permanent fixing, so they loosen more easily during mechanical processing, or are easier to access and remove for the purpose of repair (see section above). Stakeholders have also indicated that the motivations for recycling of printed circuit boards for the purpose of material recovery e.g. of valuable metals (i.e. not for depollution of hazardous substance) are weaker for dishwashers and washing machines compared to the boards of information and communication technologies (ICT) products, as the concentration of these substances is much lower. This makes measures in this field less effective than some studies may suggest.

7.3.6.2.1 Recycled content

Stakeholders reject in general requirements on the use of recycled material. They argue that most metals are indeed stemming from a mix of virgin and recycled origin. For plastics, it is difficult to use recycled technical plastics, as it is not certain that they will meet specific performance requirements. Quality standards for those recycled materials do not exist at the moment. For example, in some cases the use of plastics with recycled content would increase the dimensions and weight of components to deliver the

---

[2] Including appliance manufacturers, and capacitor producers including Europe Chemi Con,Frolyt,FTCAP,Kemet and TDK

same mechanical properties, and this is not always possible for space reasons. In other cases, the recycled material is not available in a given colour (e.g. white) that is preferred for aesthetic reasons.

The requirements above refer usually to the composition of appliances currently on the market and will appear in the end of life stage in approx. 12.5 years from now. They refer to the present recycling techniques, which are mainly based on mechanical treatment, starting with shredding and followed by mechanical and manual separation. It is argued that the technology of recycling is very slow moving. Given that washing machines and washer-dryers have an average real lifetime of 12.5 years; it is difficult to judge how the future recycling techniques will have evolved when e.g. more appliances with displays come to the end of their lives. Recycling business models vary: some recyclers work on high flows, and generate large volumes of not very pure fractions of e.g. copper, steel, aluminium, or plastics, while others treating specific appliances individually, e.g. manually, and obtain higher quality material yields from which they obtain a compensatory profit. One-fits-all recipes have to be considered cautiously, as recyclers with business models based on high flows would probably not benefit from the requirements of manual dismantling of specific components of the machine. Thus the effect on the real-life recycling praxis is still not clear.

In conclusion, in order to be widely accepted and implemented the proposals, measurement and verification standards will be needed, and incorporate profound knowledge of the market mechanisms that drive recycling.

7.4 Scenario analysis for washing machines

7.4.1 Introduction

The objective of this section is to set up a stock model (2015-2030) and calculate the impact of different policy scenarios regarding resource use (energy and water), emissions (CO_2eq), consumer expenditure and employment depending on the market evolution of washing machines (including the washing process of the washer dryers). The different policy options have been outlined in section 0 above. Policy options taken into account for assessing their impacts are further described below. Note that the calculated impacts for the different scenarios are indicative. A full impact assessment will be developed later in the policy process, where the findings from this study can be refined. Parameters that could be taken into account in the full impact assessment, but are not taken into account in this study are e.g. sensitivity analysis of some parameters, price elasticities and refined impact estimation of the material efficiency proposals.

7.4.2 Model description

In order to assess the effects of possible ecodesign requirements and changes in the energy label a model has been developed. For the assessment of the different scenarios the following common points have been considered.

7.4.2.1 Machine specific parameters

Machine specific parameters (e.g. average capacity, water and energy consumption, number of cycles, etc.) are based on the base case presented in Task 5 and the improvement options presented in Task 6.

7.4.2.2 Consumptions under real life conditions (correction factors)

The model determines the average annual energy and water consumption of washing machines by multiplying the number of cycles per year (avg 220 cycles per year) by the energy consumption per cycle.

The energy consumption per cycle was estimated in Task 5 and is based on the real-life conditions and the information provided by the stakeholders on the consumption of each washing programme. This has been called the real-life conditions.

The correction factors equal the ratio of the annual energy consumption under real-life conditions and the annual energy consumption declared in accordance with the standard conditions. For the base case the calculation of the correction factor can be found in Table 7.12.

Lasic et al (2015) have proposed a multiple linear regression to model the behaviour of the washing machines and to calculate their consumption of water, energy and detergent in dependence of the rated capacity, washing temperature, duration of the main wash, load size and washing performance. These regressions were calculated for cotton programmes only. Based on this study, further correction factors for other programmes have been estimated, as shown in Table 7.12 for the energy consumption, water consumption and duration. Note that these correction factors between the declared values and the real life conditions were applied in the model regardless the energy efficiency of the machines.

Table 7.12: Correction factors for the energy consumption between the standard conditions and the real-life conditions

	Load (kg)	Capacity (kg)	Temp (C)	Time (min)	corr f time	Water (L/cycle)	Water corr factor	Energy (kWh/cycle)	Ener corr factor	kWh/kg	Ener per kg corr factor
40, Std	declared	7.0	40	190		68.3		0.88		0.13	
	real	3.4	40	177	93%	46.6	68%	0.70	79%	0.21	163%
60, Std	declared	7.0	48	204		68.3		1.08		0.15	
	real	3.4	48	190	93%	46.6	68%	0.90	83%	0.26	171%
40, Normal	declared	7.0	40	173		68.3		0.84		0.12	
	real	3.4	40	152	88%	46.6	68%	0.64	76%	0.19	157%
60, Normal	declared	7.0	60	166		68.3		1.23		0.18	
	real	3.4	60	142	85%	46.6	68%	1.02	83%	0.30	171%
super quick	declared	2.8	32	21		43.2		0.13		0.04	
	real	1.8	32	19	87%	36.6	85%	0.07	59%	0.04	96%
normal quick	declared	4.5	42	54		53.2		0.48		0.11	
	real	3.8	42	47	87%	48.7	91%	0.43	90%	0.11	108%
Synthetic + easy care	declared	4.0	35	122		50.2		0.49		0.12	
	real	2.8	35	106	87%	43.1	86%	0.40	82%	0.14	116%
Cotton 30C programme	declared	7.0	30	105		68.3		0.48		0.07	
	real	3.4	30	91	87%	46.6	68%	0.29	61%	0.09	126%
mix programme	declared	5.0	40	94		56.3		0.56		0.11	
	real	3.7	40	82	87%	48.4	86%	0.48	85%	0.13	115%
Cotton 90C programme	declared	7.0	85	152		68.3		1.69		0.24	
	real	3.4	85	132	87%	46.6	68%	1.49	88%	0.44	182%
Cotton 20C programme	declared	7.0	20	181		68.3		0.46		0.07	
	real	3.4	20	157	87%	46.6	68%	0.26	55%	0.08	113%

Depending on the implemented design option the future energy and water consumption under the real life conditions will progressively change, however the frequency of use of each of the washing programmes is supposed to remain unchanged. This is illustrated in section 7.4.3.3.

7.4.2.3 Real lifetime

This section describes how possible impacts on the lifetime regarding durability and reparability requirements could be taken into account. The reference point is the average technical lifetime of a washing machine which is considered to be 12.5 years (taken as average lifetime of the first useful service life of washing machines replaced due to a defect in accordance with Prakash et al. (2016)). However, the real lifetime of a machine can be shorter or longer than its average technical lifetime due to different reasons such as differences in quality of different models, re-use after first useful life, repair in case of a defect, etc. This section aims at modelling the different pathways for the end of life of the appliances and studying the possibilities for extending its real lifetime beyond its average technical lifetime.

The model assumes that for the real lifetime of a washing machine two parts or paths can be considered. The first path lasts until the end of the useful service life for the first owner. At that point, two possibilities are considered:

h) the machine could be replaced without having a failure, e.g. if the consumer wants to buy a new machine for aesthetic reasons or for having lower operational costs due to the higher energy efficiency of the new machines. This machine can go straight to a waste stream or can be re-used or sold in the second hand market (in this last case, the second part of the lifetime starts and the machine is supposed to be kept in the stock until it breaks)
i) a failure occurs. If a failure occurs the machine can be replaced or the machine can be repaired. If the machine is repaired, the lifetime can be extended (probably when repaired close to its end of life) or will be the same as the original technical lifetime (probably when repaired in an early stage).

Machines that are replaced in the stock are assumed to follow a Weibull distribution with its characteristic parameters $\alpha = 1.64$ and $\beta = 13.72$ for the BAU scenario according to Prakash et al. (2016) having an average lifetime on the market close to 12.3 years. The model aggregates the discarded machines into three classes, i.e. less than 5 years old, between 6-11 years and more than 11 years old. An overview is given in Annex 1.1.1

The real lifetime calculated in this way is the lifetime that is assumed for 2015 in the stock and sales model. The literature reports that the real and technical lifetime of the appliances have not been kept constant along the years. A reduction of the lifetime of the machines has been observed by several authors and modelled by changing the characteristic parameters of the Weibull distribution along the years. For the years 1981-2014 the values considered are in accordance with Balde et al. (2015). For years before 1981, the same parameters are assumed as in 1981. For years after 2014 the parameters are set according to the assumptions which have been repeated in section 0. For scenarios not related to end of life the parameters are equal to those in year 2015. If the real lifetime is extended or shortened this would have an effect on the total sales, the turnover of the machines, the annual energy and water consumption and the consumer expenditure among other aspects. Further information of the assumptions considered for scenario 3 can be found in section 7.4.3.5.

7.4.2.4 Stock and sales of the products

The overall stock of washing machines on the European market is estimated by the number of households (Eurostat 2016d) and the estimated penetration rate (CLASP 2013). The number of households was estimated based on the 2005-2015 historical series reported in Eurostat for private households and population (Eurostat 2016a, 2016b). Forecasting was also available in the case of population (Eurostat 2016c).

Penetration (ownership rate) of washing machines in European households in 2015 was 92%, according to stakeholders' estimations. Penetration in the past was considered to increase progressively, therefore it was estimated that past penetration values are as follows: 62% in 1970, 82% in 1990, 84% in 1995, 86% in 2000, 905 in 2005 and 91% in 2010.The stock values can be found in Annex 8.9.1.

The total sales in year *j* are defined as

Total sales (j) = New sales (j) + Replacement sales (j)

Where the *total sales (j)* are the overall sales of appliances in the EU28 in year *(j)*, the *new sales (j)* are the number of new installations in year *(j)* and the *replacement sales (j)* are the units of appliances retired and replaced in that year *(j).*

The *new sales* in year *(j)* are calculated as the difference between the overall stock washing machines in year *(j)* and year *(j-1)*. This difference represents the number of households that own a washing machine for the first time, i.e. the number of households increases as there are smaller families.

The *replacement sales* are estimated based on assumptions about the lifetime of the washing machines and are estimated by calculating the number of machines that "*survive*" in a certain year. This survival rate is based on a Weibull cumulative function with specific parameters per year defined in Annex 0. The replacement sales in year *j* are thus estimated as

Replacement sales (j) = Stock (j) – New Sales (j) – Survivals (j)

This sales accounting provides an estimate of the age distribution of the washing machine stock for all years. The age distribution of in-service washing machines serves as an input to both the consumption and cost calculations, because the costs and resource consumption for a certain year depend on the age distribution of the stock. The sales figures can be found in Annex8.9.1.

The results of these calculations show that the EU28 total sales remains stable in the coming years, around 16.3 million units (Figure 7.3). The forecast of the total sales in 2030 consists of approximately 2% of new sales and 98% of replacement sales. In the same period the EU28 washing machine stock increases only in 7.25 million units (Figure 7.4). The expected increase in stock is due to the assumed increase of the number of European households at a constant penetration rate (See Annex 8.9.1).

The modelled and forecasted total sales were compared to the available sales data and forecasted sales found in the literature. VHK (2014 / status 2013) predicts approximately 14.9 millions of units to be sold in 2015 and 16.3 millions of units in 2030. With the model applied in this study a sales figure of 15.0 million units is estimated for 2015 and 16.3 million units for 2030 (see Figure 7.3).

The sales figures obtained in this study are very close to the figures predicted in VHK (2014).

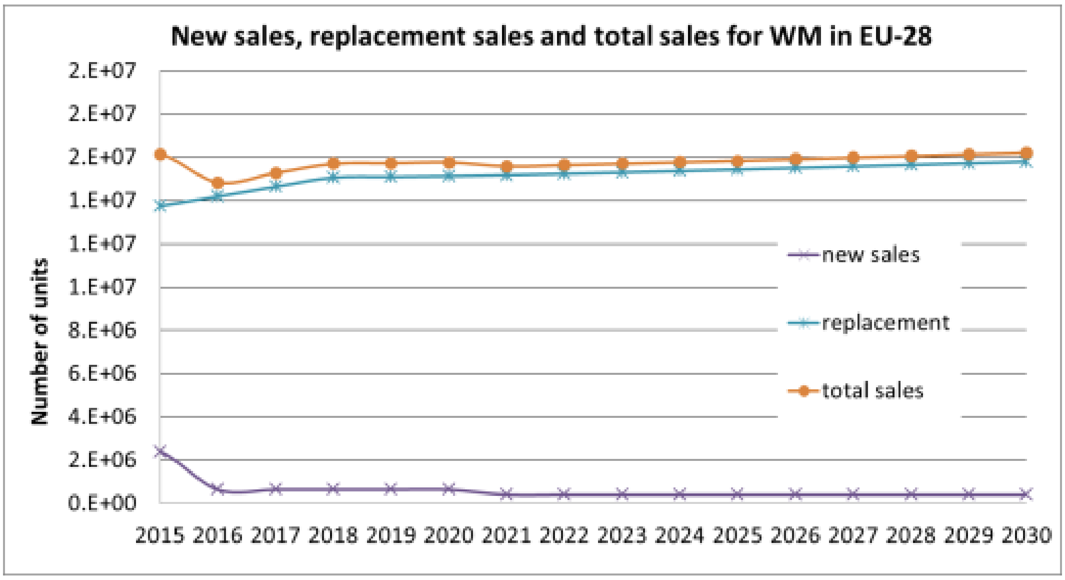


Figure 7.3: Forecast of the sales of appliances in million units in the EU28 market

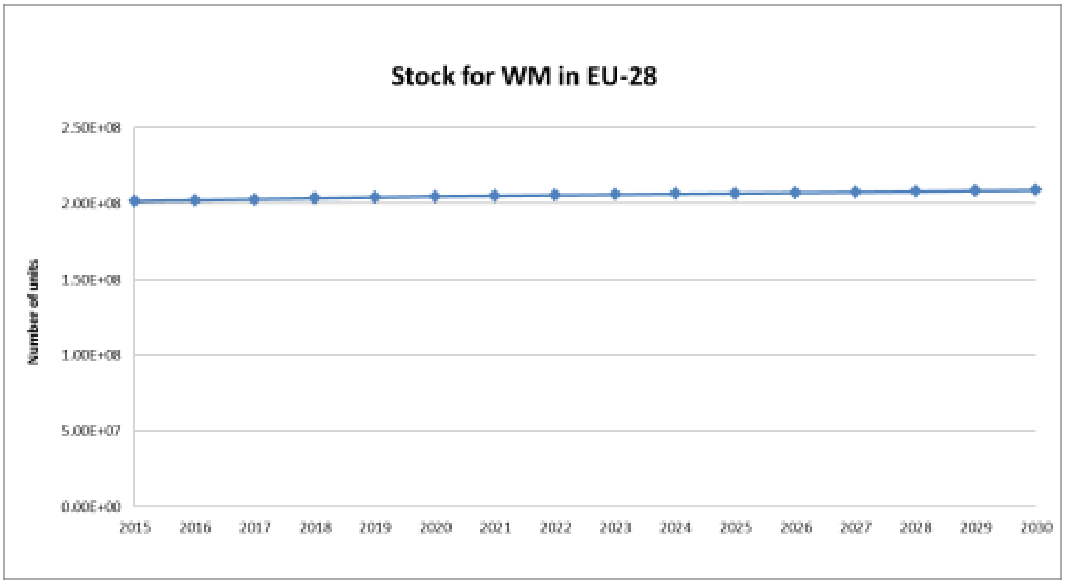


Figure 7.4: Forecast of the stock of appliances in the EU28 market

7.4.2.5 Consumer expenditure

The impacts of possible policy measures on the consumer expenditure have been analysed. These impacts include a change in the operating expenses (which are usually decreased because of more energy efficient machines) and a change in the purchase price (which is usually increased). The consumer expenditure is calculated as the life cycle cost (LCC), i.e. including purchase costs and operating costs (energy and water costs, auxiliaries' costs and repair and maintenance costs).

7.4.2.5.1 Purchase price

The *purchase price* is estimated based on the information included in Table 5-1 regarding manufacturing costs, mark-ups for the manufacturers and retailers and the VAT. The manufacturing costs include, when appropriate, the additional manufacturing costs of the improvement options which are added to the base case to achieve better energy performance (see section 6.1).

The real cost of a product usually decreases over time because of the manufacturer's experience in producing that product (see also section 6.1.2.8). In the case of washing machines a part of the downward trend in purchase price might also be attributed to a change in sales channels, i.e. from specialised electronics retailers to big supermarket chains and internet sales.

To arrive at the purchase prices beyond 2015 the manufacturing cost in 2015 was corrected by the experience curve and the mark-ups. Prices beyond 2015 are reported in $Euro_{2015}$ to avoid uncertainties due to future inflation.

An experience curve connects the real cost of the production with the manufacturer's cumulative production and could be described as $Y(j) = a\,X(j)^{-b}$ where *a* is the initial purchase price (which in this case is set to the price in 2015), *b* is a positive constant known as the experience rate parameter, *X(j)* are the units of cumulative production and *Y(j)* is the purchase price in year *j*. The constant *b* was estimated by fitting the experience function, corrected by the harmonized consumer price index (HCPI), to the harmonized index of consumer prices for household appliances ($HCPI_{appliances}$) provided by Eurostat (2016a). The fitting results in a value of b = 0.3. This factor was applied to all technologies.

The state of development of the heat pump technology for washing machines was considered to be not as mature as other technologies[3]. This means that technologies that are considered already mature and widely applied will have a softer effect of gaining experience than heat pumps that are considered to have a higher improvement potential. The difference was modelled by considering a different level of cumulative production of washing machines equipped with heat pumps compared to appliances without this technology. The cumulative production is derived in each of the scenarios modelled from the penetration of certain technologies which in turn comes from the assumptions of sales distribution of the different energy classes (see 7.4.3.3 and 7.4.3.4).

7.4.2.5.2 Operating costs

The operating costs consist of the electricity and water cost, maintenance and repair costs, and auxiliaries' costs (detergent).

The energy consumption of the overall stock at EU28 level per year is calculated as follows

$$AEC_{EU\,28}\,(j) = \sum_{i=1}^{j} Survival_{(j-i)}\; UEC_{(j-i)}$$

Where AEC_{EU28} *(j)* is the EU28 annual energy consumption in year *j*, $survival_{(j-i)}$ is the number of units surviving in year *j* which have entered the market in year *j-i* and $UEC_{(j-i)}$ is the average energy consumption of a machine in year *j-i* in which the product was purchased as a new unit. The average energy consumption of a new machine is calculated from the distribution of the sales over the label classes when it is purchased.

The energy and water consumption of each washing machine in a certain label class is calculated at the maximum value of that energy class. For example, for the current A++ class the energy consumption of the machine is considered to consume 198 kWh/year and the current A+++ class is split into four groups which respective energy consumption ranges from 175 kWh/year to 103 kWh/year. This stems from observing the energy consumption of appliance models in CECED database, where most models of a given energy class cluster around the maximum EEI of that class.

To calculate the EU28 cost for electricity use from washing machines, AEC_{EU28} *(j)* is multiplied with the corresponding cost for electricity per kWh in year *j*. The same approach is applied for calculating the water

[3] This refers to the heating of water only. For washer-dryers (as for tumble dryers), HP are widely to heat air, and this is a mature technology used commercially.

cost at EU28 level. The energy price trends are estimated considering the projections in the EU Reference scenario 2016 (European Commission 2016) and the water trend prices are estimated by an escalation factor of 2.5%. Annex 8.9.4 shows the price values per year that were used in the calculation.

The repair and maintenance costs include costs associated with repairing or replacing components that have failed and costs associated with maintaining the operation of the washing machine. As already outlined, it is assumed that small incremental changes in product energy efficiency produce no changes in repair and maintenance costs over the base case costs. However, appliances that have significantly higher energy efficiencies (such as those equipped with heat pumps) are more likely to incur higher repair and maintenance costs, because their increased complexity and higher number of parts typically increases the cumulative probability of failure. This difference was not considered in the model. The repair and maintenance costs in the reference year are shown in Table 5.1. This value was reported for the years to come and kept constant (in $Euro_{2015}$).

For the auxiliaries cost, the cost per year per machine (Table 5-3) is multiplied by the stock on the EU28 market in that year. The annual average price is assumed constant, the same as for the repair and maintenance costs.

7.4.2.6 Annual emissions of CO_{2eq} and annual primary energy consumption

The *annual emissions of* $CO_{2\ eq}$ related to the use of washing machines are estimated based on the annual electricity consumption. Yearly emission factors (g of $CO_{2\ eq}/kWh_{electricity}$) were considered to convert electricity consumption into greenhouse gas (GHG) emissions. The value of the emission factor depends on the electricity mix at EU-level. Historical data series show that this value has been changing along the years due to among other reasons the higher proportion of renewable energy sources and the European targets to reduce the GHG emissions. The forecast for future emission factors was calculated from the EU Reference scenario 2016 (European Commission 2016) and is tabled in Annex 8.9.5.

The *annual demand of primary energy* associated to the use of electricity of washing machines at the EU level was modelled based on the current primary energy factor (PEF) included in the Directive 2012/27/EU (European Parliament 2012b) on energy efficiency and its expected trend in accordance with the EU Reference Scenario 2016. Directive 2012/27/EU establishes in Annex IV a default coefficient of 2.5 which may be applied by Member States when transforming electricity savings into primary energy savings. As the real electricity generation in the EU-28 is comprised of a variety of different power plants and generation installations using different technologies, fuel types and qualities the conversion factors are not a constant value. The estimated values of PEF in the future assume an increase in the efficiency in generating electricity from fuels as well as a higher integration of more renewable and carbon-neutral technologies. The forecast for the future primary energy factors is tabled in Annex 8.9.8

7.4.2.7 Impacts on jobs of manufacturers and retailers

In this preparatory study, a first rough estimate of employment figures has been produced. Employment estimates have been calculated based on data reported in the Impact Assessment of 2008 (European Commission 2012a) on the basis of the average turnover per employee in each sector (manufacturing industry: 188 000 € / employee and white good retailers: 60 000 € / employee).

Further, more sophisticated calculations are to be made in the Impact Assessment. The total turnover per year is calculated from the average purchase price of that year multiplied by the total sales of that year. This turnover is then partitioned over the manufacturers and retailers according to the mark-ups of each sector (see section 5.1.3). Even though it is a rough estimation, it provides an initial insight. Local levies and recycling contributions are not taken into account.

7.4.3 Policy scenarios

7.4.3.1 Description of the assessed scenarios

Table 7.13 shows the policy options that have been assessed in this study. The business-as-usual scenario (BAU) is used as a reference. This scenario implies no changes in the legal requirements for washing machines, i.e. no changes in ecodesign or other requirements and no changes in the energy label. Possible changes of those regulations are reflected in the assessed policy scenarios that are summarized in Table 7.13.

The scenarios analysed for washing machines are firstly focused on assessing corrective measures of the standard that will bring it closer to the real life conditions (scenario 1). It is expected that the market-push potential of the Ecodesign, which has already been largely exploited and resulted in little market differentiation, will be limited as currently there is little technology development potential. Therefore, it is important for a revision to evaluate the missing potential of the revision of the energy label in the transition of the market towards more efficient machines. This assessment is carried out in Scenario 2 and Scenario 3, where firstly the role of the energy label in combination with ecodesign is assessed, the strictness of this instrument is assessed.

Table 7.13: Policy scenarios under consideration

Scenario	Sub-scenario	Comments
0. BAU	0. BAU	Reference scenario based on real-life conditions with no implementation of further policy instruments or changes/modifications in the current ones
1. ECODESIGN	1.a 40C cotton as testing programme	Only a 40C cotton programme is used for testing. The testing 40C cotton programme is optimized and preferred by the consumers
	1.b Time cap	The testing programmes must not exceed 180 min. Consumers would thus increase their use of this programme, but also the average energy consumption of the testing programme increases compared to BAU, as in order to keep performance, time reduction has to be compensated with e.g. higher temperature. The policy sub-option of including time in the EEI formula would be in between the results of BAU, and option 1.b
	1.c Merge of standard programmes to increase average loading	The testing programmes are merged in a single, wider-range programme, with the purpose that consumers chose and load more the merged programme
	1.d Additional lightly soiled programme	An additional programme is obligatory in all machines. The programme is designed for lightly soiled laundry, thus reproducing user behaviour trends. Consumers The objective is that consumers choose this programme regularly.
2. ENERGY LABEL? YES or NO	2.a Only Ecodesign	Only Ecodesign requirements are proposed. The minimum energy performance is adapted to the new standard
	2.b.1 Ecodesign and energy label – Class A	Ecodesign and Energy label are simultaneously implemented. Ecodesign requirements are similar to the current ones but the energy label is re-scaled according to the revised Energy Label

Scenario	Sub-scenario	Comments
	and B are empty	Framework Directive. The best performing machine at the time of writing is placed in class C (regulation 2017/1369)
	2.b.2 Ecodesign and energy label – Class A is empty	Ecodesign and Energy label are simultaneously implemented. Ecodesign requirements are similar to the current ones but the energy label is re-scaled according to the revised Energy Label Framework Directive. The best performing machine at the time of writing is placed in class B (regulation 2017/1369)
	2.b.3 Ecodesign and energy label – Best WM with HP technology in class A	Ecodesign and Energy label are simultaneously implemented. Ecodesign requirements are similar to the current ones but the energy label is re-scaled according to the revised Energy Label Framework Directive. The best performing machine at the time of writing is placed in class A (regulation 2017/1369)
3. DURABILITY	3.a Increase in the technical lifetime of the machines	The technical lifetime of the washing machines is assumed to increase in 2.5 years from 12 years to 15 years
	3.b Increase in repaired machines	The share of machines that are successfully repaired is assumed to increase from 30% to 50%
	3.c Increase in reused machines	The share of machines that are reused is assumed to increase from 8% to 18%

7.4.3.2 BAU

The definition of the Business as Usual (BAU) scenario for washing machines is based on the assumption that no changes on the current or additional regulation are implemented. Given the diagnosis of washing machines in Europe under the current regulatory framework, as reported in section 7.1, the BAU scenario is only used as reference.

The BAU scenario does not mean that without further regulation the sector will not improve the energy efficiency of its products. However, given the development of the energy consumption of the washing machines over time (see figure 2.22), it could be assumed that a "plateau" is reached and, as improving energy efficiency comes at a high costs, further improvement is not implemented quickly.

In this scenario it is assumed that there are little additional energy efficiency improvements. As the energy label is losing its potential for making a differentiation among the washing machines, manufactures have little incentive to go beyond the current energy label class A+++, except for advertising claims such as 20% more efficient than the A+++ class. Not bound to legal rules, these claims would be difficult to verify. Note that currently approximately half of the models in A+++ are already facing this situation. This top class could thus be further populated in the coming years even if no additional policy measures are implemented. The estimated evolution of the sales distribution over the different classes in the BAU scenario is shown in Figure7.11.

7.4.3.3 Scenario 1 ECODESIGN: modifications of the standard for measurement to bring it closer to real-life conditions

The main target of scenario 1 is to adapt testing and label reporting to real-life behaviour, while analysing if energy and water saving still can be obtained with EU ecodesign/energy label. This scenario does not analyse the energy label as a policy tool and it is considered that it remains unchanged.

Data on energy consumption of the programmes are based on own estimates based on consumer survey on washing machines. The values estimated are in line with other studies published recently (BMWi, 2017)

7.4.3.3.1 Scenario 1a: 40 °C cotton programme as testing programme

This scenario aims at simplifying the standard for measurement to a single programme (40°C programme),. A second programme can be tested for the purpose of ecodesign, but not for the energy label (see below).

This scenario assumes that for the calculation of the energy consumption and other performance parameters of household washing machines, the programmes which clean normally soiled cotton laundry at 40 °C and 60 °C shall be used. These programmes correspond to the current 'normal 40°C' and 'normal 60°C' cotton programmes' and NOT to today's standard cotton programmes. According to the 2015 consumer survey, these 'normal cotton' programmes are today's the two most often used programmes for washing cotton load.

Especially for the normal cotton 40°C programme, the main benefit of this approach is the better alignment to the most used programmes in real-life conditions for washing cotton load. Manufacturers can still offer and promote programmes that are more efficient than the normal cotton programmes used for testing. A potential challenge of this option is that some manufacturers may decide not to offer any longer the efficient, long duration programmes (currently standard programmes) that use lower temperatures, which may potentially result in overall increase of energy use in the EU. The nominal energy consumption indicated on the energy label of washing machines could in such case increase compared to today's energy consumption, something that would need to be communicated adequately. An issue of concern in this respect is the absence of rules for how manufacturers will promote the programmes that are more efficient than the normal cotton programmes. This freedom may result in the provision to consumers of confusing or unreliable information for consumers (e.g. 'super cotton saver -50% more efficient than the normal cotton of the label'), in the absence of a standardised measurement procedure for the programmes.

This policy scenario would deliver some savings compared to the BAU scenario, as it is reasonable to assume that the normal cotton programmes would be further technically optimised. It is also reasonable to assume that some of these technical innovations might also improve the efficiency of other programmes used.

The option for consumers to change / adapt the normal cotton 40°C programme, e.g. by reducing the time shall be made clear and restricted for the purpose of testing, because that could deviate from the conditions used for testing and label declaration. For users, more flexibility could be provided, but appropriate communication of the consequences of it to the energy and water consumption of the programme shall be then requested. Additionally, it may be requested that the programmes is offered by the machine as default, whenever a machine has this option

- This scenario is expected to align to present real-life conditions better than current standard programmes. It is assumed that consumers will react positively increasing the frequency of use of these programmes.

The assumptions in this scenario are that:

- The energy and water values measured under the 40°C cotton programme are used for declaration in the energy label, and are also subject to ecodesign thresholds.
- The energy and water values measured in the 60°C cotton programme are subject to in ecodesign thresholds. This is done to ensure that the appliances marketed in the EU are able to run hot programmes with reasonable energy consumption.
- The maximum temperature reached by the 40°C programme has to be declared, and is to be measured in the laundry (inside the drum). This is to make aware consumers if the programme is suited for textiles with certain temperature care labels.

- Based on data of currently marketed machines, reaching 40°C temperatures means in practical terms being able to reduce the programme time way below 3 hrs, ensuring acceptability by consumers.
- A time limitation, e.g. to 3 hrs may be introduced in combination with Scenario 1.a - see more details in Scenario 1b.
- No modifications to these programmes are allowed prior to or during testing (i.e. button or switches to change temperature or time). If available, the effects of using these post-modifications on the energy and water use of the programme must be clearly communicated to the consumer in the machine's display (if equipped with a display) or in a marking adjacent to those buttons, as well as in the booklet of instructions.
- More energy-efficient cotton programmes (e.g. using lower wash-temperatures and longer programme times) can be offered for consumers willing to change their washing behaviour. These programmes are however not used for testing purposes. It is assumed that these programmes are more efficient than the normal 40°C cotton programme and will have energy consumption similar to the actual standard cotton programme, and that they will be used as often as a shorter, also energy-efficient alternative. The reduction in the use of these programmes is assumed to be 50% of the current frequency of use of the standard programmes.
- It shall be requested that the programmes are selected by default, whenever the appliance has this function

In this scenario, it is expected that the normal cotton programmes would be further technically optimised and that some innovations might also transfer to other programmes.

Table 7.14 summarizes the assumptions, expected benefits and possible drawbacks and risks identified for the Scenario 1a.

Table 7.14: Assumptions, expected benefits and possible drawbacks and risks identified for scenario 1a

Policy options for Scenario 1a	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
TIME	No change compared to BAU		
TEMPERATURE	1) Consumer information (e.g. in the user manual) about the temperature reached by all main programmes 2) Adding a requirement for a minimum temperature and time to be reached, at least in the 60 °C cotton programme where hygienisation is sought for	1, 2) Knowledge of the temperature for the consumers that know its effects (e.g. hygiene, odours) and choose the programme deliberately for this reason. 1) If not introduced, the offer of cotton programmes where the actual temperature is not the declared may continue and further spread. 2) Overall average hygiene of the machine's wet areas improves. Imposing this condition makes the testing be sufficiently demanding on the machine's heating system performance.	1,2) Testing protocol needed. Measurement method for the temperature inside the drum (textile load) needs to be defined/adapted from professional WMs. Testing burdens increase. 2) If introduced, manufacturers reduce their leeway (Sinner circle). Most appliances will cluster on fewer energy classes, potentially reducing the influence of the label on purchase 2) Limiting the temperature is a workable option. However, it may result in overall energy use increase. As a regulator, the interest is on energy saving, and wide use of the programme in real life, not in reaching a given temperature. 2) The exact temperature and duration of the hygiene programme may be difficult to justify, an option can be a consensus over a minimum common denominator (e.g. 52 °C for 15 minutes), but making it possible to offer combinations delivering equal pathogen reduction.
	Mandatory presence of a separate programme for specific hygienic needs	Clear indication for consumers; no need to increase the energy consumption of the standard programmes as hygienic needs only occur seldom; increasing transparency for consumers	Consumers might choose the hygiene programme more often as really needed, i.e. energy consumption might increase compared to today's choice of standard 60° cotton programme for hygienic needs A method for assessing the hygiene performance would be needed. The absence of a standard cotton 60 °C programme that in practice washes at 45-50 °C may increase energy consumption of the 60 °C programme.

Policy options for Scenario 1a	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
LOAD	Change of standard Test cycle change: 1) Full / half loads 2) Full load and fixed load(s), e.g. 3.4 kg or 2kg and 4 kg. 3) Full and partial loads (e.g. 1/4 and 1/2) 4) Partial loads (e.g. 1/3 and 2/3)	Machines should be subject to a demanding test that rewards that better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles) Partial loads of a full load (e.g. ¼, ½., 1/3, 2/3) are marginally easier (cheaper) in practical terms to implement for testing than fixed loads, because of the distribution of load items between cycles (e.g. 3.4kg). However, fixed loads allow comparison across machines regardless of their capacity. The results of the fixed partial loads would likely not be on the label, but would be declared on the product fiche. On the label, in order to simplify the information provided, the results would likely be weighted for the loads (¼, ½, 1/3, 2/3, fixed partial, full).
PERFORMANCE	No change to BAU Is to be kept >1,03	Continuity and market differentiation. If the temperature of the reference machine wash is lowered from 60ºC to 40 ºC, the comparison basis is more similar (40ºC), but there is less market differentiation.	One shall ensure that the measurement of performance on average or on sub cycles (e.g. after full load, and after partial load) is designed to avoid playing with average performance, as this may be against the objective of rewarding load adaptation. Additional weighting factors may be introduced to encourage appliance adaptation to low loads. Proposing performance references <1.03 may create distrust among consumers in the WM washing ability, as well as reduce the potential for market differentiation
PROGRAMME RESTRICTION for other programmes with similar purpose	1) limitation of 'eco', 'super saver' (lower temperature, long duration) 2) limitation of additional cotton programmes	1) None 2) Avoid other programme names that consumers can associate to testing or to the 'normal' or 'daily' use	1) There is no reason for restriction in the long-duration, energy saving programmes. If consumers are willing to use them, this should not be hindered, as their use contributes to save energy. Some rules may be needed to harmonise the declarations of 'eco' or 'super saver' that are more efficient than the normal cotton.

Policy options for Scenario 1a	Possible sub-options	Expected benefits	Possible drawbacks and risks
			2) Enforcement can be challenging
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 'cotton 40 ºC'. No arrow symbol	Clarity The arrow is the result of communication 2012/c206/05. It was intended to result in standardisation of the arrow symbol, but this never took place. Despite the efforts and investments made, recent consumer surveys indicate that the meaning of the arrow associating a programme to the label declaration is not understood. It is thus proposed to discontinue the use of the arrow.	Discontinuity of the arrow symbol. Investments and efforts lost. Consumers may need time to adapt: no arrows or standard programmes any more
	Programme indication on the display: 'Standard cotton programme' / arrow symbol	Continuity	People might not understand the underlying design of the programme and thus not choose it
	Default programme selection (when available in the appliance)	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult; consumers might easily overcome such default selection

7.4.3.3.2 Scenario 1b: Time limitation for the current standard programmes

In this scenario, the calculation of the energy consumption and other performance parameters of household washing machines are based on the current two 'standard cotton programmes' which clean normally soiled cotton laundry at 40°C and 60°C. However, this scenario assumes additional requirements with regard to the duration, temperature, load and/or performance. These requirements are:

- A time cap of 180 min. This time cap aims at making the standard programmes more attractive to the consumers. An increase in the frequency of use of approximately 4 percentage points is assumed for each standard programme.
- The time cap would increase the energy consumed by those programmes, in comparison to today's standard programmes when there is no time limit. The increase in the energy consumption is estimated to be between 0.1 kWh/cycle

- Machines are assumed to keep offering the 'normal cotton 40°/60°C' programmes' and 'super eco' programmes can be developed based on current practice, more energy efficient than the standard programmes and exceeding the time cap.

A benefit of this scenario is the continuity of the current model of 4 cotton programmes (2 normal, 2 standard) standard for the performance of washing machines which has been in place only since 2010. This scenario is expected to lead to an increase in the use of the standard cotton programmes and a decrease in the use of the 'normal cotton 40°/60°C programmes', which would still coexist, but be more similar. The normal cotton programmes would allow further time reduction and higher energy use compared to the standard programmes, or be chosen when reaching the temperature of 40ºC or 60ºC is important for the consumer.

This scenario is set in order to simulate an extreme. Alternative, more flexible practical means of removing the incentives for long programmes are:

1) to rely only on communication (on the label, on the product fiche, on booklet of instructions). Consumers have to then figure out themselves if their priority is a good energy class and long programme duration, or shorter duration programmes and a lower energy class. A number of stakeholders have expressed their doubts that these 'ideal' conditions of perfect communication and consumer understanding will work, as recent user surveys reveal that most consumers still do not understand the 'Sinner circle' trade-offs and limitations that govern the operation and design of washing machines.

2) the introduction of an incentive/disincentive mechanism in the calculation of the energy index (EEI) calculation formula. This would be done introducing an additive coefficient to the formula that provides a bonus to programmes shorter than 180 minutes and a malus to programmes exceeding 180 minutes. This would disincentive manufacturers to pursue test programmes with long duration, as these would not obtain better energy indices, and would incentivise development of energy-saving programmes that are shorter than 3 hours. This strategy is less transparent than the plain declaration of the programme time on the label (pt. 1 above), and takes away from the consumer the decision of going for a short but less efficient programme or a long but efficient programme. On the other hand, it is a possible compromise-oriented, pragmatic approach that addresses the lack of understanding by consumers of the effect of programme duration on energy consumption. This approach somehow helps consumer not to decide on this trade-off.

One of the potential challenges and risks of a cap are that consumer may still perceive the time cap of 180 min as excessively long and decide not to change their behaviour.

In any of the options above, it is likely that the declared values for ED/EL will be higher than currently, something that needs adequate communication not to lead to confusion among consumers, especially in the transition period.

Table 7.15 summarizes the assumptions, expected benefits and possible drawbacks and risks identified for the Scenario 1b

Table 7.15: Assumptions, expected benefits and possible drawbacks and risks identified for scenario 1b

Policy options for scenario 1b	Possible sub-options	Expected benefits	Possible drawbacks and risks
TIME	Adding prominently the programme time of the standard cotton programme(s) on the Energy label (see energy label scenarios)	Manufacturers may reduce the time of the programmes if they see consumers understand the energy-time trade-off, and respond buying machines with shorter programme times. to the labelling	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Ecodesign: Cap on the maximum programme time for the tested cotton programmes, which in user surveys is set at approximately 3 hrs.	The declaration of the time on the label may not be sufficient, and justifies the time cap. Stakeholders indicate that if the only requirement is the declaration of time, manufacturers would offer the same programmes as today, indicating the time, and not change practice unless they see consumers react and buy machines offering faster standard programmes. The transformation without a cap may be l Restriction of the playing field to areas that are known to be acceptable for consumers As a consequence the use of such programmes may increase	Manufacturers reduce their lead way. Appliances will cluster on fewer classes, potentially reducing the influence of the label on purchase. If time is capped, there is a risk that rinsing is skipped. A time cap will only work if a reliable method for rinsing performance exists, and a minimum requirement is set simultaneously.
	Ecodesign: introduction of time in the EEI calculation, with reference 3 hrs to provide incentives (<3h) /disincentives(>3h).	A possible compromise-oriented, pragmatic approach that addresses the lack of understanding by consumers of the effect of programme duration on energy consumption. This approach somehow helps consumer not to have to decide on the energy-time trade-off.	This strategy is less transparent than the plain declaration of the programme time on the label (pt. 1 above), and takes away from the consumer the decision of going for a short but less efficient programme or a long but efficient programme. Weighting for the bonus/malus will have to be fine-tuned to make the system work, once the first results of tests with the new standard are available.
TEMPERATURE	No change compared to BAU Temperature of all main		

Policy options for scenario 1b	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
	programmes has to be declared		
LOAD	Change of standard Test cycle change: 1) Full / half loads 2) Full load and fixed load(s), e.g. 3.4 kg or 2kg and 4 kg. 3) Full and partial loads (e.g. 1/4 and 1/2) 4) Partial loads (e.g. 1/3 and 2/3)	Machines should be subject to a demanding test that rewards that better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles) Partial loads of a full load (e.g. ¼, ½., 1/3, 2/3) are marginally easier (cheaper) in practical terms to implement for testing than fixed loads, because of the distribution of load items between cycles (e.g. 3.4kg). However, fixed loads allow comparison across machines regardless of their capacity. The results of the fixed partial loads would likely not be on the label, but would be declared on the product fiche. On the label, in order to simplify the information provided, the results would likely be weighted for the loads (¼, ½, 1/3, 2/3, fixed partial, full).
PERFORMANCE	No change to BAU Is to be kept >1,03	Continuity and market differentiation. If the temperature of the reference machine wash is lowered from 60ºC to 40ºC, the comparison basis is more similar (40ºC) , but there is less market differentiation.	One shall ensure that the measurement of performance on average or on sub cycles (e.g. after full load, and after partial load) is designed to avoid playing with average performance, as this may be against the objective of rewarding load adaptation. Additional weighting factors may be introduced to encourage appliance adaptation to low loads. Proposing performance references <1.03 may create distrust among consumers in the WM washing ability, as well as reduce the potential for market differentiation
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 1) BAU 'Standard cotton	1) Continuity 2) Term introduced and well accepted for dishwashers; best reflects the character of	1) People might not understand the underlying design of the programme and thus not choose it 2,3) manufacturers will likely offer ECO plus, or

Policy options for scenario 1b	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
	programme' / arrow symbol 2) 'ECO' term 3) 'ECO' in combination with the arrow-symbol (e.g. inside)	the programmes, easy to understand for consumers 3) Joint benefits	ECO+, or Super ECO for long duration programmes. People might associate thus 'ECO' with (too) long programme duration and/or underperformance, thus not choosing any ECO. 2) Difficult as more than one standard programme (40 °/60 °C); It has been proposed to display the temperatures combined as 40º-60ºC,to indicate that larger loads can be combined, however some stakeholders indicate e this is confusing, and consumers may reject to introduce 40ºC textiles fearing that 60ºC will deteriorate them (see scenario 1C below). 3) the combination of the two above
PROGRAMME RESTRICTION for other programmes with similar purpose	1) limitation of ECO/super ECO/ECO plus (lower temperature, long duration) 2) limitation of other cotton programmes	1) none 2) Avoid programmes names linking to testing or the 'normal' or 'daily' use. Restriction of normal cotton programmes would be an extreme measure to promote higher use of standard cotton programmes,	1) There is no reason for restriction in the long-duration, energy saving programmes. If consumers are willing to use them, this should not be hindered, as their use contributes to save energy. Some rules may be needed to harmonise the declarations of 'eco' or 'super saver' that are more efficient than the normal cotton. 2) Enforcement can be challenging. Users may be not satisfied with the temperature reached with the standard cotton programmes if no hygiene programme is offered
	Default programme selection (when available in the appliance)	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are two standard programmes; consumers might easily overcome such default selection

7.4.3.3.3 Scenario 1c: Merge of programmes to increase average loading per wash, and improved programme identification

Scenario 1c tries to overcome that consumers on average still underload their washing machines, and this effect is further exacerbated by increasing machine rated capacities on the market.

In this scenario, products are designed in a way that they offer only one standard cotton programme for the purpose of testing the energy consumption and other performance parameters. This programme is able to clean normally soiled cotton laundry declared on the textile label to be washable at 40 °C and/or 60 °C together in the same cycle. This scenario intends to model a programme that fits to the consumer needs, and allows combining normally soiled 40 °C and 60 °C cotton loads on higher average loadings. To realise this, the following assumptions are considered in this scenario:

- The single standard programme is clearly identifiable by the consumer with a univocal name and symbol, like ECO. It is assumed that the ECO programme has energy consumption identical to the average energy consumption of the current standard programmes. It is assumed that this programme replaces 8% and 5% of the washes currently made by the normal 40°C /60°C cotton programmes. This assumption was done based on the experience of dishwashers since the introduction of the term ECO. The term 'ECO' is already introduced and known from dishwashers, and indicates that this programme is particularly economic/energy-efficient. On the other hand, some consumers may identify ECO with long term or underperformance, and refuse to use it, especially if alternative cotton 40 °/60 °C programmes are still available.
- A temperature of maximum 40 °C is assumed, as in scenario 1a.
- Separate ‘hygiene programmes’ might be offered and clearly displayed for those few wash loads which explicitly require 60 °C or higher temperatures due to hygienic needs.
- The offer of competing programmes (e.g. 'super-eco', 'normal cotton 40-60C programmes') are allowed but they may not use the word ECO, to avoid misunderstandings and rejection to all ECO programmes. This requirement aims to reinforce the attractiveness of the ECO standard programme, and the clustering of laundry batches in fewer, but larger loads.

Table 7.16 summarizes the assumptions, expected benefits and possible drawbacks and risks identified for the Scenario 1c

Table 7.16: Assumptions, expected benefits and possible drawbacks and risks identified for scenario 1c

Policy options for scenario 1c	Possible sub-options	Expected benefits	Possible drawbacks and risks
TIME	No change compared to BAU		
TEMPERATURE	No change compared to BAU Temperature of all main programmes has to be declared		

Policy options for scenario 1c	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
LOAD	Change of standard Test cycle change: 1) Full / half loads 2) Full load and fixed load(s), e.g. 3.4 kg or 2kg and 4 kg. 3) Full and partial loads (e.g. 1/4 and 1/2) 4) Partial loads (e.g. 1/3 and 2/3)	Machines should be subject to a demanding test that rewards those better adapting energy uses to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles) Partial loads of a full load (e.g. ¼, ½, 1/3, 2/3) are marginally easier (cheaper) in practical terms to implement for testing than fixed loads, because of the distribution of load items between cycles (e.g. 3.4kg). However, fixed loads allow comparison across machines regardless of their capacity. The results of the fixed partial loads would likely not be on the label, but would be declared on the product fiche. On the label, in order to simplify the information provided, the results would likely be weighted for the loads (¼, ½., 1/3, 2/3, fixed partial, full).
PERFORMANCE	No change to BAU Is to be kept >1,03	Continuity and market differentiation. If the temperature of the reference machine wash is lowered from 60ºC to 40ºC, the comparison basis is more similar (40ºC), but there is less market differentiation.	One shall ensure that the measurement of performance on average or on sub cycles (e.g. after full load, and after partial load) is designed to avoid playing with average performance, as this may be against the objective of rewarding load adaptation. Additional weighting factors may be introduced to encourage appliance adaptation to low loads. Proposing performance references <1.03 may create distrust among consumers in the WM washing ability, as well as reduce the potential for market differentiation
	Displaying the washing performance class on the label again	Reliability for consumers that this “new” programme fulfils certain performance	Overload of labelling information; linkage of performance to ECO programme might still not be understood
PROGRAMME INDICATION AND	Programme indication on the display: It has been proposed to display the temperatures combined	Potential energy savings by bundling loads, and running less cycles at higher average load	ALL) People might not understand the underlying design of the programme and thus not choose it 2) The range denomination (hyphen between 40-60

Policy options for scenario 1c	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
SELECTION	as 40º-60ºC,to indicate that larger loads can be combined, 1) 'Standard cotton programme 40-60' / arrow symbol 2) 'ECO 40-60' term 3) 'ECO 40-60', possibly in combination with the arrow-symbol (e.g. ECO inside the arrow)		or other) indicates a range that can be confusing to consumers, they may reject to introduce 40ºC textiles fearing that 60ºC will deteriorate them. Large communication efforts will be necessary. 3) the benefits of bundling can be explained by other means, such as communication campaigns, and not necessarily introduced in a programme name. 4) to some extent, many consumers already bundle cycles and wash at lower temperatures clothes that one may wash individually at 60ºC
	Default programme selection (when available in the appliance)	Introduced already for dishwashers; should be possible as only 1 standard programme which reflects an often used programme choice of consumers	Positive impact of a default selection (for DW) not yet analysed / proven; consumers might easily overcome such default selection
PROGRAMME RESTRICTION for other programmes with similar purpose	1) limitation of use of ECO term in any other programme of the machine (e.g. super-eco' or 'long-ECO' with lower temperature, or longer duration than ECO) 2) normal cotton	1) Overuse of the term ECO may be counterproductive; as some consumers may identify ECO with long and reject the use of all ECO, including the standard. The concern is less if the term ECO is not allowed for the long programmes. However, if consumers are willing to use the long programmes, this should not be hindered 2) Extreme measure to promote higher use of eco-programme	1) more energy saving programmes could be not offered; enforcement can be challenging 2) complaints from consumers, enforcement can be challenging

7.4.3.3.4 Scenario 1d: Additional programme for lightly soiled laundry (ECO light)

This scenario is a further refinement of scenario 1C, where the programme portfolio is complemented with a shorter cycle for lightly soiled cotton clothes. This scenario aims at addressing the fact that approximately 70% of the cotton loads are only lightly soiled and that the washing of those loads with normal cotton programmes or standard cotton programmes consume more energy and water than necessary. This scenario assumes that consumers are able to change their behaviour and select this new programme that is able to clean lightly soiled cotton laundry declared to be washable at 30 °C, 40 °C and/or 60 °C together in the same cycle, and ideally with high loads.

To realise this, the following assumptions were considered

- The actual washing temperature of the ECO light standard programme will be at maximum 30 °C (which is already similar to most of today's standard cotton 40 °C programmes).
- Separate 'hygiene programmes' might be offered and clearly displayed for those few wash loads which explicitly require 60 °C or higher temperatures due to hygienic needs
- Consumer will have the option of selecting normal or lightly soiled cotton programmes. This option was modelled by introducing a new programme with a frequency of use of 25% and an energy consumption of 0.69 kWh/cycle. The frequency of use of other programmes has been accordingly modified.
- Clear identification of the programme suitable for washing lightly soiled laundry is provided. This can result in the appliances offering an 'ECO light' programme in addition to the 'ECO' programme

It is not expected that the new programme would replace existing short programmes which have different targets (e.g. facilitating quick wash), configuration (lower washing temperatures and small loads for lightly soiled or delicate laundry, higher temperatures at partial or full loads for quick wash) and thus different performances (lower or higher energy consumption compared to normal or standard cotton programmes). It is also difficult to foresee to what extent consumers would choose the ECO programme or the ECO light programme. In any case, both are energy-saving options compared to current practice.

Potential drawbacks and risks in this scenario relate to the identification of the ECO light cycle by the consumers and its duplication by other short programmes. In order to overcome these problems, consumer awareness campaigns would be needed to explain the benefits of this new programme. Alternatively, should the Eco light programme not be introduced, it could be discussed if short programmes should be offered mandatorily.

Table 7.17 summarizes the assumptions, expected benefits and possible drawbacks and risks identified for the Scenario 1d

Table 7.17: Assumptions, expected benefits and possible drawbacks and risks identified for scenario 1d

Policy options for WM scenario 1d	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
TIME	Adding the programme time of both the ECO & ECO light programmes on the Energy label	Manufacturers may reduce the time of the programmes if they see consumers pay attention to this and respond to the labelling	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the

Policy options for WM scenario 1d	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
			energy, shorter programmes may not be offered. Overload of label information if time indication for even two programmes
	Optionally, a cap on the maximum programme time for the ECO light cycle (e.g. 1.5 hours, to be defined after preliminary testing), or a bonus/malus be added to the EEI formula, similarly to the options discussed for scenario 1 b	Restriction of the playing field to areas that are known to be acceptable for consumers ≤ 1.5 hour would likely be well accepted by consumers. Most short programmes of machines on the market are <40 minutes, but are designed for small loads (<3.5 kg) and no more than 40 °C.	Manufacturers reduce their leeway (Sinner circle) to show difference to other manufacturers. Most appliances will cluster on few classes, reducing the influence of the label on purchase
TEMPERATURE	Requirement that this programme shall allow washing together - normally soiled cotton laundry labelled for 40 °/60 °C. (max temp 40 °C) - lightly soiled cotton laundry labelled for 30/40/60 °C (max temp 30 °C)	Avoiding textile damage of the laundry if the wash temperature is much higher than care label i.e. 30 °C (ECO light) or 40 °C (ECO)	This restriction for ECO light is unlikely needed if one aims to combine 30, 40 and 60 °C cotton loads. Measurement method for the temperature inside the textile load needs to be defined/ adapted from professional WMs. Testing burden increases.
	Indication of the temperature of the ECO programmes on the machine's display: 1) Indication of a range (e.g. ECO 40-60 °; ECO light 30-60 °) 2) No temperature indication at all	1) transparency for consumers; might facilitate the intention of using it for both laundry types; functioning for dishwashers 2) might be better to implement on the displays	1) Might be difficult to understand; complicated to implement on the machine's display 2) More difficult to understand for consumers; minimised effect of using it for 60 ° labelled laundry (could even have reverse effect of using more often the hygiene programme)
LOAD	Change of standard Test cycle change: 1) Full / half loads 2) Full load and fixed load(s), e.g. 3.4 kg or 2kg and 4 kg.	Machines should be subject to a demanding test that rewards those better adapting energy uses to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles) Partial loads of a full load (e.g. ¼, ½., 1/3, 2/3) are marginally easier (cheaper) in practical terms

Policy options for WM scenario 1d	Possible sub-options	Expected benefits	Possible drawbacks and risks
	3) Full and partial loads (e.g. 1/4 and 1/2) 4) Partial loads (e.g. 1/3 and 2/3)	suffice.	to implement for testing than fixed loads, because of the distribution of load items between cycles (e.g. 3.4kg). However, fixed loads allow comparison across machines regardless of their capacity. The results of the fixed partial loads would likely not be on the label, but would be declared on the product fiche. On the label, in order to simplify the information provided, the results would likely be weighted for the loads (¼, ½., 1/3, 2/3, fixed partial, full).
PERFORMANCE	1) ECO: >1.03 2) ECO light: lower, e.g. >0.97? (the final value to be discussed after sufficient measurement results become available)	1) continuity; should be possible as most of today's standard cotton programmes work at these lower temperatures 2) This would reflect the fact that a lower washing performance is sufficient for lightly soiled laundry. The ambition is to increase the use of a single programme for different cotton loads	1) / 2) No experience with the washing performance of such new programme. One shall ensure that the measurement of performance on average or on sub cycles (e.g. after full load, and after partial load) is designed to avoid playing with average performance, as this may be against the objective of rewarding load adaptation
	Displaying the washing performance classes of ECO and/or ECO light programme on the label again	Reliability for consumers that these "new" programmes fulfil certain performance	Overload of labelling information; linkage of performance to ECO programme might still not be understood
PROGRAMME RESTRICTION for other programmes with similar purpose	1) use of ECO in any other programme of the machine (e.g. super-eco' or 'long-ECO' with lower temperature, or longer duration than ECO) 2) normal cotton	1) Overuse of the term ECO may be counterproductive, as some consumers may identify ECO with long and reject the use of all ECO. The concern is less if the term ECO is not allowed for the long programmes. However, if consumers are willing to use the long programmes, this should not be hindered 2) Extreme measure to promote higher use of eco-programme	1) More energy saving programmes could be not offered; Enforcement can be challenging 2) Possible complaints from consumers. Enforcement can be challenging

Policy options for WM scenario 1d	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 1) 'Standard cotton programme' / arrow symbol 2) 'ECO' term 3) 'ECO', possibly in combination with the arrow-symbol (e.g. ECO inside the arrow)	1) Continuity 2) Term well introduced for dishwashers; reflects the character of the programme best, easy to understand for consumers 3) Joint benefits	1) People might not understand the underlying design of the programme and thus not choose it 2) People might combine 'ECO' with (too) long programme duration and/or underperformance, thus not choosing it 3) joint drawbacks above
	Default programme selection (when available in the appliance)	Introduced already for dishwashers	Commitment to one of both ECO programmes necessary Positive impact of a default selection (for DW) not yet analysed / proven; consumers might easily overcome such default selection

7.4.3.3.5 Impacts on resources for scenarios 1a, 1b, 1c and 1d

Table 7.18, Table 7.19 and Table 7.20 show the values considered for the share of frequency of use of each programme, the energy consumption for each programme for full loads and the water consumption for each programme for full loads, respectively. The model considers, however, the loading normally used by the consumers for each of the programmes.

Table 7.18: Summary of the share of frequency of use for each sub-scenario

Share of use Scenarios ecodesign					
	BAU	Scenario 1a	Scenario 1b	Scenario 1c	Scenario 1d
standard 40° cotton programmes	10%	8%	14%	18%	9%
standard 60° cotton programmes	7%	5%	10%	12%	6%
normal 40°cotton	15%	19%	12%	8%	8%
normal 60° cotton	11%	11%	8%	5%	5%
- super quick (20-30 min)	5%	5%	5%	5%	5%
- normal quick (45-70 min)	8%	8%	8%	8%	8%
Synthetic/easy care	11%	11%	11%	11%	11%
Cotton 30°C	10%	10%	10%	10%	5%
Mix	9%	9%	9%	9%	5%
Cotton 90°C	5%	5%	5%	5%	5%
Cotton 20°C	4%	4%	4%	4%	4%
Eco light	0%	0%	0%	0%	25%
Others	5%	5%	5%	5%	5%

Table 7.19: Summary of the energy consumption per cycle for each sub-scenario for full loads

	Energy consumption (kWh/cycle)				
Programme	BAU	Scenario 1a	Scenario 1b	Scenario 1c	Scenario 1d
Standard cotton 40 °programmes, average	0.750	0.750	0.840	0.840	0.750
Standard cotton 60 ° programmes, average	0.965	0.965	1.062	0.840	0.000
Normal 40 °cotton programmes, average	0.931	0.840	0.931	0.931	0.931
Normal 60 ° cotton programmes,	1.181	1.062	1.181	1.181	1.181

	Energy consumption (kWh/cycle)				
average					
Quick/Short programme 20 min	0.207	0.207	0.207	0.207	0.207
Quick/Short programme 45 min	0.510	0.510	0.510	0.510	0.510
Synthetic/easy care 30/40 °C	0.630	0.630	0.630	0.630	0.630
Cotton 30 °C	0.367	0.370	0.370	0.370	0.370
Mix	0.738	0.740	0.740	0.740	0.740
Cotton 90 °C	2.189	2.190	2.190	2.190	2.190
Cotton 20 °C	0.331	0.330	0.330	0.330	0.330
Eco-light	0.750			-	0.690
Other programmes	0.000	N.C.	N.C.	N.C.	N.C.
Average	0.798	0.771	0.807	0.770	0.700

Table 7.20: Summary of the water consumption per cycle for each sub-scenario for full loads

Water consumption (l/cycle)					
Programme	BAU	Scenario 1a	Scenario 1b	Scenario 1c	Scenario 1d
Standard cotton 40 °programmes, average	50.4	50.4	59.15	50.4	50.4
Standard cotton 60 ° programmes, average	50.4	50.4	59.15	50.4	50.4
Normal 40 °cotton programmes, average	62.4	57.75	62.4	62.4	62.4
Normal 60 ° cotton programmes, average	62.4	57.75	62.4	62.4	62.4
Super quick 20-30min	43.8	43.8	43.8	43.8	43.8
Normal quick 45-60 min	43.8	43.8	43.8	43.8	43.8
Synthetic/easy care 30/40 °C	62	62	62	62	62
Cotton 30 °C	53.3	53.3	53.3	53.3	53.3
Mix	68.6	68.6	68.6	68.6	68.6
Cotton 90 °C	66.8	66.8	66.8	66.8	66.8
Cotton 20 °C	82.9	82.9	82.9	82.9	82.9
Eco-light	-			-	63.45
Other programmes	N.C.	N.C.	N.C.	N.C.	N.C.
Average	58.39	57.42	59.73	56.74	59.09

The different scenarios act differently on the evolution of resource consumption (energy and water) in the EU28. The effects of the different scenarios on energy and water consumption for an average washing machine (a washing machine of 7 kg rated capacity) in the period 2015-2030 are shown in Figure 7.5 for the energy consumption and in Figure 7.6 for the water consumption. For all the scenarios the distribution of the energy classes in the future remains equal to the BAU scenario and therefore, the differences observed at a unit can be easily extrapolated to EU28 level (Figure 7.5).

For all scenarios, the energy and water consumption of a washing machine decreases over time. Figure 7.5 forecasts a maximum energy saving for scenario 1d of 15.01 kWh/year per machine (approx. 3.54 TWh/year) in 2030. This is about 12% of the energy consumption in the BAU scenario estimated in 2030. The feasibility of this scenario (1.d) requires an important user behaviour change as it assumes that consumers will understand and widely use the new ECO light programme that is suited for lightly soiled laundry. As explained above, this is the scenario where a widest behavioural change would be needed, and largest communication efforts will have to be deployed to make it succeed.

The second most saving scenarios are scenarios 1a and 1.c, which in Figure 7.5 almost overlap.

These scenarios provide maximum energy saving of 4.45 and 4.11 kWh/year per unit in 2030, respectively (approx. 2.76 or 2.77 TWh/year in 2030 at EU level). Additionally, (1.a) assumes that a restriction on the offer of the cotton programmes will lead to an optimization of its performance and an increase in their use by the consumers. In a way, it is a conservative approach that resembles the type of testing that was in place before the 2010 revision of the WM regulation. Scenario (1.c) reaches almost equal savings but by adopting a more challenging approach, which is to merge cotton programmes and push consumers to cluster their laundry in less washes, but with higher loads each.

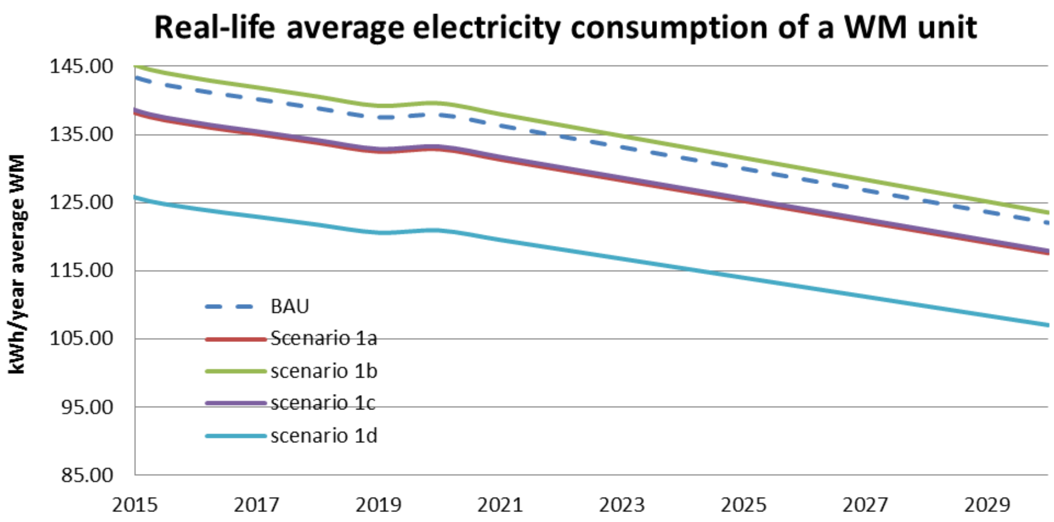


Figure 7.5: Estimated annual real life average electricity consumption of a washing machine unit for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.

A maximum water saving of 245 l/year per average unit is expected in 2030 for scenario 1c (Figure 7.6). This is around 2% of the water consumption expected in 2030 in the BAU scenario for the average washing machine. The second best result is obtained by scenario 1a. In this case, water savings forecasted are approximately also 2% of the BAU scenario.

The values for electricity and water consumption are provided in table form in Table 8.25 to Table 8.28in Annex 8.9.7.

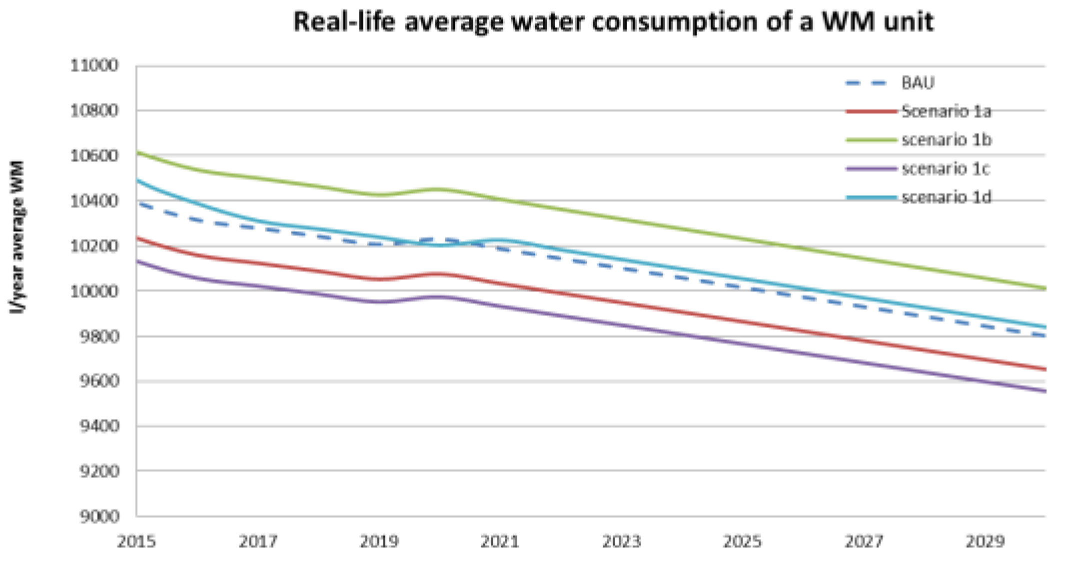


Figure 7.6: Estimated annual real life average water consumption of a washing machine unit for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.

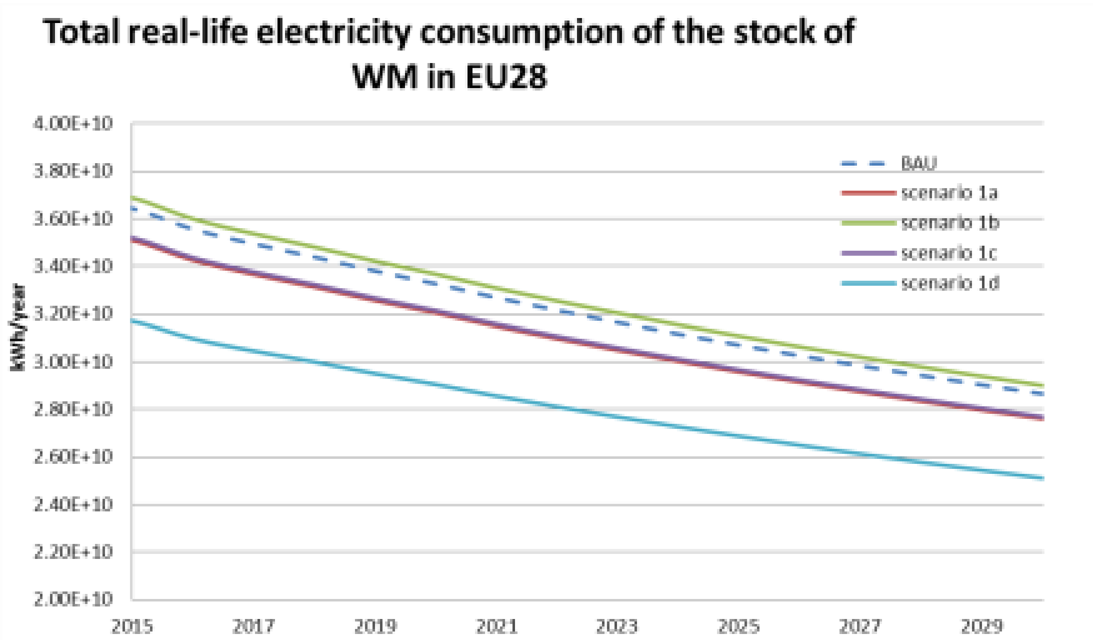


Figure 7.7: Estimated annual energy consumption of the EU28 washing machine stock for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.

The impacts on GHG emissions and the consumption of primary energy are directly linked to the electricity consumption. The environmental impact in terms of GHG emissions is illustrated in Figure 7.8. It is observed a decrease of CO_{2eq} emissions in all scenarios and especially in scenario 1d as it reaches savings of around 12% of the emissions estimated to the BAU scenario in 2030. Scenario 1a and 1c deliver GHG emission savings of 4% and 3% of the emissions estimated to the BAU scenario in 2030, respectively. The calculated values are provided in table form in Annex 8.9.8.

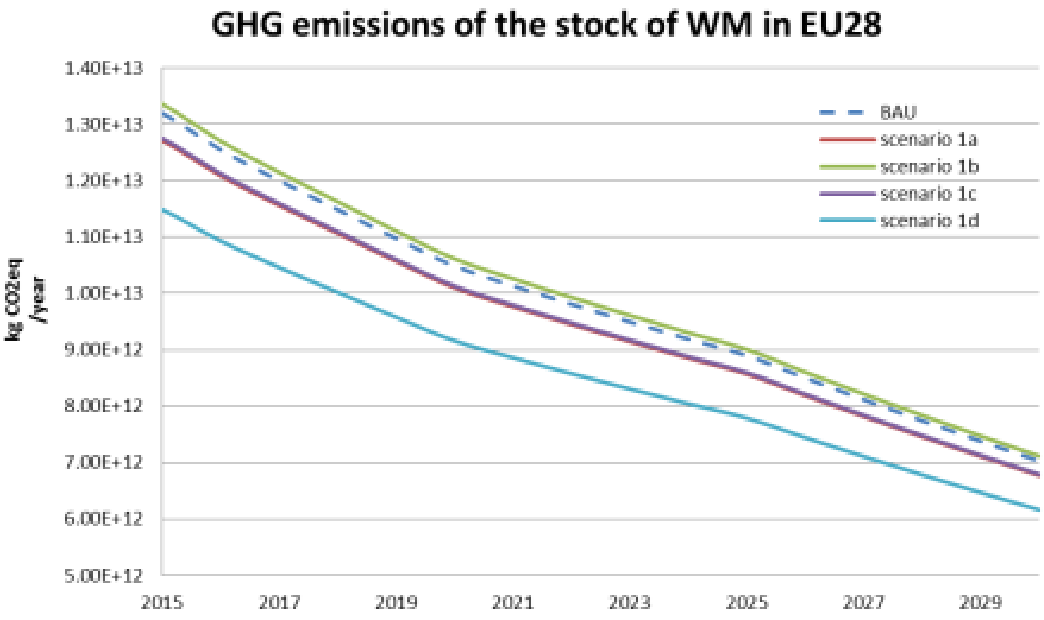


Figure 7.8: **Estimated annual GHG emissions of the EU28 washing machine stock for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.**

Regarding the consumption of primary energy related to the electricity use of the average washing machine, it can be observed from Figure 7.9 that the total primary energy is expected to decrease in the coming years even more that the decrease expected in the electricity consumption. This is due to the expected lower primary energy factor in the future. The calculated values can be found in table form in Annex 8.9.9.

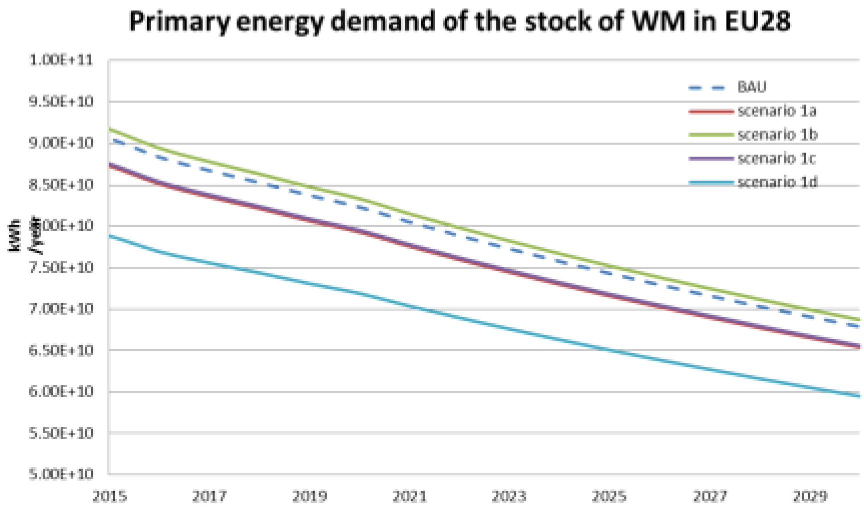


Figure 7.9: **Estimated annual primary energy demand of the EU28 washing machine stock for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.**

Impacts on the consumer expenditure and jobs for the scenarios 1a, 1b, 1c and 1d

The impacts of the different scenarios on the consumer expenditure are shown in Figure 7.10. The average unitary price (ORP) is kept constant in all the scenarios as the sales distribution in the future is also kept constant.

The total consumer expenditure shows an increasing trend. This is because the utilities prices as well as the number of machines are expected to increase in the coming years (the forecasted price of the electricity is shown as well in Figure 7.10). The different consumption of each of the scenarios triggers the differences among them. This results in a decrease of the total EU 28 consumer expenditure for the scenarios 1d in comparison to the BAU scenario of around 7.5 billion of euro$_{2015}$ for scenario 1d and 2.12 and 2.16 billion of euro$_{2015}$ for scenario 1a and scenario 1d per year, respectively in 2030. This would be around 6% and 1% of the BAU scenario, respectively.

Even if in previous sections energy and water savings have been estimated for all the scenarios, no economic savings are predicted (see Figure 7.10). This is due to the increasing forecasted prices of the utilities. Figure 7.10 shows as an example the forecasted price of the electricity. This shows a steady increasing tendency. The energy savings estimated in previous sections are not sufficient to compensate this increasing tendency.

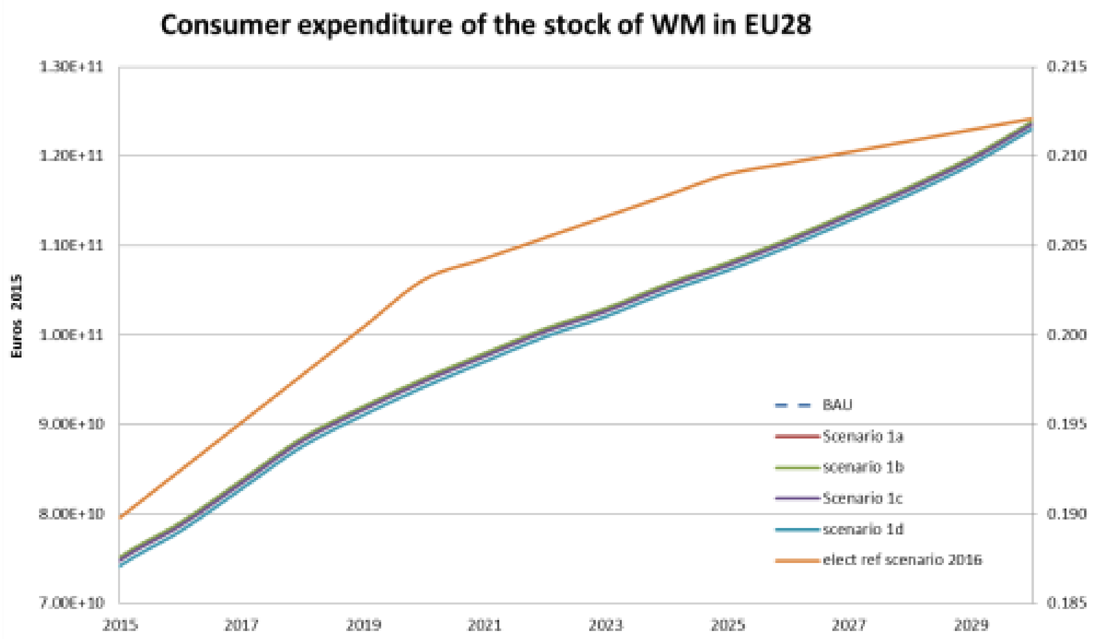


Figure 7.10: Estimated annual consumer expenditure of the EU28 washing machine stock for scenarios BAU, scenario 1a, scenario 1b, scenario 1c and scenario 1d.

7.4.3.3.6 Stakeholder feedback on scenario 1 and implications on the measurement standard

Stakeholders have agreed widely on the diagnosis made of divergence between the tested programmes and real practices of use. If the tested programmes are not used, the label will not be effective and estimated energy savings cannot be realised. However, different views on how to overcome this obstacle are offered.

Abundant feedback has been received with regard to the proposed policy scenarios (1a, 1b, 1c and 1d). Preferences for the scenarios vary, not reaching clear consensus for one specific scenario. The two most supported scenarios have been 1a, and 1c. Additional comments on specific requirements (temperature, time, loading, naming, etc.) proposed.

According to stakeholders, prerequisites for the revision of the ecodesign requirements and energy label would be:

1. to keep a balanced trade-off between real-life conditions and a manageable testing effort with a reasonable number of tests for manufacturers and market surveillance authorities. In other terms,

the revised requirements should not lead to an increase of the overall costs without producing additional cost-effective energy savings;

2. to ensure a meaningful differentiation between the products on the market.

Feedback provided by stakeholders for the different policy scenarios are summarised in the following.

7.4.3.3.6.1.1 *Scenario 1a and scenario 1b*

Stakeholders highlighted that requirements and declarations should be based on the most used (cotton normal) programmes, which as a consequence of this requirement will be improved and will become as efficient as possible.

To realise this requirement, the normal programmes could limit their duration and wash at lower temperatures than they currently do. The use of these normal programmes could increase especially if their duration is limited (i.e. <3 hrs) and the duplication of 'parallel' programmes (shorter or longer) is avoided. In this sense, it seems to be essential that the regulation should include a clause requiring that only one version of the programmes the label is referring to is allowed (i.e. no ‘standard’, ‘normal’, ‘everyday’ or similar 40 °C / 60 °C cotton programmes are permitted). Programmes with lower energy consumption such as ECO, quick or other special programmes could be accepted. If additional cotton programmes are allowed, there would be a risk that consumers switch to other programmes, especially, if the “normal” programmes last longer than the alternative programmes (e.g. <2h).

Finally scenarios 1a and 1b were considered to be basically the same, with different conventions used for the programme names. The programme that is relevant for the label will always be optimised as much as possible regarding energy efficiency, no matter its name, and the most straightforward way of doing it is by extending duration and reducing temperature.

7.4.3.3.6.1.2 *Scenario 1c and 1d*

Most stakeholders supported either the scenario 1c or scenario1d because they are closer to the real use of washing machines (according to the results of the 2015 EU consumer survey). Scenario 1d is expected to offer the highest energy saving potentials in real-life, provided that the wash cycles are short enough and provide a good washing performance to consumers.

One stakeholder suggested that the ECO cycle and the ECO light/short cycle should not be too long (e.g. < 2.5 h for ECO programme and <1 h for ECO light programme, which should be preferably be called 'ECO short'). However, other participants preferred no time restrictions and argued that the time indication on the energy label would be sufficiently strong to drive a market transformation. In terms of washing performance it was indicated that 1.00 could be enough for the ECO programme and 0.97 for the ECO light/short programme.

The success of these scenarios would depend on the consumers’ acceptance of washing clothes with different care labels in only one programme (without necessarily a temperature indication). If consumers are willing to do that, scenarios 1c and 1d could result in the highest energy savings, especially scenario 1.d. (as shown in Figure 7.10). If not, there will be no significant change compared to the current situation (e.g. users stick to their habits of choosing the usual temperature programmes being indicated on the clothes’ care labels).

Furthermore, it was indicated that the use of the name 'ECO' could be misleading since the most energy saving programme is the 20 °C programme and it is present in the portfolio of all washing machines. The stakeholder thus proposed to take the 20 °C wash programme as reference for the ECO light programme. The low energy consumption for heating of this programme will promote the use of more efficient motors and, as a consequence, more efficient washing machines. Finally, it was proposed to add additional ecodesign requirements on the maximum energy consumption of a 'normal' cotton 60 °C programme with a time cap of two hours. This requirement will ensure that machines offer hygienisation by means of high temperature, rather than by use of chemicals at lower temperatures. It was argued that otherwise, there could be machines on the market that can hardly heat up water and that are fully dependent on chemicals for hygienisation purposes.

7.4.3.3.6.1.3 *Additional comments*

One stakeholder proposed to consider a 'very low energy scenario' as the programme combination to test for the EU Ecodesign and Energy label measurements. This would include one cold programme, one low temperature programme (20 ° or 30 °C) and one 40 °C cotton programme. According to the stakeholder, this scenario would facilitate reducing the energy consumption.

In real life there is a broad use of programmes which run at 60 °C or even higher temperatures. Therefore it is of relevance to optimize the energy use these washing programmes, or at least limit the maximum energy use.

No alteration of the testing programmes should be permitted (i.e. shorter time, higher temperature or more spin speed), unless consumers are properly informed of the energy use consequences of the choice (e.g. through a display). For example, if the programme ECO 30 °C is the default programme, the user would be obliged to use it without modifications and any modification (i.e. increase temperature and/or reduce time) will be only done when it is really necessary. Under these conditions, a time cap would not be needed if consumers understood the relationship between time, mechanical and chemical action and energy consumption, but surveys indicate that this concept is complex and currently not understood.

To test the machine at three different load sizes and three different programmes in five different testing conditions would increase test burdens and costs significantly. Additionally, programmes with temperatures higher than 65 °C are not considered strictly necessary for hygienic purposes. A cold programme should continue to be offered on the machines which, however, should not be part of the EEI measurements. Finally, too long washing programmes may have a negative effect on textiles by affecting their stability.

To base the energy label declaration on a 40 °C programme with a time indication on the label was another proposal. This testing (e.g. ¼, ½ and full rated capacity or 2kg, 4kg and full rated capacity) would stimulate the load adaptation ability of the machines. The temperature should be part of the programme name, since consumers do not trust on programmes without it, and should be actually reached. 40 °C is the most frequently selected temperature, and additionally is close to the actual temperature of the today's standard cotton 60°C programmes.

All in all, these modifications are expected by some stakeholders to result in slightly higher energy consumption per cycle of the testing programme, but lower than today’s normal programmes, and would be compensated by larger consumer acceptance. The minimum washing performance could be set as 1.03, unless new references for lightly soiled laundry are defined. Alternatively the washing performance could be higher than 0.97 if 60 °C is taken as reference.

It has been also highlighted by stakeholders that the most important eco-design requirement is to achieve a certain washing performance, and not a certain temperature. Nowadays, the r programme used as reference for comparisons during testing washes at 60°C. If cotton 40°C is used as new tested programme for the energy label, it could make sense to also change from 60°C to 40°C the reference. However, a modification to a 40°C reference programme would imply lower differentiation in terms of performance of the machines on the market.

A stakeholder has proposed to use the testing portfolio shown in Table 7.21 for evaluating washing machines. One has to note that this proposal considers four test conditions, which would increase test burden and testing costs.

Table 7.21: Testing alternatives proposed by a stakeholder during the revision of the ecodesign regulation for washing machines

Name	Duration	Temperature	Load	Performance
40 ^{0}C cotton (or: ECO 40 ^{0}C cotton)	< 240 min (and indication of duration of longest programme on the label)	Not defined (temperature indication in name only indicates that textiles with the 40 ^{0}C symbol (or higher temperatures) can be washed)	Full	> 1,03
40 ^{0}C lightly soiled cotton (or: Quick 40 ^{0}C cotton)	< 120 min	Not defined (temperature indication in name only indicates that textiles with the 40 ^{0}C symbol (or higher temperatures) can be washed)	Full	> 0,97
60 ^{0}C cotton (or: ECO 60 ^{0}C cotton)	< 240 min and indication of duration of longest programme on the label	Not defined (temperature indication in name only indicates that textiles with the 60 ^{0}C symbol (or higher temperatures) can be washed)	Full	> 1,03
60 ^{0}C cotton (or: ECO 60 ^{0}C cotton)	< 240 min and indication of duration of longest programme on the label	Not defined (temperature indication in name only indicates that textiles with the 60 ^{0}C symbol (or higher temperatures) can be washed)	2 kg	> 1,03

Finally, a proposal for focusing on a balanced mix of specific policy options such as programme duration, temperature, load and other key aspects influencing energy consumption and consumer acceptance such as the washing performance was highly recommended. Those parameters should be regulated for the programmes used for declaration on ecodesign and energy label in such a way that consumer rejection is avoided

Beside these comments, CECED informed in November 2016 that a programme combination consisting of:

- 40°C – Full load (2 runs),
- 40°C – Half load (2 runs),
- 30°C – ¾ load (2 runs),
- 30°C – ¼ load (2 runs).

was agreed as a possible compromise by a majority of manufacturers, although not unanimously.

7.4.3.4 Scenario 2: Energy label? Yes or no

The main objective of scenario 2 is to analyse if the Energy Label can trigger additional energy and water savings in addition to the Ecodesign scenarios assessed in Scenario 1. Scenario 3 in the next section explores some aspects of resource efficiency. Scenario 2 includes four sub-scenarios, Scenario 2a considers that only Ecodesign requirements are implemented (for reference and comparison purposes), while scenarios 2b1, 2b2 and 2b3 consider that both current Ecodesign and the new Energy label are implemented.

The energy label framework regulation has been revised recently (Regulation (EU) 2017/1369) and proposes a re-scaling of the energy efficiency classes back to the A-G scale.

The analyses of Scenario 2 assume the standard measurement method currently in place, i.e. it refers to BAU in Scenario 1 and does not add to it. It does not refer either in BAU to any of the Scenario 1 options (1a-1d).

The scenario 2 assumes a differentiation in sales distribution of the future due to different aspects related to the implementation of the energy label regulation. Energy labelling is a mechanism to help consumers make a better informed decision regarding energy consumption of the machine. At the same time, the energy label pushes manufacturers to offer better products in terms of energy efficiency.

The Figure7.11 shows the estimated sales distribution for the BAU scenario, assuming that no further changes will be introduced in the current energy label regulation.

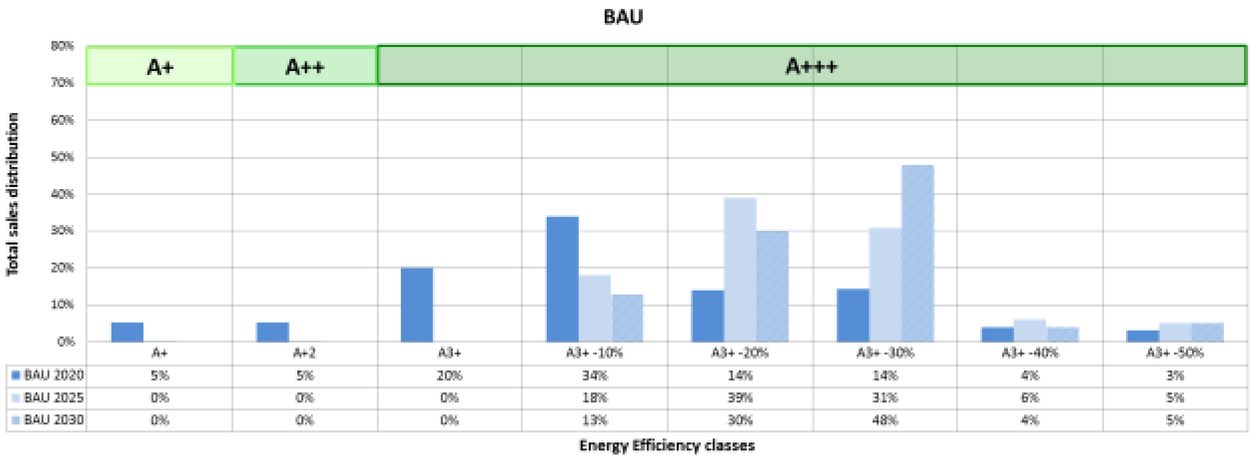


Figure7.11: Estimated sales distribution for the BAU scenario according to declared kWh/year consumption values. The current label classes are indicated

Table 7.22 summarizes the four sub-scenarios estimated under Scenario 2.

Table 7.22: Summary of the sub-scenarios assessing the implementation of an energy label and an eco-design regulation for washing machines

Sub-scenario	Model assumptions
Scenario 2a	Only Ecodesign is implemented. It is assumed that most of the manufacturers will try a differentiation of their products based on costs (lower purchases of the machines) while some few manufacturers will keep on improving their products from the energy efficiency point of view.
Scenario 2b1	Ecodesing and Energy label are implemented The currently most efficient washing machines (90kWh/year) fall in class C, leaving class A and class B completely empty. It is assumed that the producers of washing machines without advanced technology would have no or few incentives to improve their products regarding energy efficiency.
Scenario 2b2	Ecodesing and Energy label are implemented The currently best washing machines fall in class B, leaving class A completely empty at the moment of writing.

Sub-scenario	Model assumptions
Scenario 2b3	Ecodesing and Energy label are implemented The class A would initially be almost completely empty with exception of the very best appliances. It is assumed that manufacturers are strongly incentivized to improve the energy performance of the machines.

7.4.3.4.1 Scenario 2a: Only Ecodesign requirements

In this scenario the option is to explore removing the energy label, and implementing only ecodesign requirements. Ecodesign requirements can be as today's requirements, or be stricter/different (i.e. introducing some of the modifications 1a-1d assessed in Scenario 1).

The manufacturers would not be encouraged to improve the washing machines beyond the mandatary requirements since there would be no differentiation based on energy efficiency. They could focus on decreasing the costs or focus on other non-energy parameters such as durability, internet connections, etc. Some manufacturers, however, will keep improving their products and communicate their improved energy efficiency to the consumers

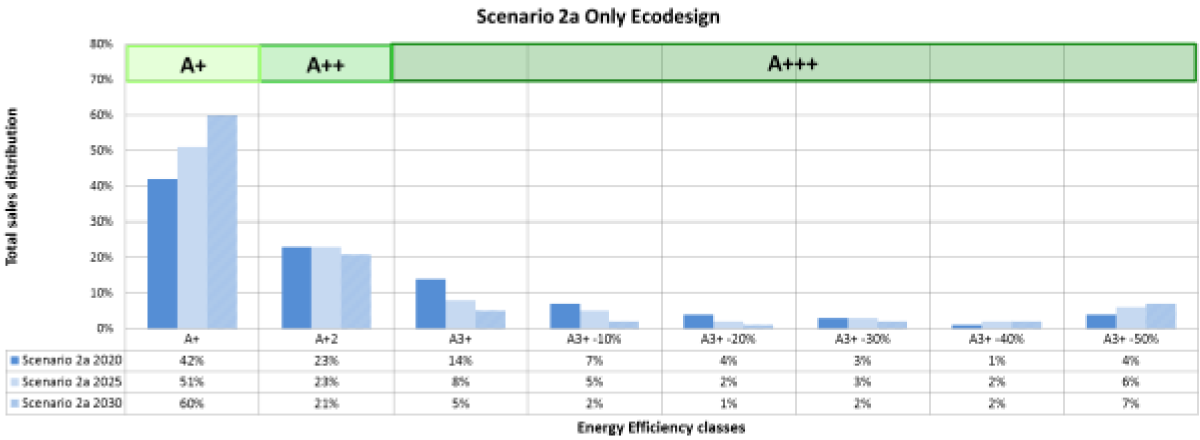


Figure7.12: Estimated sales distribution for the scenario 2a according to declared kWh/year consumption values. The current label classes are indicated

The estimated evolution of the sales distribution over different energy consumption values in this scenario shows that the market will be split into two main groups: economic washing machines and washing machines with a high energy efficiency. The rationale behind is that without an energy label, most of the manufacturers will focus their efforts on a cost competition and try to decrease the cost per unit. Some few manufacturers will decide to compete in terms of quality offering very energy efficient products, but as the economies of scale of these products are not well developed, these devices are more expensive.

7.4.3.4.2 Scenario 2b: New Energy Label

Energy labelling is a mechanism to help consumers make an informed decision regarding energy consumption of the machines. It serves to differentiate products and identify the best energy performing machines. This scenario considers the policy options discussed in section 0 regarding the implementation of new energy label classes.

In these scenarios, a new label class differentiation is created with a full scale of seven energy classes ranging from A to G. The three sub-scenarios (2b1, 2b2, 2b3) differ mainly regarding the strictness of the requirements for the label. No additional ecodesign requirements are put forward, as they have been analysed in sub-scenarios 1a to 1d described above. The addition of benefits or drawbacks due to the simultaneous/synergic implementation of changes in the ecodesign regulation and the energy label regulation are not assessed.

The label class thresholds for the three sub-scenarios are shown in Table 7.23. These label class thresholds are also illustrated in Figure7.13 which also show the estimated washing machine sales evolution.

Table 7.23: Label class thresholds for the three sub-scenarios for a washing machine with a rated capacity of 7kg

Since 2011					Revision (kWh/a)						
Label class	EEI min	kWh/a	EEI max	kWh/a	Label class	Scenario 2b1		Scenario 2b2		Scenario 2b3	
						min	max	min	max	min	max
A+++			46	175	A		60		77		90
A++	46	175	52	198	B	60	78	77	95	90	105
A+	52	198	59	225	C	78	100	95	113	105	122
A	59	225	68	259	D	100	123	113	134	122	142
B	68	259	77	293	E	123	150	134	159	142	166
C	77	293	87	331	F	150	184	159	189	166	193
D	87	331			G	184	225	189	224	193	225

* the classes marked in red are not allowed because of ecodesign requirements which are already implemented.

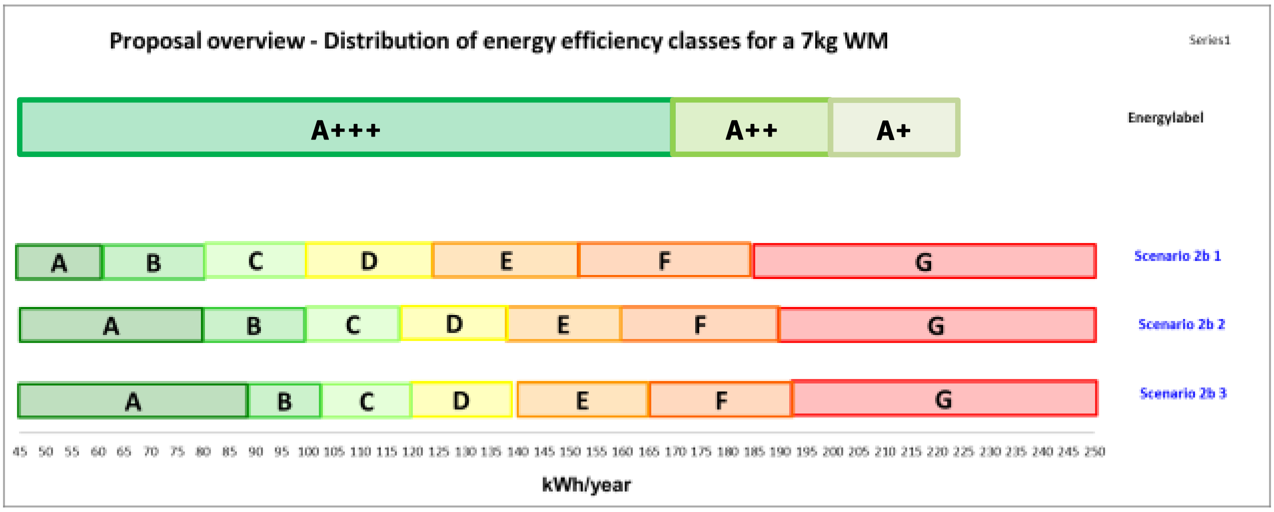


Figure7.13: Label class thresholds for the three sub-scenarios for a washing machine with a rated capacity of 7kg

To better understand the implications of the different thresholds it is important to know the EEI of the best available appliances currently on the market, which are shown in Table 7.24.

Table 7.24: Annual energy consumption and EEI of the best available washing machines on the market (end 2015)

	Rated capacity	Annual energy consumption
A+++ -50% (heat pump or other advanced technology in the washing machine)	7 kg	88 kWh/year
A+++ -30% (best WM without heat pump or such an advanced technology)	7 kg	123 kWh/year
A+++ - 10%	7 Kg	158 kwh/year

Scenario 2b3 would allow the best appliances on the market, heat pump or other combinations of very energy efficient technology, resulting in ca 90 kWh/year be assigned to energy class A from the start of the revision. This is however in conflict to Art 11(8) of the recently revised energy labelling regulation (2017/1369) directive revision that *"Where a label is introduced or rescaled, the Commission shall ensure that no products are expected to fall into energy class A at the moment of the introduction of the label and the estimated time within which a majority of models falls into that class is at least 10 years later''.*

One may discuss if heat pump equipped appliances or appliances with very advanced energy efficiency technology could be considered as "*a product on the market*". The sales figures for heat pump equipped appliances are currently very low (estimated to be less than 2000 units per year or less than 0.08% of the total sales of ca. 15 Million units). The sales figures of appliances that currently reach approx. 90 kWh/year with combinations of energy efficient technologies (spray or water injection, very energy efficient motors) are not known. While the observed retail price of current HP models is ca. 2500-4000eur, non-HP appliances on the market with similar efficiency are offered for about 1200eur.

At the moment of editing this report (Summer 2017) the best machines on the market had a consumption of ca. 90 kWh/year, meaning an EEI of about 20.5. This means that class A would initially be almost completely empty for scenario 2b3 (with exception of the very best appliances). In this scenario, the manufacturers could be motivated however to develop machines that can achieve higher energy label classes (i.e. classes A to C) as there are already washing machines on the market that achieve the proposed class B (currently between A^{+++}-30% and A^{+++}-40%). The proposed classes A and B are seen to be positioned to allow for innovation and exploit possible improvement potentials. Washing machines that currently reach A^{+++} would be classified in the proposed class E, current A^{++} washing machines would be classified in class F and current class A^{+} would be in class G. It has to be noted that currently half of all washing machines are classified with A^{+++} (or claimed to be better than that by means of self-declarations). The majority of washing machines would therefore still be classified between B and E, leaving some room for improvement.

Scenario 2b2 shows an energy label class revision where the currently best washing machines fall in class B, leaving class A completely empty at the moment of writing. Art 11(8) of the revised energy labelling regulation foresees the option of leaving classes A and B empty if a rapid technological development is expected. However, given that this is the second revision of the energy label for washing machines, it can be assumed that further energy improvement would imply a slow technological progress for washing machines. Hence, it can be justified to only keep label class A empty instead of keeping label class A and label class B empty from the beginning (as simulated in the most strict scenario, 2b1).

In Scenario 2b2, the distribution of classes would leave the second best current WM models (A^{+++}-30%, 125 kWh/year in class D. Washing machines that currently reach A^{+++}-20% would be classified in class E, current A+++-10% washing machines would be classified on the border of class E and all other washing machines would fall in class F and G. This may contribute to a market split into very advanced technology equipped machines, which are more complex and expensive, and reach the best classes, and (cheaper) washing machines without those technologies, that are tailored to the price-conscious consumers that do not pay that much attention to the energy label. In this scenario, it could happen that producers of washing machines have fewer incentives than in other scenarios to transfer energy-saving technologies to the lower, less expensive machines.

Scenario 2b1 shows an energy label class revision where the most efficient washing machines (90kWh/year) fall in class C, leaving class A and class B completely empty. Keeping energy class B empty at the start of the revision would mean very little differentiation among the products. The distribution of this scenario leaves the second best washing machine group (120-125 kWh/yr.) placed in class E, meaning that a large part of the market is clustered among classes E, F and G). In scenario 2b1, good label classes would require expensive technologies. Due to the high purchase price, there might be a lower than expected uptake of advanced technologies. However, the economies of scale of these technologies have not yet been exploited. Furthermore, as all washing machines without advanced technology would be in the low half of the energy efficiency classes (E to G), this might result in the perception that most machines in general do not perform well.

A market change concerning heat pumps has taken place over the last years with tumble driers, generalising the use of heat pump appliances. It should be mentioned however that the energy savings attributed to a heat pump in tumble driers are much more significant than for washing machines. Currently, some models of washing machines combine energy efficient technologies to reach the same energy consumption than heat-pump equipped machines. For the time being, most manufacturers seem have tested heat pump technology prototypes, but are hesitant to market them widely.

The estimates of the evolution of the sale distribution for the scenarios 2b and 2b1, 2b2 and 2b3 is shown in Figure7.14 to Figure7.17

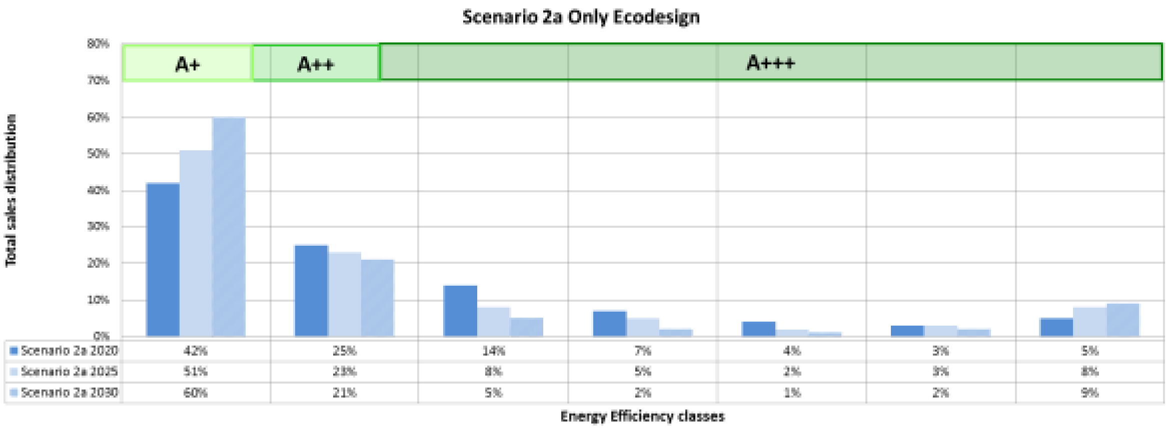


Figure7.14: Estimated sales distribution for the scenario 2a according to declared kWh/year consumption values. The current label classes are indicated

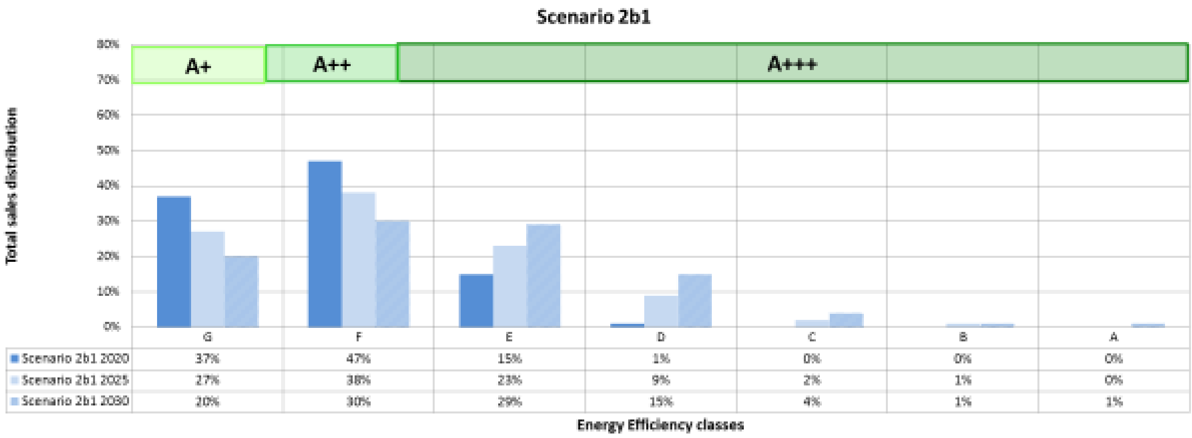


Figure7.15: Estimated sales distribution for the scenario 2b1 according to declared kWh/year consumption values. The current label classes are indicated

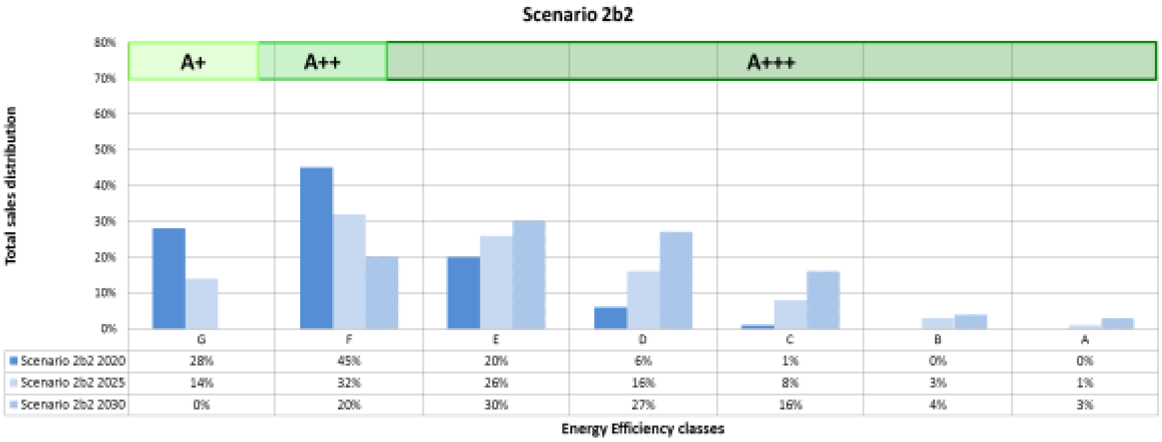


Figure7.16: Estimated sales distribution for the scenario 2b2 according to declared kWh/year consumption values. The current label classes are indicated

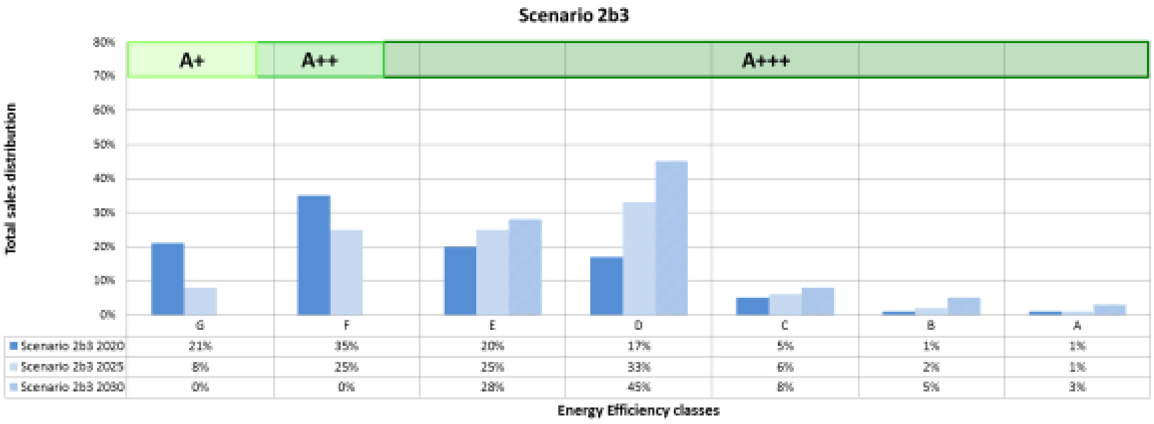


Figure7.17: Estimated sales distribution for the scenario 2b3 according to declared kWh/year consumption values. The current label classes are indicated

7.4.3.4.3 Impacts on resources for scenarios 2a, 2b1, 2b2 and 2b3

The different scenarios act differently on the evolution of resource consumption (energy and water) in the EU 28. The effects of the different scenarios on energy consumption for the EU28 in the period 2015-2030 are shown in Figure7.18, Figure7.19and Figure7.20.

show the average individual machine consumption of energy and water over the period 2015-2030, respectively. Note that scenario 2b1 is not the most efficient overall, even though intuitively this would be expected as it poses the strictest requirements. This counter-intuitive observation is due to the assumptions made in the distribution of the appliances. In the strictest scenario (2b1), the penetration of appliances into higher energy efficiency classes does not occur as fast as in other scenarios. Scenario 2a (only Ecodesign) shows the lowest overall savings. This indicates that the implementation of a revised energy label into the market has still potential to save resources in the coming years. The results of scenario 2a are due to the assumption made in the distribution of the appliances split into two big groups over the different label classes (highly efficient machines and machines falling in the lower energy efficiency classes).

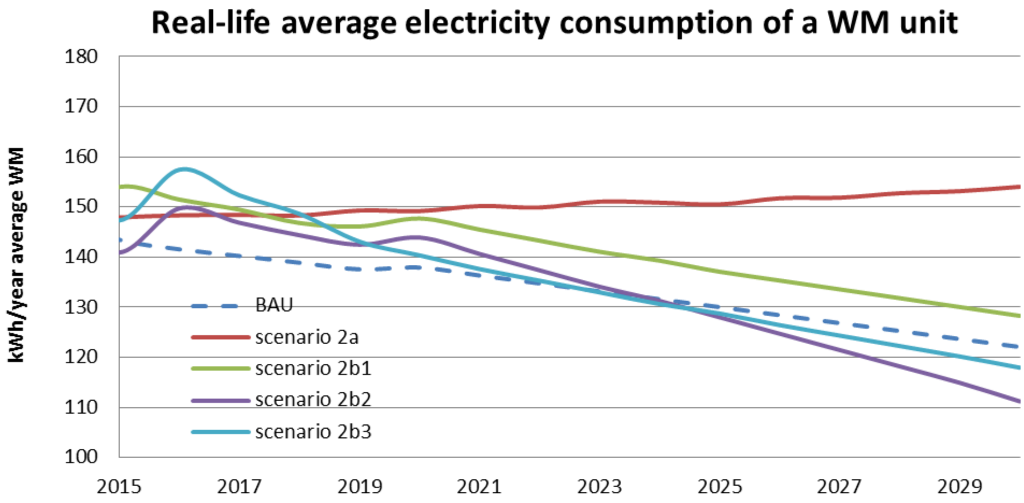


Figure7.18: Estimated annual real life average electricity consumption of a washing machine unit for scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

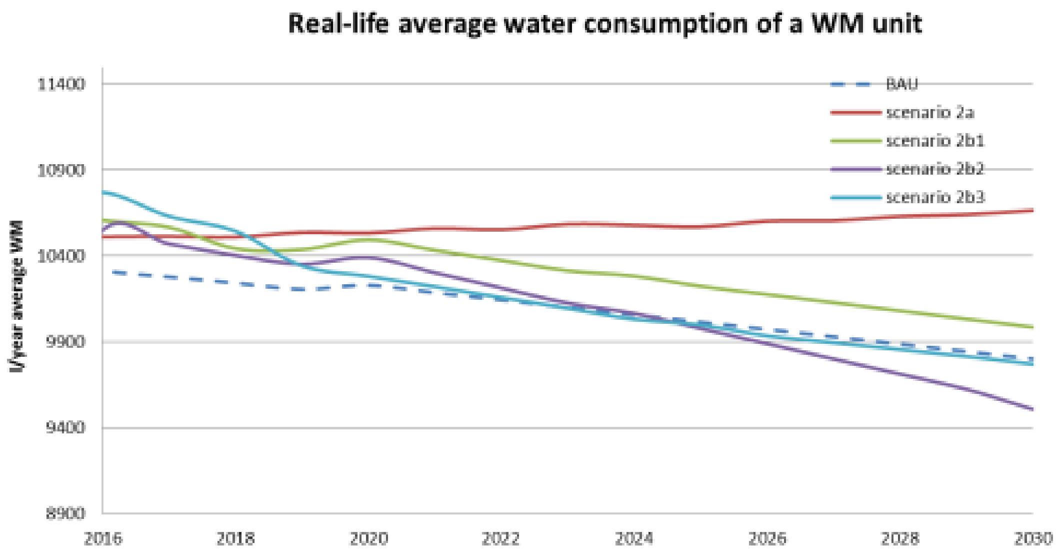


Figure7.19: Estimated annual real life average water consumption of a washing machine unit for scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

For all scenarios, the overall energy and water consumption of washing machines in the EU 28 decrease between 2015 and 2030. This is due to the decreases in the individual machine's consumptions and the assumption that it is a saturated market. New machines replace with time all machines of the stock, increasing the energy efficiency of the overall stock.

From Figure7.20 can be seen that the maximum energy saving is expected for scenario 2b3, closely followed by scenario 2b2, with energy savings of 0.45 and 0.25 TWh/year in 2030 respectively, compared to the BAU, which remarkably also decreases considerably its energy consumption. In both scenarios, this is about 1.5% of the washing machine energy consumption in the BAU scenario estimated in 2030. Maximum water saving of 52 million m^3 per year is expected in 2030 for scenario 2b2. This is around 4% of the water consumption expected in 2030 in the BAU scenario for washing machines in EU28.

The values for electricity and water consumption are provided in table form in Annex 8.9.7

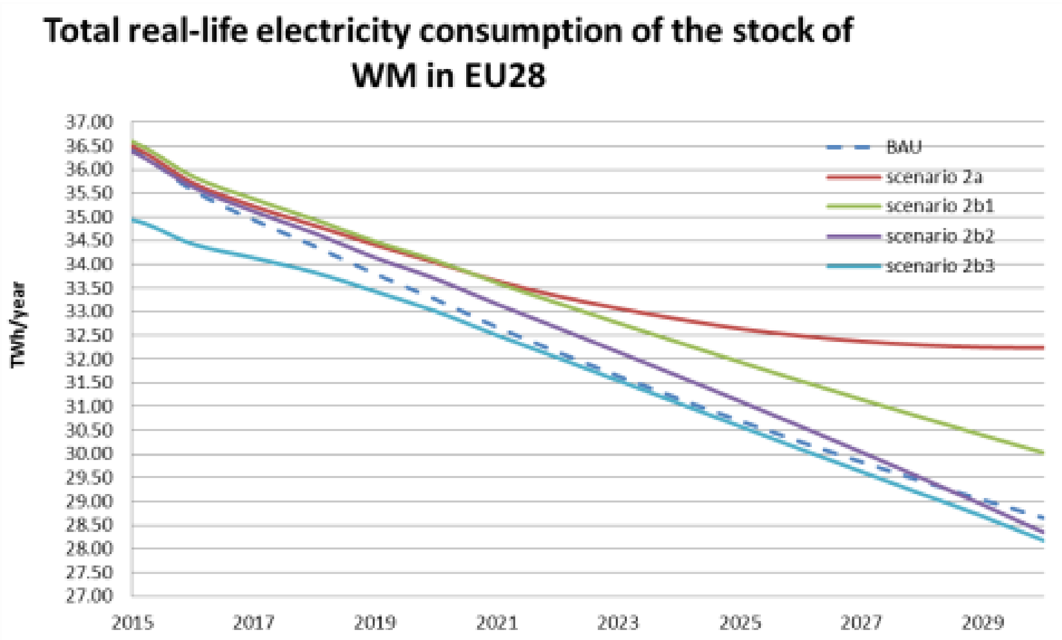


Figure7.20: Estimated annual real life electricity consumption of the stock of washing machines in the EU 28 for the scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

Impacts on GHG emissions and primary consumption for the scenarios 2a, 2b1, 2b2 and 2b3

The GHG emissions and the primary consumption are, as commented for the scenario 1, directly linked to the energy consumption. The environmental impact in terms of GHG emissions is illustrated in Figure7.21. The reduction of carbon emissions attributed to the electricity in the coming years is considered to exceed the higher electricity demand of the European washing machines and therefore a decreasing trend line is seen.

Figure7.21 shows a decrease of CO_{2eq} emissions in all scenarios and especially in scenarios 2b2 and 2b3, as they reach GHG emissions below the predicted emission for the BAU scenario. The calculated values are provided in table form in Annex 8.9.8

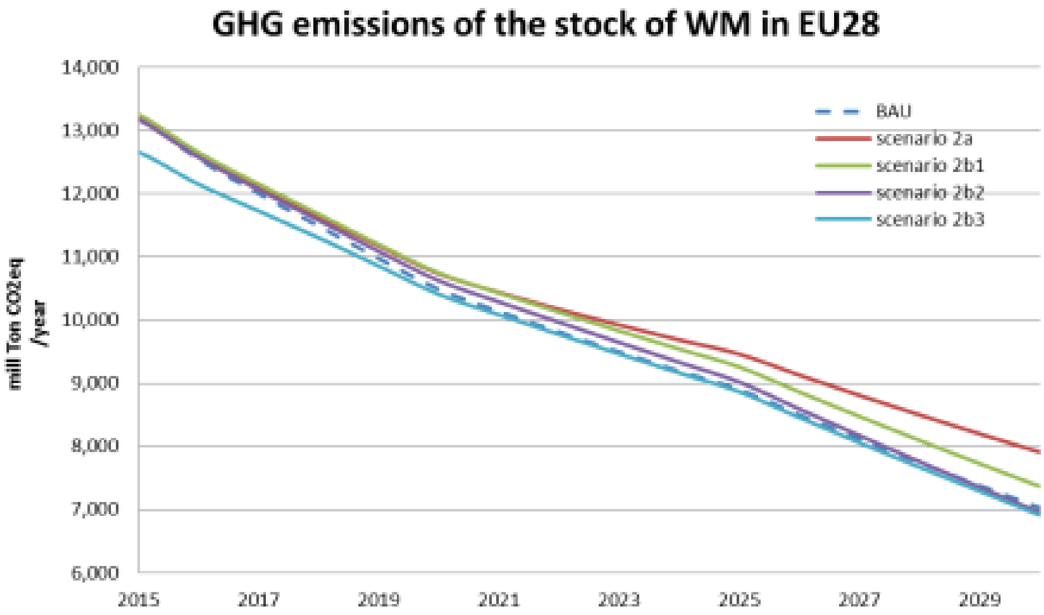


Figure7.21: Estimated annual CO_{2eq} emissions from the electricity use of the stock of washing machines in the EU 28 for the scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

Regarding the consumption of primary energy related to the electricity use of the washing machines at EU 28 level, it can be observed from Figure7.22 that the total primary energy is expected to decrease in the coming years due to the effects of lower energy consumption of the washing machine stock and the forecasted decrease in the primary energy factor. The calculated values can be found in Annex 8.9.9.

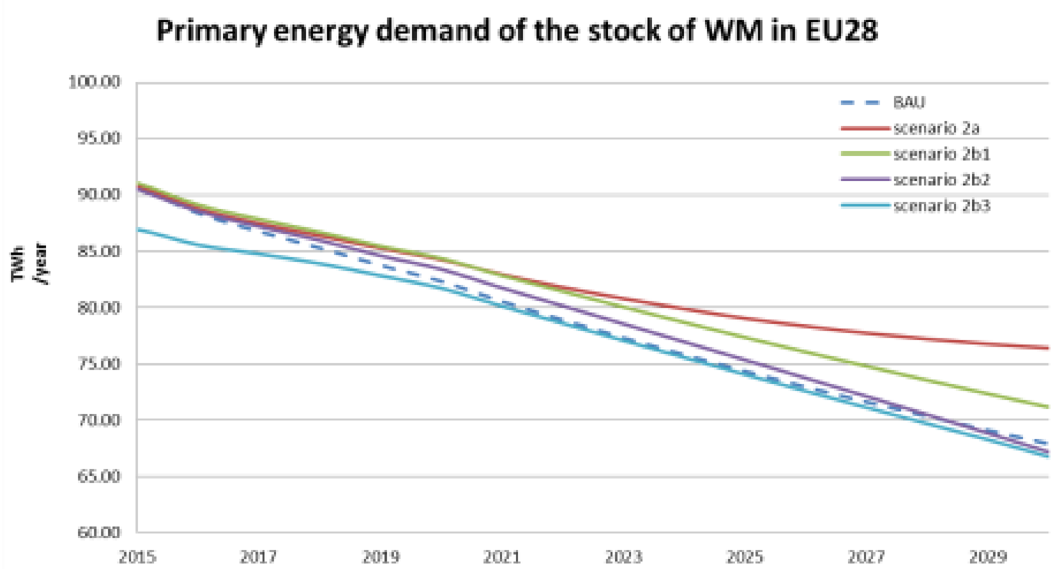


Figure7.22: Estimated primary energy consumption from electricity use of the stock of washing machines in the EU 28 for the scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

Impacts on the consumer expenditure and jobs for the scenarios 2a, 2b1, 2b2 and 2b3

The impact of the different scenarios on the consumer expenditure is shown in figure 7-47. The average unitary price (observed retail price) is shown in Figure7.23.

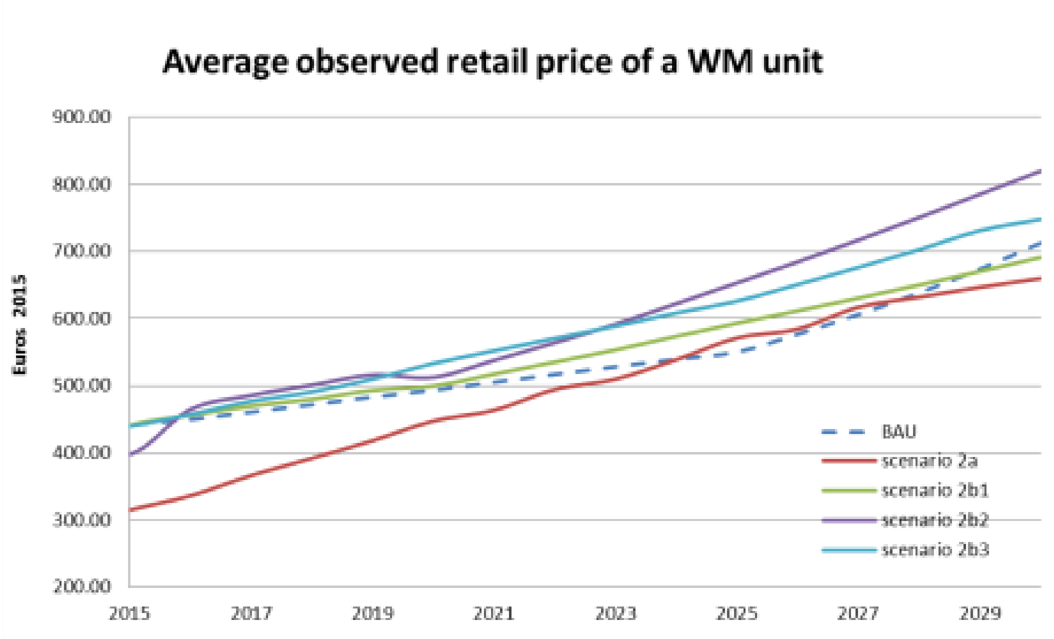


Figure7.23: Estimated average unitary observed retail price of washing machines in the EU 28 for the scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

Compared to the ORP in Figure7.23, the total consumer expenditure in Figure7.24 shows a similar trend. This is because in the coming year not only the purchase prices but also the energy and water prices are expected to increase (as shown in Figure xx). Repair and maintenance costs are the same in all scenarios, but purchase price, energy and water costs change.

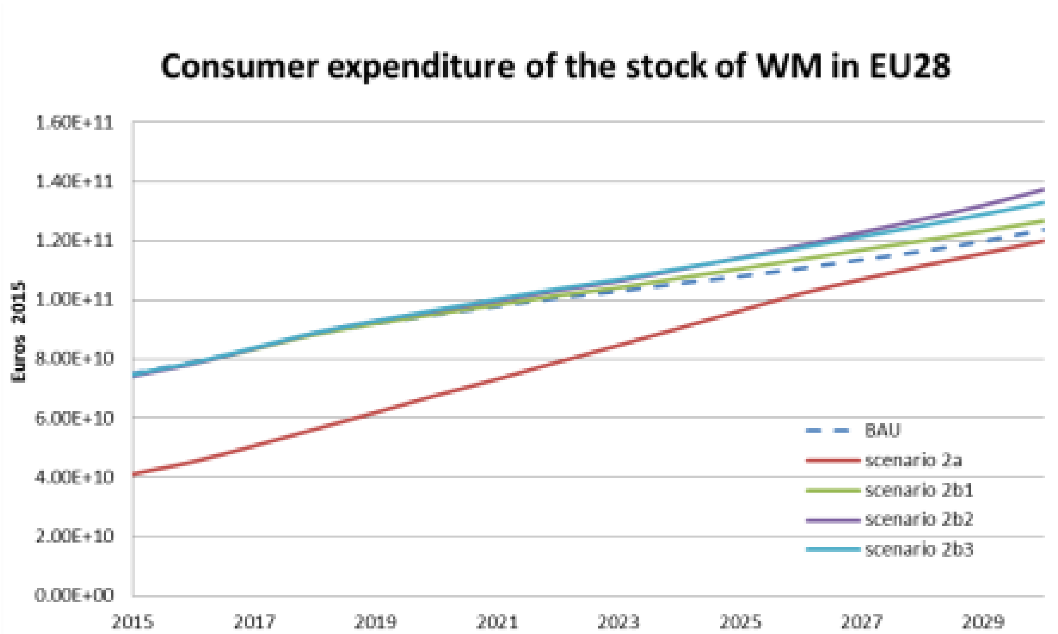
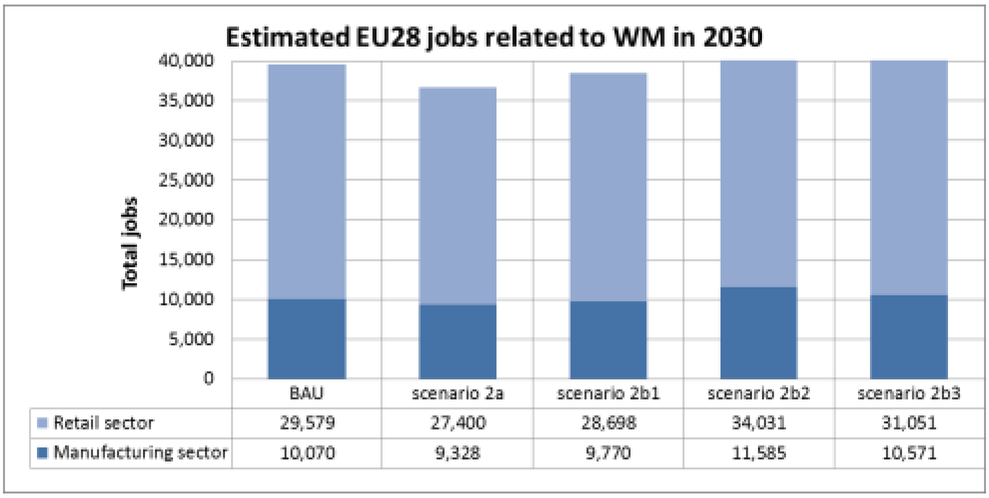


Figure7.24: Estimated consumer expenditure of the stock of washing machines in the EU 28 for the scenarios BAU, scenario 2a, scenario 2b1, 2b2 and 2b3

7.4.3.4.4 Impacts on employement for scenarios 2a, 2b1, 2b2 and 2b3

Finally, the impact in terms of expected job is considered on a very basic level. As explained in section 7.4.2.7 and recommended in the current MEErP guidelines, a rough estimate of job creation can be obtained using the turnover of companies. For instance, a ratio of 188000 euro/employee for the manufacturing industry and 60000 euro/employee for white good retailers can be used. The turnover of the manufacturers and the white good retailers is calculated as the number of sold machines times the price at the manufacturer's door and the selling price, respectively (excluding VAT). The results are shown in Figure7.25.



	BAU	scenario 2a	scenario 2b1	scenario 2b2	scenario 2b3
Retail sector	29,579	27,400	28,698	34,031	31,051
Manufacturing sector	10,070	9,328	9,770	11,585	10,571

Figure7.25: Estimated number of jobs by 2030 in the EU washing machine sector

7.4.3.5 Scenario 3: Durability

As shown in section 7.3.6, the complex question of whether or not to replace more quickly an older appliance with a more energy efficient appliance needs to be addressed. This question can also be read as if an extension of the product lifetime will bring benefits. In this study, only preliminary estimations are made which could be further refined in the full impact assessment.

The repair of performance failures in the appliances will have an impact on the average time of a product on the European stock. This study assumed that in the BAU scenario, old in-service appliances will be replaced by new ones after, on average, 11.86 years. The amount of machines that will display a failure along their lifetime will be approximately 75%. This scenario considers that 30% of the appliances are repaired once in their lifetime, and that 8% of the machines that were discarded without a failure are foreseen to be reused.

The scenario on durability/reparability models possible extensions of the time an average product remains in the stock (in-service) either by manufacturing more robust machines (i.e. increasing the technical product lifetime, scenario 3a) or by increasing the number of machines that are repaired (scenario 3b) or reused (scenario 3c). The increase of the machines that can be repaired can be either due to measures that increase the technical feasibility of repair and/or decreasing the cost of repair. The extension of the in-service time of an appliance will have an impact on the forecasted sales (especially replacement sales), the consumer expenditures, the energy and water savings and all other related parameters. Only the impact on electricity consumption, total sales and direct effects of manufacturer and retail jobs are shown in this document. The influence of these scenarios on the use of resources has not been studied here. Intuitively, one could think that more durable products would save resources, but this has not been quantified in detail in this study. Examples of studies elaborating on this issue are: Cases I Sampere (2015); Bobba et al (2015) and Hur et al (2005).

The three following sub-scenarios were used to estimate the impacts of extending the time a machine remains in-service. For clarity, the durability/reparability scenarios are applied to the BAU scenario.

7.4.3.5.1 Scenario 3a: Increasing the robustness of the machines

This scenario is modelled by assuming an increase in the technical lifetime of the machines with 2.5 years, i.e. from 12.5 years to 15 years. This would shift the in-service time of an average washing machine from 11.86 year to 14.49 years. No other parameters, e.g. the purchase cost are changed due to this assumption. The percentages of machines repaired (30%) or reused (8%) are kept the same as well.

7.4.3.5.2 Scenario 3b: increasing the rate of machines repaired

This scenario is modelled by assuming an increase in the rate of machines with a failure that are repaired, i.e. from 30% to 50%. This scenario represents either a higher number of washing machines that are sent to be repaired by the consumers, or an increase in the ratio of those that are technically and economically successfully repaired. The original technical lifetime of 12.5 years and the ratio of 8% of machines reused are kept in the model, together with all other parameters. This would shift the in-service time from 11.86 years to 12.98 years.

7.4.3.5.3 Scenario 3c: Increasing the rate of machines reused

This scenario is modelled by assuming an increase in the rate of machines that are reused when discarded without failure, i.e. from 8% to 18%. The original technical lifetime of 12.5 years and the rate of 30% of machines repaired are kept constant, together with all the other parameters. As the machines that are considered to be reused are only a part of those machines that would be discarded without any failure and replaced by new machines, the overall effect of the increase in the rate of machines that are reused is very diluted. In this sense, the time in-service of the washing machines hardly changes and an average washing machine will stay around 11.88 years in the European washing machine stock.

Table 7.25: Parameters changed in comparison to the BAU scenario

Scenario	Measure	Technical lifetime (years)	% repairs	% reused machines without failure	Average in-service time (year)
BAU	--	12.5	30 %	8 %	11.86
Scenario 3a	Increase in the technical lifetime	15	30 %	8 %	14.49
Scenario 3b	Increase of % repaired	12.5	50 %	8 %	12.98
Scenario 3c	Increase % of reused machines without failure	12.5	30 %	18 %	11.88

7.4.3.5.4 Impacts on resources for scenarios 3a, 3b and 3c

The total electricity consumption for the different scenarios is shown in Figure7.26. It shows that none of the scenarios (3a, 3b and 3c) significantly affect the real-life electricity consumption under the assumptions proposed in scenario BAU. The scenarios 3 have no additional potential for electricity savings in addition to those shown by scenario BAU. Conversely, they increase energy consumption (in terms of electricity) by an amount (0.98 TWh/year for scenario 3a).

However, it should be noted that the previous figure is an increase in the electricity needed to run the washing machines during the use phase, but this figure does not consider the energy consumed along the whole lifecycle of the washing machines. This means that it does not include the energy consumption of the production and end-of-life phases. Comparing the energy consumption of the overall lifecycle of the washing machines can result in different results and conclusions.

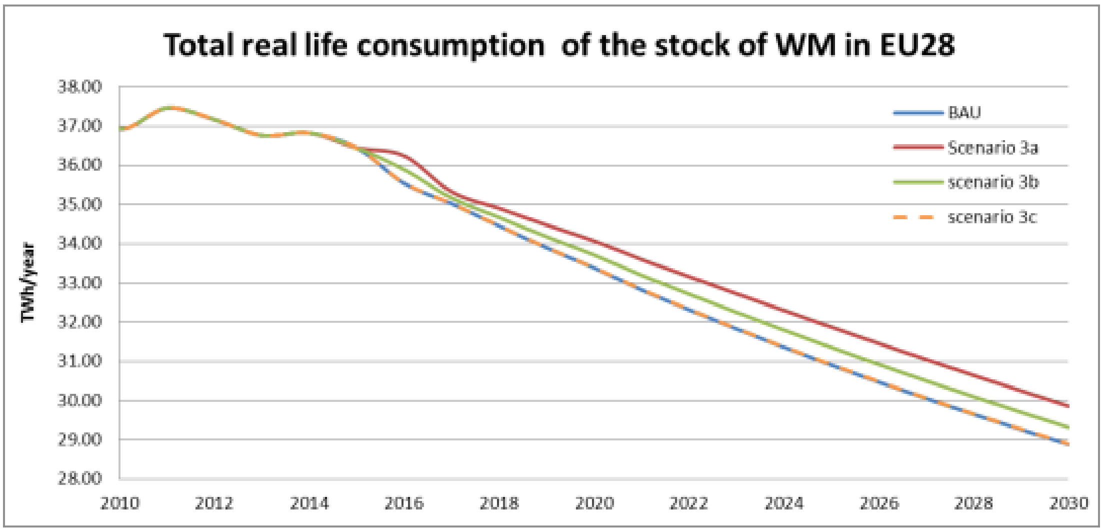


Figure7.26: Estimated annual total real life electricity consumption of the stock of washing machines in the EU 28 for the scenarios BAU, scenario 3a, scenario 3b and scenario 3c.

7.4.3.5.5 Impacts on total sales, employment and labour markets

The total sales figures for the BAU scenario and the scenarios 3a, 3b and 3c are shown in Figure7.27. Scenarios 3a and 3b lead to a decrease in the total annual sales figures, which has an impact on the turnover of the manufacturers and the retailers and therefore for the creation of jobs in both sectors (**Error! Reference source not found.**).

Figure7.27: Estimated annual total sales of washing machines for the scenarios BAU, scenario 3a, scenario 3b and scenario 3c.

The decrease in the total sales is observed for both scenarios where policy measures promoting a higher technical lifetime (scenario 3a) are considered. This is due to the longer in-service time and consequently the lower need of the consumers to buy new products for replacing the old ones.

A prolongation of the service lifetime of appliances may have different impacts on the economic activities of the various sectors involved, e.g., product manufacturers, product retailers, maintenance and repair sectors, rental/ leasing, and End of Life resource/ recovery/ waste management enterprises.

Deloitte, on behalf of the European Commission, is carrying out an ongoing study (Deloitte 2017), addressing the socioeconomic effects of increased reparability. Among other aspects, variations in turnover, and knock-on effects regarding employment and labour markets have been considered. The authors have concluded to date that there would be expected marginal gains in the total aggregated impacts on the turnover of the relevant sectors affected (manufacturing, retailing of new and old products, repair and waste treatment), and that where manufacturers do experience losses, these would be more likely to occur outside the EU.

Another recent study (Montalvo et al, 2016), commissioned by the European Parliament's Committee on Internal Market and Consumer Protection (IMCO), highlighted that some benefits should accrue via longer-lifetime products in the EU due to changes in EU value-added economic benefits, the related balance of trade between the EU and extra-EU, and changes in labour markets. This study pointed out that:

- European jobs are likely to be created if businesses increase their added-value within the territory of the EU, especially in non-tradeable services that need to be provided locally. The job creation estimations vary between Member States.
- Increasing the longevity of products may have an influence on the balance of trade, because fewer imports would be required to maintain the current level of product stocks within the European market.
- Many jobs created would be linked to employment in maintenance and repair activities. These types of jobs have tended to decrease in the EU in recent decades partly owing to globalisation, coupled with relatively high average EU wages, and few fiscal incentives (at Member State level) to encourage maintenance and repair.

Negative effects regarding extending the lifetime of products could be expected to occur in the manufacturing sector**,** regarding some losses in sales and/or market share. The drop in product manufacturing is expected to be partially counterbalanced by the increased production of spare parts and the increase of repair services for those manufacturers which provide such services. However, the overall effect on the turnover of manufacturers is expected to be slightly negative.

It is important to note that the above effects may have positive future effects on the EU/ outside-EU balance of trade, depending upon the reactions of manufacturers, in-house repairs that these manufacturers may offer, and – in parallel - the reaction of the EU-based independent repair sector. Evidence which supports this statement consists of the following:

1. More than half of the value (54%) of the EU's annual sales of new washing machines occurs as a result of products that are imported from outside of the EU (Deloitte 2016). Hence, in parallel, any manufacturing job losses are projected to occur proportionately more outside of the EU than within the EU's borders.

2. There is a relatively higher percentage of the total imported mass of washing machines (62%) made outside the EU, but sold on the EU markets. This can be extrapolated to signify that a higher proportion of lower-value washing machines are produced outside of the EU (Deloitte 2016)., when compared with the above statistic.

3. Available (slightly dated) information on the ownership of retailer businesses selling washing machines and washer dryers on the EU market shows that c.80% are in EU ownership (European commission 2008b). Owing to the increased lifetime of new products within scope, these businesses may also face a reduction in turnover. However, this drop may be partially counterbalanced by the increased sales of spare parts and repair services.

The potential measures aimed at extending the lifetime for products may result in benefits especially to those companies (both manufactures and retailers), which are able to adapt, and to provide a variety of efficient after-sales services, e.g., an increase in the provision and consumption of possibly intra-EU goods (e.g., product components) and services related to repair and maintenance. This may also lead to a shift of jobs from manufacturing or product retail per se, towards offering a provision of services, including service packages (including maintenance and repair), or service-based contracts (e.g., on a pay-per-use basis, rather than product ownership), product leasing, product rental, etc. It is important to note that EU-based businesses have the commercial advantage of being geographically much closer to their customers in EU markets, for this potential re-orientation of their after-sales services, since distance – and time - to the client are key cost factors.

Another factor to take into account is that the priorities of the Research & Development sector/ component of companies may be expected to partly shift, from reducing costs in production to also placing an increasing emphasis on designing more durable and reparable products. Such R&D shifts would assist the market penetration of the above potentially redefined commercial strategy.

7.5 Summary of the scenarios for washing machines

The main outcomes of the ecodesign and energy label scenarios are summarized in Table 7.26 and Table 7.27. Scenario 3 on durability and reparability are not included in these tables, as the impacts of these measures are not as thoroughly developed as scenario 1 and 2.

Direct comparison between scenario 1 and 2 and the BAU scenario should be done carefully to avoid possible confusion. Direct addition of the savings and potential environmental benefits of scenario 1 and 2 should not be done, although some added environmental benefits can be expected.

Table 7.26: Summary of the outcomes of the scenarios BAU, 1a, 1b, 1c and 1d

Main impacts 2030			**Ecodesign scenario**				
			BAU	**Scenario 1a**	**Scenario 1b**	**Scenario 1c**	**Scenario 1d**
Environment							
	Electricity	TWh/a	28.65	25.89	29.01	27.69	25.11
	Energy	PJ/a	244.44	220.90	247.45	236.20	214.23
	GHG	Mt CO_2 eq/a	7.03	6.35	7.12	7.12	6.79
	Water (use phase)	Millions m^3/a	2083.16	2051.69	2128.08	2026.84	2031.09
CONSUMER							
EU totals	Expenditure	€ bin./a*	107.05	106.48	107.13	106.84	106.30
	Purchase costs	€ bin./a	8.28	8.28	8.28	8.28	8.28
	Electricity costs	€ bin./a	6.08	5.49	6.15	5.87	5.33
	Water costs (use phase)	€ bin./a	0.44	0.45	0.44	0.43	0.44
	Consumables (detergents, etc.)	€ bin./a	8.35	8.35	8.35	8.35	8.35

Main impacts 2030			Ecodesign scenario				
	Maintenance costs	€ bin./a	9.39	9.39	9.39	9.39	9.39
Per product	Product price	€	600	600	600	600	600
	Installation cost	€	0.00	0.00	0.00	0.00	0.00
	Energy costs	€/a	25.89	23.40	26.21	25.02	22.71
BUSINESS							
EU Turnover	Manufacturers	€ bin./a	3.19	3.19	3.19	3.19	3.19
	Retailers	€ bin./a	6.23	6.23	6.23	6.23	6.23
EMPLOYMENT							
Employment (job creation)	Industry EU (inclu OEM)		8480	8480	8480	8480	8480
	Retailers		24910	24910	24910	24910	24910
	TOTAL		33390	33390	33390	33390	33390

Scenario 1 compares policy options for washing machines which aim at correcting the current divergence observed between real life use of the machines, and the standard programmes used for measuring energy and water consumption. .

The result of the assessment indicates that ED requirements, with the consequent adaptation of the standard measurement method, would produce beneficial effects at EU level.

In particular, two scenarios have been identified as the most beneficial: scenario 1d and scenario 1a. Scenario 1d (an additional programme for lightly soiling) relies considerably on the understanding by consumers of the lower energy and water use of low temperature cycles, and increasing the loading of each cycle. The energy saving potential of this scenario is the highest of the scenarios analysed, but it has the associated risk of not being fully achieved if consumers do not behave as predicted.

Scenario (1a) aims at increasing the use of the standard programme 40°C cotton by adjusting a number of aspects in this programme that have been identified as inconvenient by consumers. The scenario 1a would result in a limitation of the duration of the 40°C cotton programme, and to achieve this higher temperature than currently. The scenario assumes acceptance of the consumer of the programme, compared to the current standard cotton 40°C, as the new programme would fit better the consumer's needs.

These conclusions are considered to be also applicable to the washing phase of washer-dryers.

Table 7.27: Summary of the outcomes of the scenarios BAU, 2a, 2b1, 2b2 and 2b3

Main impacts 2030	Energy label scenario				
	BAU	Scen 2a	Scen 2b1	Scen 2b2	Scen 2b3

Environment							
	Electricity	TWh/a	28.65	32.24	29.46	28.03	27.96
	Energy	PJ/a	244.44	275.05	251.34	239.11	238.52
	GHG	Mt CO_2 eq/a	7.03	7.91	7.23	6.88	6.86
	Water (use phase)	Millions m^3/a	2083.16	2180.49	2108.29	2067.44	2074.18
CONSUMER							
EU totals	Expenditure	€ bin./a*	107.05	108.64	108.69	119.66	113.49
	Purchase costs	€ bin./a	82.80	83.60	84.26	95.54	89.38
	Electricity costs	€ bin./a	6.08	6.84	6.25	5.95	5.93
	Water costs (use phase)	€ bin./a	0.44	0.46	0.45	0.44	0.44
	Consumables (detergents, etc.)	€ bin./a	8.35	8.35	8.35	8.35	8.35
	Maintenance costs	€ bin./a	9.39	9.39	9.39	9.39	9.39
Per product	Product price	€	599.92	593.53	528.68	694.02	575.33
	Installation cost	€	0.00	0.00	0.00	0.00	0.00
	Energy costs	€/a	25.89	32.67	26.26	22.87	23.67
BUSINESS							
EU Turnover	Manufacturers	€ bin./a	3.19	3.15	2.81	3.69	3.06
	Retailers	€ bin./a	6.23	6.16	5.49	7.20	5.97
EMPLOYMENT							
Employment (job creation)	Industry EU (inclu OEM)		8480	8390	7,473	9810	8132
	Retailers		24910	24645	21952	28,817	23889
	TOTAL		33390	33034	29425	38,627	32021

Scenario 2 assesses the benefits of implementing jointly Ecodesign and Energy Label regulations, and includes several options for re-scaling the label.

Scenario 2b3 and 2b2 would achieve the largest energy consumption savings for the washing machines. Scenario 2b3 assumes that the nowadays best performing washing machine is placed in the future in class A, while scenario 2b2 assumes that it is placed in class B. Scenario 2b3 conflicts with the new Energy Label requirements, which are met by Scenario 2b2. Additionally, scenario 2b2 still allows for product differentiation and communication of the performance parameters to the consumers, which are essential objectives of the energy label regulatio

7.6 Scenario analysis for washer dryers

7.6.1 Introduction

The objective of this section is to set up a stock model (2015-2030) and calculate the impact of different policy scenarios regarding resource use (energy and water), emissions (CO_2eq), consumer expenditure and employment of washer dryers, depending on the market evolution. The impacts due to the washing process are assumed equal to the analysed previously for washing machines, especially those due to the changes in the standard.

The different policy options are identified in the previous sections. Policy options taken into account for assessing the specific impacts of washer dryers are further described in section 7.6. Note that the calculated impacts for the different scenarios are indicative. A full impact assessment will be developed later in the policy process, where the findings from this study can be refined. Parameters that can be taken into account in the full impact assessment, but are not taken into account in this study are among others: sensitivity analysis of key parameters and assumptions and price elasticities.

In order to assess the effects of possible ecodesign requirements and changes in the energy label, a model has been developed. The model used for assessing the different policy scenarios is based on the model described in section 7.4.2 for washing machines. Therefore, in this section only the differences between both models are described.

7.6.2 Model description

7.6.2.1 Machine specific parameters

Machine specific parameters (e.g. average capacity, water and energy consumption, number of cycles, etc.) are based on the base case presented in Task 5 and the improvement options presented in Task 6.

7.6.2.2 Consumptions under real life conditions (correction factors)

The model determines the average annual energy and water consumption of washer dryers by multiplying the number of cycles per year (220 cycles per year) by the energy consumption per cycle. The energy consumption per cycle has been estimated in Task 5 and is based on the real-life conditions and the information provided by the stakeholders on the consumption of each washing programme and drying process.

The correction factors to be used in for the washing process would be the same as those derived in the washing machine model. However, the model of the washer-dryers considered the full wash and dry process and therefore, new correction factors are derived. Due to the lack of information, the same correction factors as for washing machines were used.

Energy consumption of the appliances sold in the past was estimated by observing the historical variation of the energy efficiency class distribution from 1997 to 2015 (see figure 2.52). The model estimates the future stock, total sales, energy and water consumption of the wash&dry process and consumer expenditure following the model explained for washing machines (see section 7.2.2). There is a lack of data for some input parameters such as the Weibull factors (for statistic life expectancy estimation), the historical stock, the product lifetime, or other parameters related to the reparability of the appliances. In those cases the same values as for washing machines were used.

Finally, the penetration rate of the washer-dryers is supposed to keep constant in the future. This is derived from the information that approximately 4% of the washing machines are washer-dryers and the lack of better forecast for the coming years. Stakeholders commented that an increase in the penetration rate was expected but they did not provide more accurate data.

7.6.3 Policy scenarios

7.6.3.1 Description of the assessed scenarios

Table 7.28 shows the policy options that have been assessed more in detail in this study. The business-as-usual scenario (BAU) is used as a reference. This scenario implies no changes whatsoever in the legal requirements for washer dryers, i.e. no changes in energy label and no Ecodesign requirements. Possible changes of those regulations are reflected in the assessed policy scenarios that are summarized in Table 7.28.

The scenarios analysed for washer dryers are firstly focused on assessing corrective measures of the standard that will bring it closer to the real life conditions and better reflect the distinct characteristic of the washer-dryers (scenario 4).

For the time being, no Ecodesign requirements have been introduced in the EU legislation for washer-dryers. Some eco-design requirements are assessed in Scenario 6. Finally, it is important for a revision to evaluate the missing potential lying in the revision of the energy label in the transition of the market towards more efficient machines. This assessment will be carried in Scenario 7 (its strictness and the role of the energy label in combination with the eco-design policy tool). Scenarios assessing the policy tools related to durability and reparability of the products are not considered in this section. It is assumed that the same conclusions as those drawn in section 7.4.3.4 for washing machines can be extrapolated for washer dryers.

Table 7.28: Policy scenarios for washer-dryers

Scenario	Sub-scenario	Comments
Scenario 4 Standardization	WD Split	It keeps current standard for measure at the washing rated capacity but following the changes proposed for WM for the testing the washing process
	WD Remove	It keeps the current standard for measure but the drying process is tested at the drying rated capacity. Some cloths have to be removed in between the processes
	WD Combi continuous	A continuous wash&dry process is used for testing. It reflects the main feature of the WD but not all the WDs are equipped with this function
	WD Combi interrupted	An interrupted wash&dry process is used for testing. Clothes are taken out of the WD, stored and reloaded within 30min between the processes.
Scenario 5a	Washing performance	Most of the models of washer-dryers already achieved a washing performance Class A. This requirement will not affect the EU market
	MER (minimum energy requirements) drying process	MER for drying process will affect in a similar way that the MER for the wash&dry process. Data and conclusions drawn for that model will be considered for this scenario too.
	MER wash&dry process	MER for wash&dry process will prevent products with excessive energy consumption from entering into the EU market. Tiers are proposed, becoming progressively stricter, to ban the entrance to the EU market to today's 10% worst performing models
Scenario 5b	Class A and B empty	Energy label is re-scaled according to the revised Energy Label Regulation (2017/1369). The best performing machine at the time of writing is placed in class C

Scenario	Sub-scenario	Comments
	Class A empty	The energy label is re-scaled according to the revised Energy Label Regulation (2017/1369). The best performing machine at the time of writing is placed in class B
	Without empty classes	Energy label is re-scaled according to the revised Energy Label Regulation (2017/1369). The best performing machine at the time of writing is placed in class A

7.6.3.2 BAU

The definition of the Business as Usual (BAU) scenario for washer dryers is based on the assumption that no changes on the current or additional regulation are implemented. The BAU scenario is only used for reference, as it is highly unlikely that nothing will change in the ecodesign and energy label. The same assumptions done for the model for washing machines related to the progress of the technology are assumed for washer dryers.

In this scenario, it is assumed that there are little additional energy efficiency improvements. As commented in section 2, most of the models for washer-dryers are classified as energy efficiency Class A or Class B. Thus, it can be considered that the energy label is losing its potential for making a differentiation among washer-dryers and that manufactures will have little incentive to go beyond the current energy label class A, except for advertising self-claims such as 20% more efficient than the A class. These claims will have similar consequences than those described in section 7.4.3.2 for washing machines. This top class could thus be further populated in the coming years even if no additional policy measures would be implemented. The estimated evolution of the sales distribution over the different classes in the BAU scenario is shown in Figure7.28.

7.6.3.3 Scenario 4: Standard modifications to bring it closer to real-life conditions.

The main target of scenario 4 is to analyse if a change in the standard for measurement will trigger an improvement of those programmes that are frequently used by the consumers. This scenario does not analyse the energy label as a policy tool, and it considers that the energy label remains unchanged.

Data on energy consumption of the programmes are based on the information provided by the stakeholders and the information provided by the survey 2015.

7.6.3.3.1 Scenario 4a: WD Split

This scenario keeps the current test standard conditions regarding the drying process. Scenario 4a differs from scenario BAU in the testing of the washing performance, as in the current standard test EN 50229:2015, the washing performance is tested under the standard cotton programme at 60C.

WD Split scenario assumes that for the calculation of the energy consumption and other performance parameters of the household washer dryers, the programmes selected for testing the washing machines are used to test the washing process and the current standard EN 50229:2015 is used to test the drying process.

The expected declared energy consumption will be slightly closer to the energy consumption of real-life. This improvement will not be significant as washing process only contributes to approximately one fourth of the overall energy consumption of a wash&dry cycle. Manufacturers are expected to further develop the drying process at the rated washing capacity (in lots), but do not make efforts in increasing the energy efficiency of neither the wash&drying cycles nor the washing process at the rated drying capacity.

This policy scenario would bring some savings compared to the BAU scenario if the standard washing programmes would be further technically optimised assuming that some of these technical innovations might also improve the efficiency of other programmes used.

Table 7.29: Summary of the WD SPLIT scenario

WD SPLIT scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
STANDARD PROGRAMME FOR WASHING	Alignment to the standard programme(s) of WM is not relevant for the scenario 'WD SPLIT' as wash and dry cycles are tested independently of each other.	---	---
STANDARD PROGRAMME FOR DRYING	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles, For machines without final humidity sensor, the drying can only be regulated by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the measurement standard).	1) It is a consumer-relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario, does not fully reflect real-life consumer conditions and behaviour sufficiently 3) More complicated test programme.
	Consumer information (e.g. in the user manual) about the optimal application of different drying programmes and their specific energy consumption	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and environmental friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	Standardised text may be complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	Options: The overall load to be dried is determined by the rated washing capacity of the WD. Split rated washing capacity into 2 equal shares. Split rated washing capacity into a) rated drying capacity of the WD plus b) the "rest" Mix of full load and partial loads with regard to the	Machines should be subject to a demanding test that rewards those better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)

WD SPLIT scenario	Possible sub-options	Expected benefits	Possible drawbacks and risks
	machine's drying capacity (e.g. 1/3 and 2/3) in a series of drying test cycles		
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers, especially if equipped with heat pump, where heat delivery is slower than with other heating technologies.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 'Standard dry programme' / arrow symbol No explicit indication at all	Alignment to WM	People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection, when the appliance allows it	Introduced already for dishwashers	Positive impact of a default selection (for DW) not yet analysed / proven; more difficult, as there are several standard programmes (1 or more for each washing and drying); consumers might easily overcome such default selection

7.6.3.3.2 Scenario 4b: WD Remove

This scenario also keeps the wash cycle at full rated capacity but t**he drying process would be taken as basis for testing the drying cycle**. This fact is closer to the real-life behavior because according to the EU consumer survey 2015 on washer-dryers, consumers often remove certain laundry items from the wash load.

This policy scenario would bring some savings to the BAU scenario if the standard washing programmes would be technically optimized and these innovations are transferred to other programmes. Additionally, manufacturers are expected to optimize the drying process at the rated drying capacity, as this consumption will represent around three fourths of the overall energy consumption

Table 7.30: Summary of the WD REMOVE scenario

WD REMOVE	Possible sub-options	Expected benefits	Possible drawbacks and risks
STANDARD PROGRAMME FOR WASHING	Alignment to the standard programme(s) of WM is not relevant for the scenario 'WD REMOVE' as wash and dry cycles are tested independently of each other.	---	---
STANDARD PROGRAMME FOR DRYING	4) Iron dry 5) Cupboard dry 6) Mix of both programmes in a series of test cycles For machines without final humidity sensor, the drying can only be regulated by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the measurement standard).	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.
	Consumer information (e.g. in the user manual) about the optimal application of different drying programmes and their specific energy consumption	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and environmentally friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	Standardised text may be complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated drying capacity of the WD. 2. Mix of full load and partial loads with regard to the machine's drying capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensuring a fair selection of laundry items to test in the drying process. Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.

WD REMOVE	Possible sub-options	Expected benefits	Possible drawbacks and risks
		dryers.	
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMM E INDICATION AND SELECTION	Programme indication on the display: 3) 'Standard dry programme' / arrow symbol 4) No explicit indication at all	2) Alignment to WM	2) People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection, when the appliance allows it	Alignment to DWs. Positive impact of a default selection has been proved for DWs	Difficult, as there are several standard programmes (1 or more for each washing and drying)

7.6.3.3.3 Scenario 4c: WD COMBI continuous

This scenario **uses a continuous wash&dry cycle at the rated wash&dry capacity**, which is usually lower than the rated capacity for washing only.

The policy scenario would bring savings to the BAU scenario due to the optimization of the wash&dry process as it is chosen by the consumers in approximately 33% of the cases (being the second mostly often selection after drying the laundry on the line). However, this policy scenario will not encourage the optimization of the washing process.

Table 7.31: Summary of the WD WD_COMBI continuous scenario

WD COMBI – Continuous	Possible sub-options	Expected benefits	Possible drawbacks and risks
STANDARD PROGRAMME FOR WASHING in the wash&dry cycle	Programme selection based on the final decision of a policy scenario for WM, i.e. one or more programmes (wash temperatures), probably combing full and partial loads	Could allow potential testing synergies with WM	The currently applied combination of different WM standard programmes with different load capacities (e.g. 40/60 ° cycles at full and partial loads) would be even more complex when adding the testing of drying cycles. Some information from the wash cycle would not be comparable/measurable with the wash&dry testing.
STANDARD PROGRAMME FOR DRYING in the wash&dry cycle	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles For machines without final humidity sensing, the drying time can only be selected by a timer	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and

WD COMBI – Continuous	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
	(time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the standard).	tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	behaviour sufficiently 3) More complicated test programme.
	Consumer information (e.g. in the user manual) about the optimum application of different drying programmes and their specific energy consumption	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and environmentally friendly use of the appliance There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	Standardised text may be complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated wash&dry capacity of the WD. 2) Mix of full load and partial loads with regard to the machine's wash&dry capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy-use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 1) 'Standard wash&dry programme' / arrow symbol 2) No explicit indication at all	2) Alignment to WM	2) People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one wash&drying programme included in the standard testing

WD COMBI – Continuous	Possible sub-options	Expected benefits	Possible drawbacks and risks
	Default programme selection (when possible) 1) Standard wash programme (aligned to WM) 2) Iron-dry for the drying programme 3) None	Introduced already for dishwashers. Positive impact of a default selection (for DW) has been proven. A default selection of the iron-dry programme for the wash&dry cycle could be an option to save energy compared to cupboard dry condition.	A default selection of a wash&dry standard programme when starting the WD seems not appropriate, as consumers often use their washer-dryer for washing the laundry only. Difficult, as there are several standard programmes (1 or more for each washing and drying). Consumers might easily overcome such default selection

7.6.3.3.4 Scenario 4d: WD COMBI interrupted

This scenario uses an **interrupted wash&dry cycle at the wash&dry rated capacity**. The machine stops washing before starting the drying cycle for approximately 30 min

The policy scenario keeps continuity with the current standard for measure and can be based on the IEC 62512 standard. The scenario is expected to provide additional energy savings if the wash&dry process is optimized by the manufacturers.

Table 7.32: Summary of the WD_COMBI continuous scenario

WD COMBI – Interrupted	Possible sub-options	Expected benefits	Possible drawbacks and risks
STANDARD PROGRAMME FOR WASHING in the wash&dry cycle	Programme selection based on the final decision of a policy scenario for WM, i.e. one or more programmes (wash temperatures), probably combing full and partial loads, see below.	Could allow potential testing synergies with WM. It would be possible to measure all parameters of interest for the wash cycle	The currently applied combination of different WM standard programmes with different load capacities (e.g. 40/60 ° cycles at full and partial loads) would be even more complex when adding the testing of drying cycles. Some information from the wash cycle could not be comparable with the wash&dry testing.
STANDARD PROGRAMME FOR DRYING in the wash&dry cycle	1) Iron dry 2) Cupboard dry 3) Mix of both programmes in a series of test cycles, cf. example below the For machines without final humidity sensing, the drying time can only be selected by a timer (time-controlled drying). For testing, this time to reach the final drying status needs to be found by pre-testing (as described in the standard).	1) It is a consumer relevant programme, as this is the right programme for articles to be ironed. It has shorter testing time and lower absolute energy consumption. 2) Business as usual – experience available. More accurate testing due to less tolerance error margins. 3) It reflects consumer behaviour. Used also in tests of consumer organisations	1) Detection of accurate final humidity is more challenging and depends on water composition. Higher tolerances, thus uncertainties in measuring the energy consumption may be the consequence. 2) Simplified scenario does not reflect consumer conditions and behaviour sufficiently 3) More complicated test programme.

WD COMBI – Interrupted	**Possible sub-options**	**Expected benefits**	**Possible drawbacks and risks**
	Consumer information (e.g. in the user manual) about the optimum application of different drying programmes and their specific energy consumption	Provision of information in a clear and homogeneous form can facilitate education of consumers on the most correct and environmentally friendly use of the appliance. There is still a potential for energy saving if consumers are more conscious about the energy consumption of different washing-drying practices.	Standardised text may be complicated when designed for all countries and languages
LOAD OF THE DRYING CYCLE	The overall load to be dried is determined by the rated wash&dry capacity of the WD. 1) Mix of full load and partial loads with regard to the machine's wash&dry capacity (e.g. 1/3 and 2/3) in a series of drying test cycles	Machines should be subject to a demanding test that rewards those better adapting energy-use to different loads, as small loads are typical of real-life user behaviour. Optimization only to half load should not suffice. As consumers do not always use the maximum rated capacity, it is preferable to also test reduced load situations of the dry cycle.	Ensure that the testing procedure does not become more complex (e.g. a max amount of laundry equivalent to 5 full load cycles)
TIME	Adding the programme time of the tested dry programme on the Energy label	Manufacturers may desist from increasing the time of the programme to an unacceptable extent if they see consumers pay attention to this and respond to the labelling. This is a parameter already reported for tumble dryers.	Uncertainty on the reaction from consumers when time has to be weighed against energy use. If consumers still pay most attention to the energy, shorter programmes may not be offered.
	Cap on the maximum programme time for the tested dry programmes, e.g. 3 hrs.	Restriction of the playing field to areas that are known to be acceptable for consumers. As a consequence the use of such programmes may increase	Manufacturers reduce their leeway. Most appliances will cluster on few classes, reducing the influence of the label on purchase
PROGRAMME INDICATION AND SELECTION	Programme indication on the display: 1) 'Standard dry programme' / arrow symbol 2) No explicit indication at all	2) Alignment to WM	2) People might not understand the underlying design of the programme and thus not choose it. No clear indication in case of more than one drying programme included in the standard testing
	Default programme selection (when possible) 1) Standard wash programme (aligned to WM) 2) Iron-dry for the	Introduced already for dishwashers. Positive impact of a default selection (for DW) has been proven. A default selection of the iron-dry programme for the wash&dry cycle could be an option to save energy compared	A default selection of a wash&dry standard programme when starting the WD seems not appropriate, as consumers often use their washer-dryer for washing the laundry only. Difficult, as there are several standard programmes (1 or

WD COMBI – Interrupted	Possible sub-options	Expected benefits	Possible drawbacks and risks
	drying programme 3) None	to cupboard dry condition.	more for each washing and drying).

7.6.3.4 Scenario 5: Energy label revision

The main objective of the scenario 5 is to analyse, if energy and water savings can be triggered by Ecodesign and Energy Label. This scenario 5 includes two sub-scenarios, Scenario 5a considers that only Ecodesign requirements are implemented while scenario 5b considers that the new Energy label framework is implemented.

At present **there are no Ecodesign requirements on washer-dryers**. New Ecodesign requirements can be proposed on several aspects of the washer-dryer performance as commented in section 7.6.3.1. Some of these proposals are minimum energy performance of the drying process, minimum energy performance of the wash&dry process, minimum washing performance or maximum water consumptions. The aim of these proposals is to ban entering into the EU market products with poor environmental performance.

The energy label framework regulation has been revised, including a re-scaling of the energy efficiency classes back to the A-G scale. This has been considered in this modelling. The scenario 5b assumes a differentiation in sales distribution of the future due to different aspects related to the implementation of the energy label regulation. Energy labelling is a mechanism to help consumers making an informed decision regarding energy consumption of the machine. This means that at the same time the energy label serves push manufacturers to offer better products in terms of energy efficiency.

The Figure7.28 shows the estimated sales distribution for the BAU scenario, this means, not assuming the changes of the revised energy label regulation.

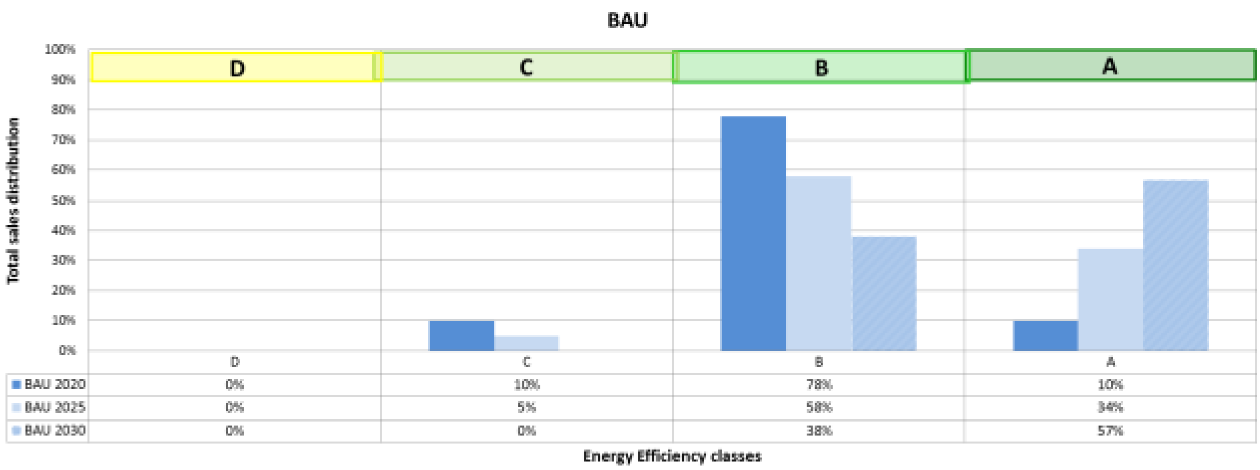


Figure7.28: Estimated sales distribution for the BAU scenario according to declared kWh/year consumption values. The current label classes are indicated

7.6.3.4.1 Scenario 5a: Only Ecodesign requirements

The main objective of scenario 5a is to analyse if new Ecodesign requirements can trigger energy and water savings in the washer-dryers. In this scenario, the option is explored to remove the energy label and introduce only the ecodesign requirements. Ecodesign requirements can be introduced on washing performance, the energy consumption of the wash&dry process or energy consumption on the drying energy consumption, as listed above. Additionally, new Ecodesign requirements for the washer-dryers on the washing process would be applied to be in line with the washing machine regulation.

Due to the removal of the energy label, it is assumed that the manufacturers would not be encouraged to improve the washer-dryers beyond the mandatory requirements, since there would be no differentiation based on energy efficiency. As discussed in previous models, manufacturers could focus on decreasing the costs or on other non-energy parameters such as durability, internet connections, etc. Some manufacturers, however, will keep improving their products and communicate their improved energy efficiency to the consumers

Scenario 5a1: Washing performance > 1,03 for the wash&dry process

A minimum washing performance of 1,03 (minimum value for washing machines) will ensure a reference for the washing process in the wash&dry process. This policy scenario might imply an increase of the energy consumption of the wash&dry process as more resources will be needed to ensure a higher washing performance. On the other hand, this requirement guarantees that consumers are satisfied with the performance of the wash&dry cycles and that this cycle will be optimized

Historical data of the washing performance of washer dryers have been collected and analysed from 2012 to 2015. Table 7.33shows the washing performance classification for the washer dryers during those years for an interrupted wash&dry process. As seen, all the appliances reached a washing performance class A in 2014 and kept this tendency in 2015.

Table 7.33: Historical data on washing performance of washer-dryers (CECED 2012, 2013, 2014 and 2015)

Washing performance	Class A	Class B
2012	94,5%	5,5%
2013	96,3%	3,7%
2014	100%	0%
2015	100%	0%

Estimating the impacts of this measure on the average washer-dryer unit and at the EU-28 level is difficult as no data have been collected regarding the washing performance of the appliances in a continuous wash&dry cycle. However, if it is considered that the washing performance of the interrupted wash&dry cycle can be similar to the washing performance of other cycles, it seems that this measure is feasible at this point in time without bringing significant impacts.

After analysing these data, no further model has been developed. The possible impacts are considered of no relevance for the washer-dryers industry

Scenario 5a2: Minimum energy efficiency index for the drying process

A minimum energy efficiency index (EEI) for the drying process will ensure that the energy consumption of this process is kept at a sensible value. Setting a minimum EEI for drying process will remove from the EU market the products that use energy excessively.

The introduction of the minimum EEI for drying process could be modelled in three steps or tiers starting in e.g. 2020 and including two additional ones by 2025 and 2030. Table 7.34 summarizes the assumptions proposed for this scenario 5a2. The figures indicated shall be treated as a first draft, and will be revised once additional testing is scheduled and data is collected.

Table 7.34: Proposed tiers for a minimum energy requirement on drying process

	Year	Energy consumption of the drying process
TIER 1	2020	0,70 kWh/kg drying
TIER 2	2025	0,65 kWh/kg drying
TIER 3	2030	0,60 kWh/kg drying

The proposed tier requirements are based on the observed evolution for the washer-dryers in the last years, as showed in Figure7.29. The energy consumption of the drying process was calculated from the declared values of the energy consumption for the wash&dry process at full washing capacity and the energy consumption of washing process only. The value obtained was divided by the washing rated capacity to get the energy consumption of the drying process per kg.

As shown in the Figure7.29., most of the models of washer-dryers have experienced a concentration around three energy consumption values for the drying process: 0,55 kWh/kg, 0,65 kWh/kg, and higher values.

Additionally, it is observed that the relative number of models of washer-dryers with an energy consumption of 0,55 kWh/kg or lower has been significantly increasing during these years. This market share has increased from less than 20% in 2012 to more than 25% in 2015. Equally remarkable is the change experienced in the models with an energy consumption of the drying process close to 0,65 kWh/kg (changing from approximately 20% in 2012 to 10% in 2015).

The tiers proposed have as main target the models with higher energy consumption than 0,65kWh/kg, whose market share in 2015 was approximately 10% of the total number of models. Due to the low percentage of products that would be affected, this requirement is considered as feasible. This model presents several similarities with the scenario 5b3, therefore the conclusions drawn in that scenario could be easily applied here.

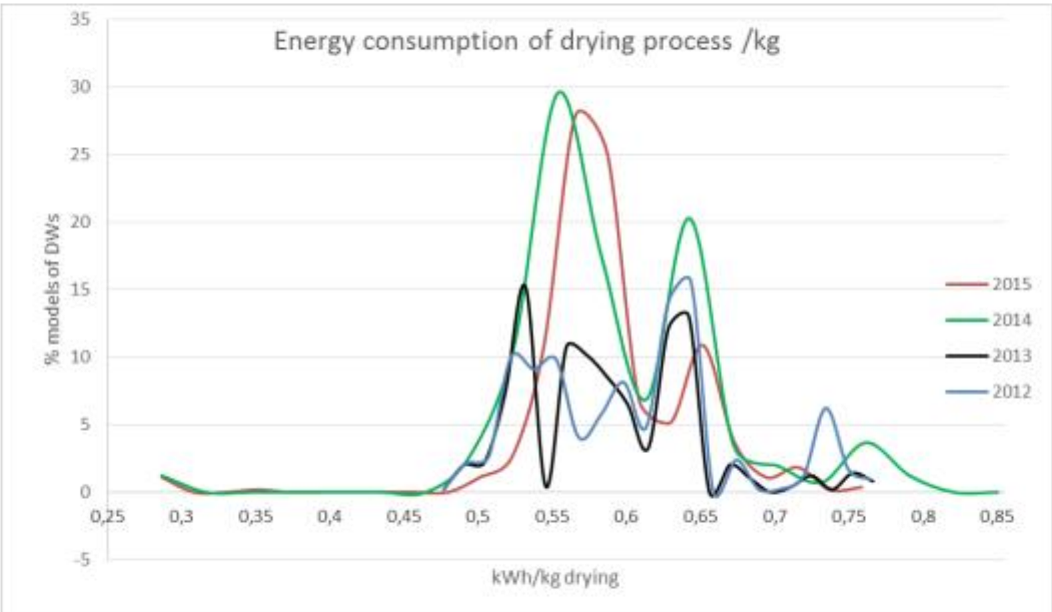


Figure7.29: Evolution of the energy consumption for the drying process in the last years. (CECED 2012-2015)

Scenario 5a3: Minimum energy efficiency index for the wash&drying process

A minimum energy efficiency index (EEI) for the wash&drying process will ensure that the energy consumption of this process is kept at a sensible value. It should be decided if this requirement affects the either the continuous wash&dry process, or the interrupted wash&dry process, or both processes. It seems reasonable to set this requirement only for those cycles that are tested under the revised standard for measure.

The introduction of the minimum EEI for the wash&drying was modelled in three steps, similar to the introduction of the minimum EEI for the drying process in scenario 5a2. The proposed requirements are summarized in Table 7.35. The figures indicated shall be treated as a first draft, and will be revised once additional testing is scheduled and data is collected.

Table 7.35: Proposed minimum energy performance for the wash&dry cycles

	Year	C (energy consumption of washing, spinning and drying)
TIER 1	2020	0,85 kWh/kg
TIER 2	2025	0,80 kWh/kg
TIER 3	2030	0,75 kWh/kg

The evolution of the energy consumption for the wash&dry cycle was analyzed to propose the tier by 2020, 2025 and 2030. As seen, there is an evolution towards appliances that are more energy efficient. Most of the appliances concentrate around energy consumption values of 0,65-0,70kWh/kg and 0,80kWh/kg.

The proposed tiers target the appliances that declared a value of the energy consumption for the wash&dry cycle higher than 0,80 kWh/kg. Considering the market shares of the washer-dryers in 2015, less than 10% of the market will be affected

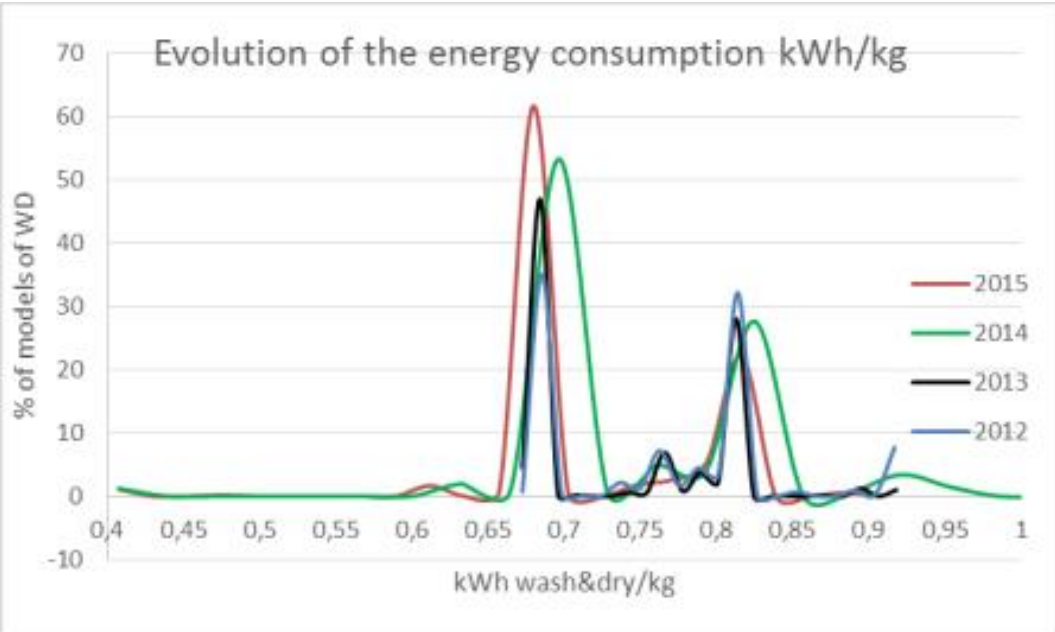


Figure7.30: Evolution of the energy consumption of the wash&dry cycle of the washer-dryer models

As shown in Figure7.29 and Figure7.30, the distribution of products based on the energy consumption of the wash&dry cycle and the estimated energy consumption of the drying process is pretty close. Therefore, the results from scenario 5a3 are considered to be similar to those that could have been obtained from scenario 5a2. Data have been collected on the energy consumption of the interrupted wash&dry process and not of the continuous wash&dry process.

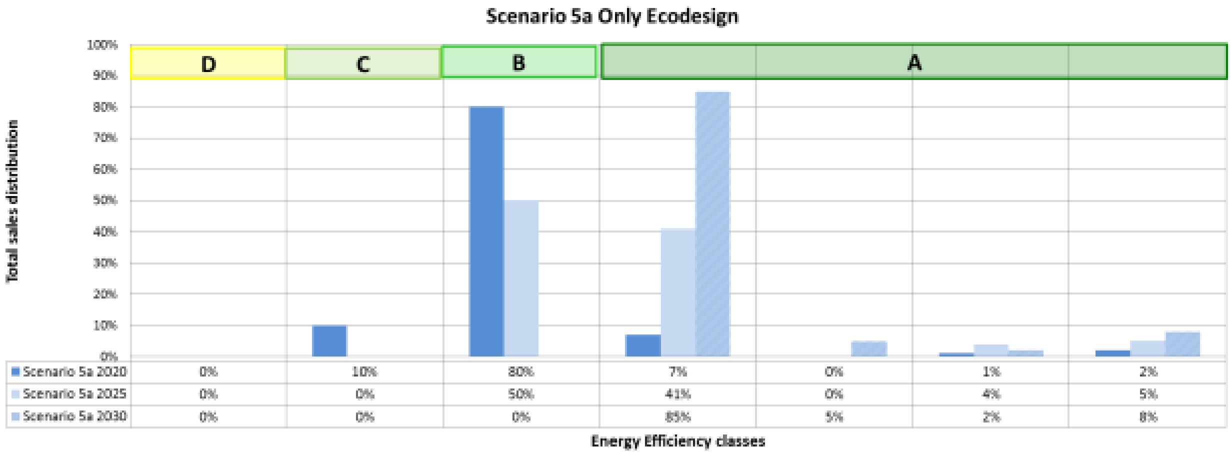


Figure7.31: Estimated sales distribution for the scenario 5a2 according to declared kWh/year consumption values.

Figure7.31 shows that the market will be split into two main groups: economical washer-dryers and washer-dryers, with very high energy efficiency. The rationale behind is that without an energy label, most of the manufacturers will focus their efforts on cost competition, and try to decrease the cost per unit. Some few manufacturers will decide to offer some models to compete in terms of quality, offering energy-efficient products.

7.6.3.4.2 Scenario 5b: Energy label

Energy labelling is a mechanism to help consumers make an informed decision regarding energy consumption of the machines. It serves to differentiate products and identify the best energy performing machines. This scenario considers the policy options discussed in section 7.2.3.4 regarding the implementation of new energy label classes.

In these scenarios, a new label class differentiation is created with a full scale of seven energy classes ranging from A to G. The three sub-scenarios differ mainly regarding the strictness of the requirements for the label. No additional ecodesign requirements are put forward. The addition of benefits or drawbacks due to the simultaneous implementation of changes in the ecodesign regulation and the energy label regulation are not assessed in this section.

The label class thresholds for the three sub-scenarios are shown in Table 7.36. These label class thresholds are also illustrated in Figure7.32 which also show the estimated washing machine sales evolution.

Table 7.36: Label class thresholds for the three sub-scenarios for a washer-dryer

Since 2011					Revision (kWh/year)						
Label class	kWh/a	kWh/kg	kWh/a	kWh/kg	Label class	Scenario 5b1		Scenario 5b2		Scenario 5b3	
	min	min	max	max		min	max	min	max	min	max
A			150	0.68	A		63		83		90
B	150	0.68	178	0.81	B	63	81	83	101	90	106

Since 2011					Revision (kWh/year)						
C	178	0.81	205	0.93	C	81	103	101	119	106	123
D	205	0.93	231	1.05	D	103	126	119	141	123	144
E	231	1.05	253	1.15	E	126	154	141	166	144	169
F	253	1.15	284	1.29	F	154	188	166	196	169	198
G	284	1.29			G	188	229	196	232	198	231

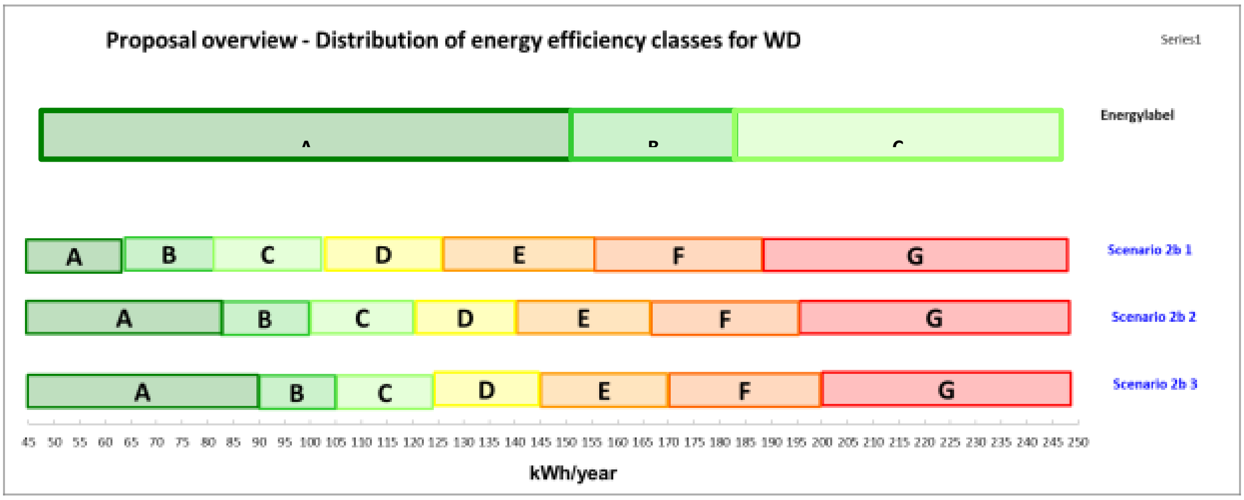


Figure7.32: Label class thresholds for the three sub-scenarios for washer-dryers

To better understand the implications of the different thresholds, it is important to know the EEI of the best available appliances currently on the market with are shown in Table 7.37.

Table 7.37: Annual energy consumption and EEI of the best available washing machines on the market (end 2015)

	Energy consumption of the wash&dry process (kWh/kg)
A -40% (heat pump washing machine)	0,41 kWh/kg (90kWh/year)
A	0,68 kwh/kg (150kWh/year)

Scenario 5b3 would allow the most energy-efficient appliances (consumption approx. 0,41 kWh/kg/cycle) in energy class A from the start of the revision. This would be in conflict to the prescriptions of the revised energy label regulation (2017/1369). The current sales figures for the most energy-efficient appliances are currently very low (estimated to be around 1,1% of the total sales).

At the moment of writing (Summer 2017), no appliances have been identified with a consumption< 0,41 kWh/ kg /cycle. This means that class A would initially be not populated for scenario 5b3). In this scenario, the manufacturers could feel that the energy label does not provide enough push to focus most of their efforts on developing the energy performance of the appliances. In this last situation most of the appliances are expected to remain in between classes E and G (currently classes A and B).

Scenario 5b2 shows an energy label class revision where the current best equipped washer-dryers falls in class B, leaving class A completely empty at the moment of writing. Given that this is the first revision of the energy label for washer-dryers, it can be assumed that stricter policy tools can foster further energy improvement and technological progress for washer-dryers. Washer-dryers that currently reach label class A would be classified in class E, current label class B washer-dryers would be classified in class F and all other washer-dryers would fall in class G.

Scenario 5b1 shows an energy label class distribution where the current best washer-dryer falls in class C, leaving class A and class B completely empty. The proposed classes A and B are seen to be positioned to allow for innovation and exploit possible improvement potentials. Keeping energy class B empty at the start of the revision would mean lower differentiation among the products and that most of the washer-dryers will be re-classified with label classes F and G. The producers of washer-dryers without very efficient technology may have fewer incentives or even be discouraged to improve their products regarding energy efficiency, and therefore this scenario shows the highest concentration of appliances in class E by 2030. It should be noted, however, that the average energy consumption of each of the label classes in this scenario is lower than in scenarios 5b2 and 5b3. Given the current knowledge, it would be very difficult to nearly impossible in this scenario 5b1 to reach a good label class without somehow expensive technologies such as heat pumps. Therefore, the class A is assumed that it will not be largely populated in 2030.

In general, the new re-classification of the energy label would re-classified the future washer-dryers with a lower energy efficiency class and it is expected that most of the appliances without the most energy-efficient technologies would achieve energy efficiency label class between E and D (but with different distributions of the market shares). This might result in the perception that machines do not perform well and that the producers of washer-dryers without the most energy-efficient technology had little incentive to improve their products regarding the energy efficiency and focused on other appliance aspects.

Evolution of the sale distribution for the scenarios 5b1, 5b2 and 5b3 is shown in the Figure7.33 to Figure7.35.

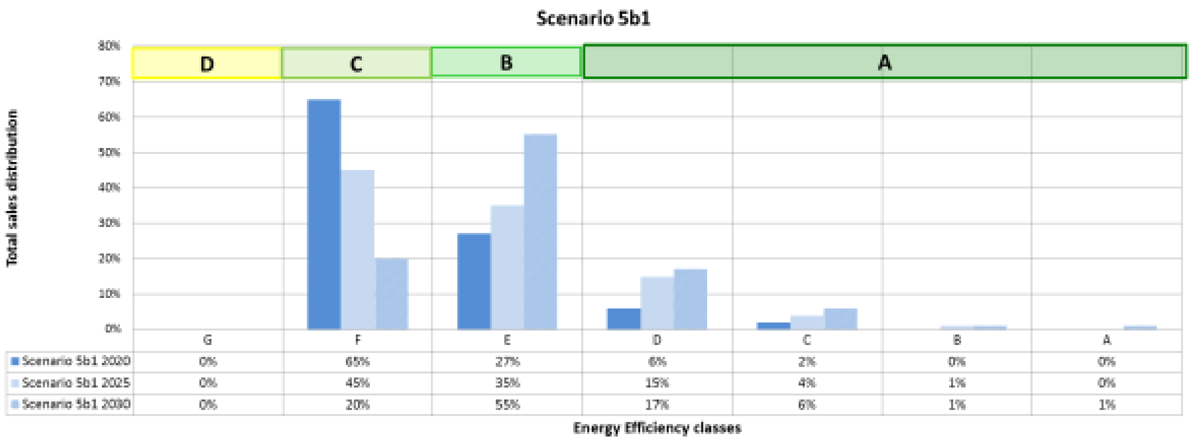


Figure7.33: Estimated sales distribution for the scenario 5b1 according to declared kWh/kg consumption values. The current label classes are indicated

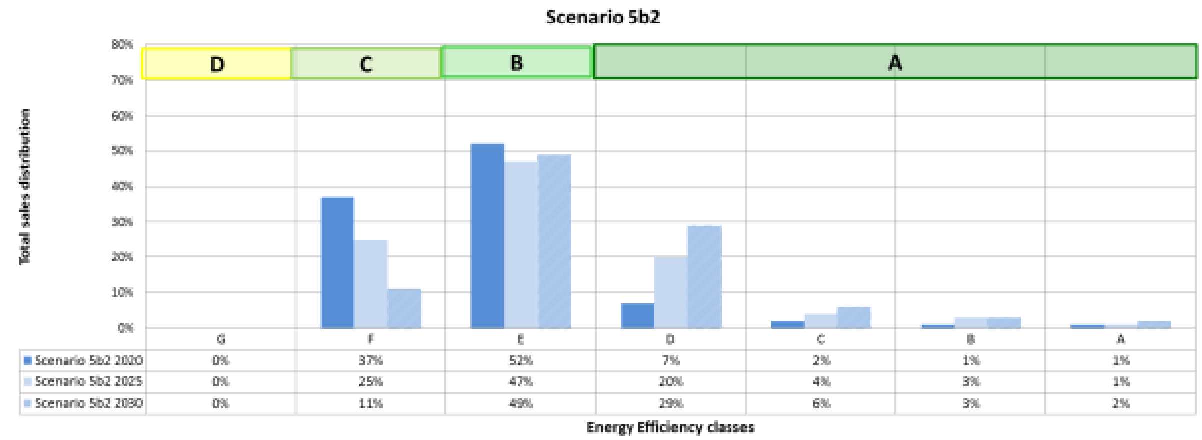


Figure7.34: Estimated sales distribution for the scenario 5b2 according to declared kWh/kg consumption values. The current label classes are indicated

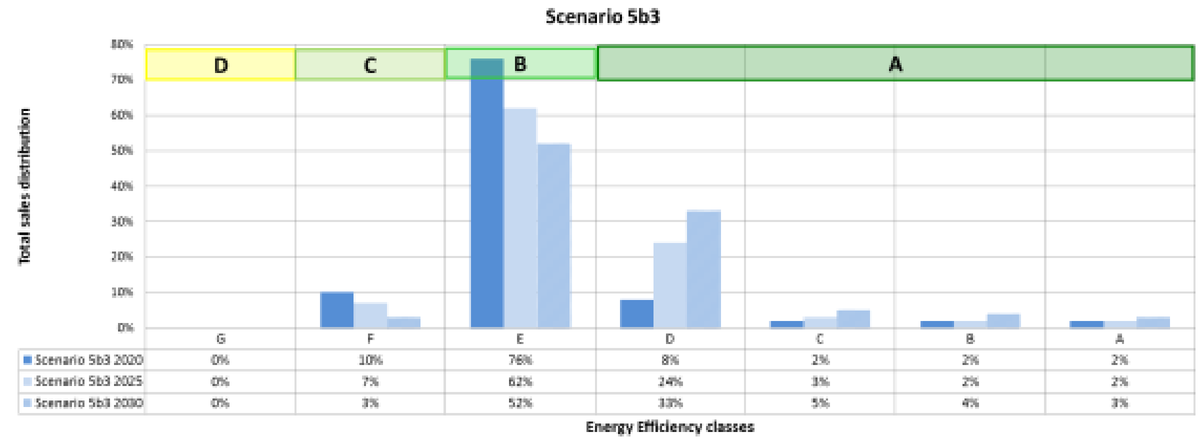


Figure7.35: Estimated sales distribution for the scenario 5b3 according to declared kWh/kg consumption values. The current label classes are indicated

7.6.3.4.3 Impacts on resources for scenarios 5a, 5b1, 5b2 and 5b3

The different scenarios act differently on the evolution of resource consumption (energy and water) in the EU 28. The effects of the different scenarios on energy and water consumption for the EU28 in the period 2015-2030 are shown in Figure7.36 and Figure7.37.

Figure7.36 and Figure7.37.show the average individual machine consumption of energy and water over the period 2015-2030, respectively. Note that in this case, scenario 5b1, the strictest one provides the best results. This observation is due to the assumption that the washer-dryers equipped with the most energy-efficient technologies will penetrate in the market faster than the other appliances due to the energy savings that this technology can bring. As shown in section 6.4.6 the simple payback time (SPP) of e.g. heat pump technology is smaller than the lifetime, indicating that the investment needed is recovered. Scenario 5a (only Ecodesign) results in less energy savings, that equal the BAU expected results in 2030. This indicates that the implementation of a revised energy label tool into the market has still potential to save resources in the coming years. The results of scenario 5a are mainly related to the assumption made in the distribution of the appliances split into two big groups over the different label classes (highly efficient machines and machines falling in the lower energy efficiency classes).

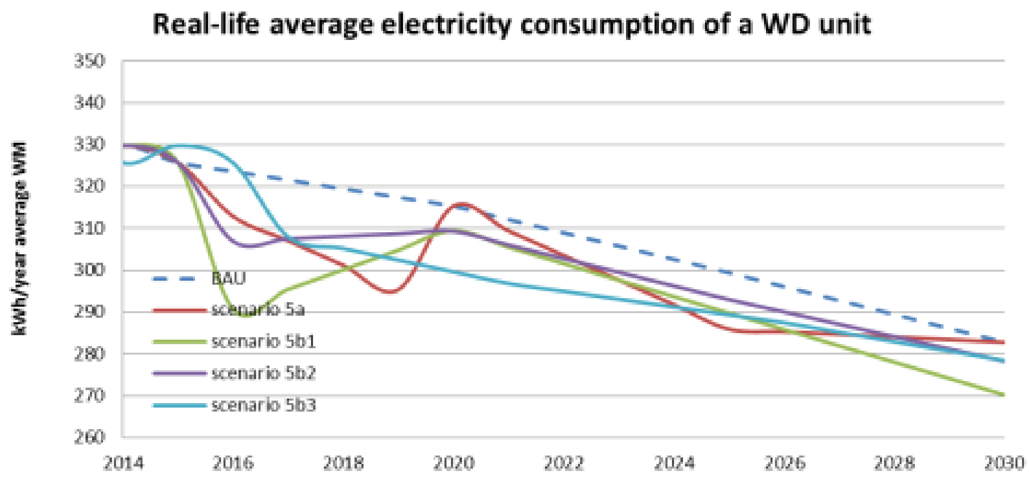


Figure7.36: Estimated annual real life average electricity consumption of a washer-dryer unit for scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

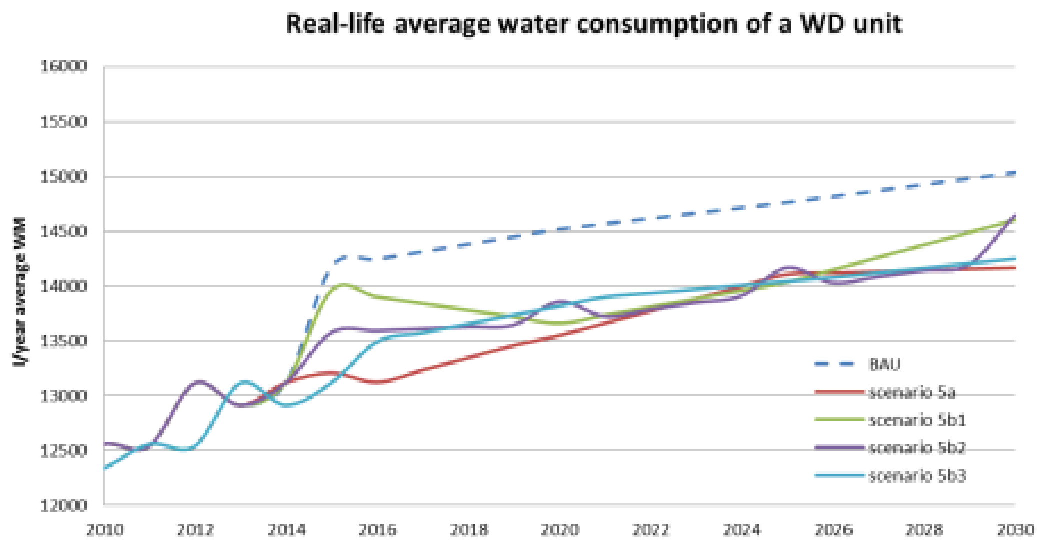


Figure7.37: Estimated annual real life average water consumption of a washer-dryer unit for scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

For all scenarios, the overall energy consumption of washer-dryers in the EU 28 decreases between 2015 and 2030. This is due to the decreases in the individual machines' consumption even if the market is expected to increase in the coming years. New machines replaced old machines of the stock increasing the energy efficiency of the overall stock.

From Figure7.38, can be seen that the maximum energy saving is expected for scenario 5b1 followed by scenario 5b2 with energy savings of 0.18 and 0.17 TWh/year in 2030, respectively. These values are about 7% and 6% of the washer-dryer energy consumption in the BAU scenario estimated in 2030. Maximum water saving of 7.6 million m^3 per year is expected in 2030 for scenario 5b1. This is around 4% of the water consumption expected in 2030 in the BAU scenario for washing machines in EU28.

The values for electricity and water consumption are provided in table form in Annex 8.9.10

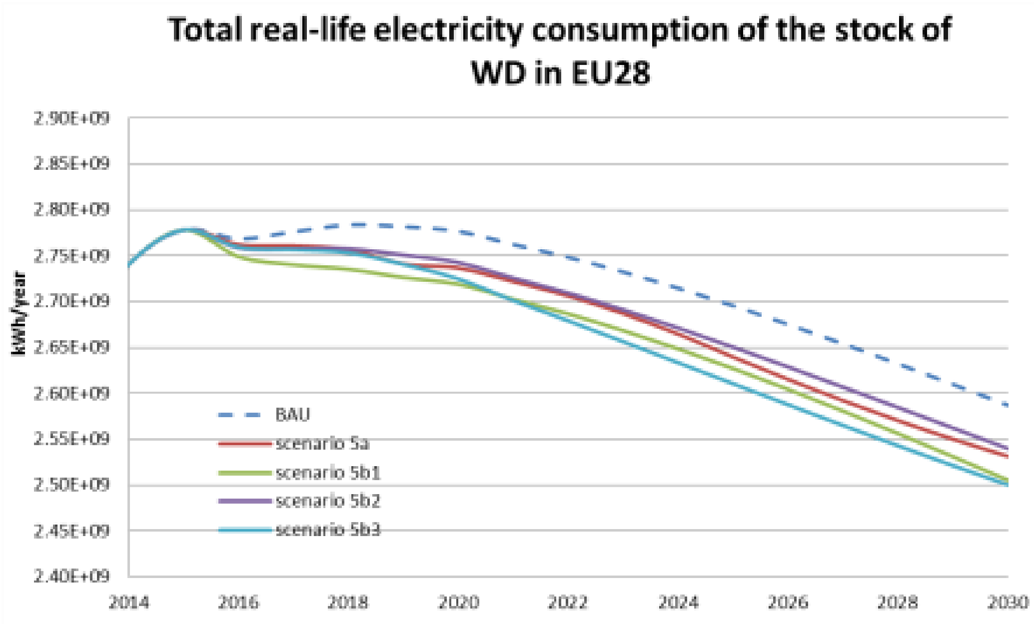


Figure7.38: Estimated annual real life electricity consumption of the stock of washer-dryer in the EU 28 for the scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

Impacts on GHG emissions and primary consumption for the scenarios 5a, 5b1, 5b2 and 5b3

The GHG emissions and the primary consumption are, as commented for the scenario 1, directly linked to the energy consumption. The environmental impact in terms of GHG emissions is illustrated in

The reduction of carbon emissions attributed to the electricity in the coming years is considered to be added to the lower electricity demand of the European washer-dryers machines shown in Figure7.38.

Figure7.39 shows a decrease of CO_{2eq} emissions in all scenarios. Scenarios 5b1 and 5b2 reach the lowest GHG emissions. The calculated values are provided in table form in annex 8.9.11

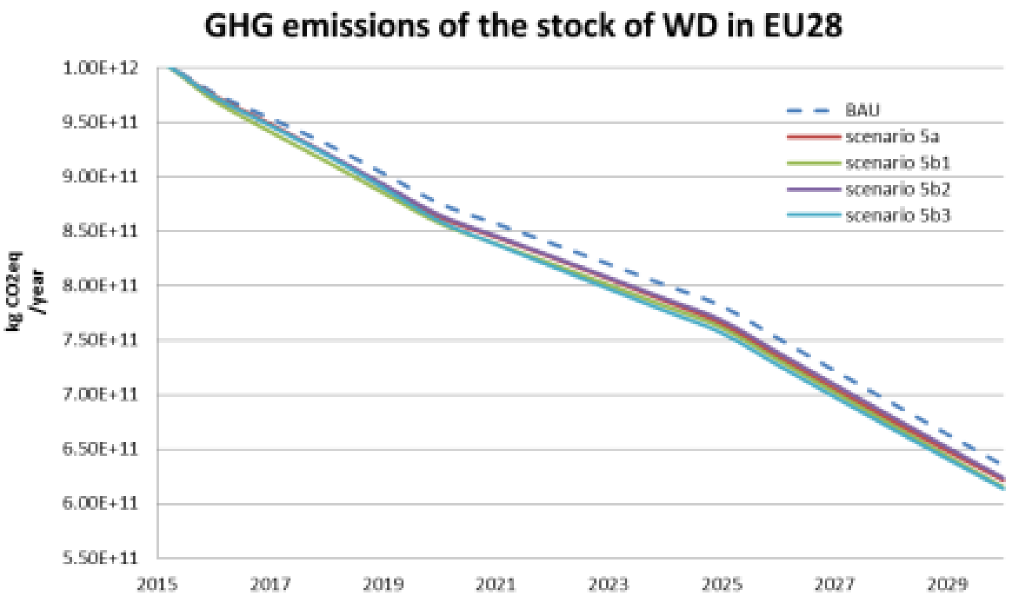


Figure7.39: Estimated annual CO_{2eq} emissions from the electricity use of the stock of washer-dryers in the EU 28 for the scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

Regarding the consumption of primary energy related to the electricity use of the washer-dryers at EU 28 level, it can be observed from Figure7.40that the total primary energy is expected to decrease in the coming years due to the effects of lower energy consumption of the washer-dryer stock and the forecasted decrease in the primary energy factor. The calculated values can be found in Annex 8.9.12.

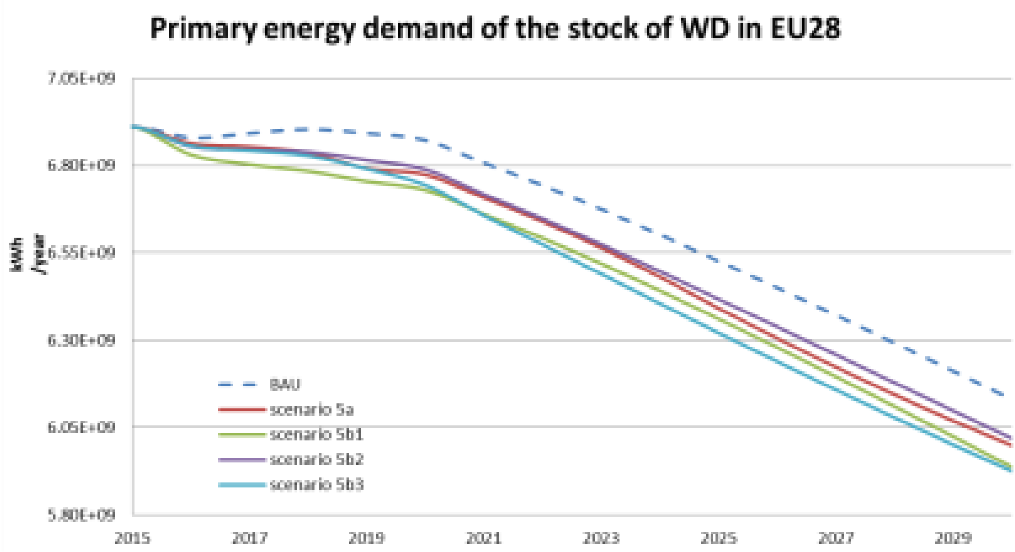


Figure7.40: Estimated primary energy consumption from electricity use of the stock of washer-dryer in the EU 28 for the scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

Impacts on the consumer expenditure and jobs for the scenarios 5a, 5b1, 5b2 and 5b3

The impact of the different scenarios on the consumer expenditure is shown in Figure7.41. The average unitary price (observed retail price) is shown inFigure7.42.

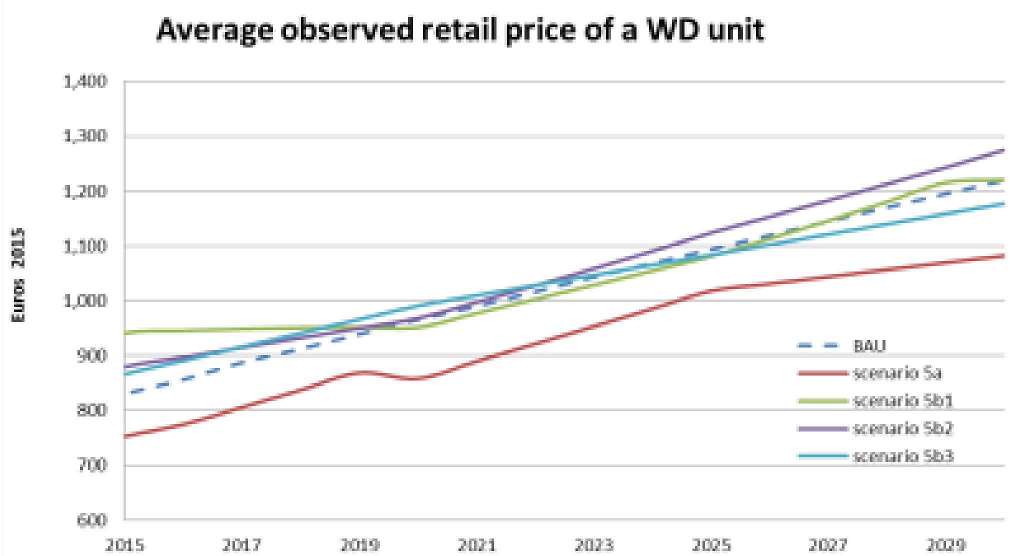


Figure7.41: Estimated average unitary observed retail price of washer-dryer in the EU 28 for the scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

Compared to the ORP in Figure7.41, the total consumer expenditure in Figure7.42 shows a similar trend. This is because in the coming years not only the purchase prices but also the energy and water prices are expected to increase. Repair and maintenance costs are the same in all scenarios, but purchase price, energy and water costs change due to the influence of the energy label.

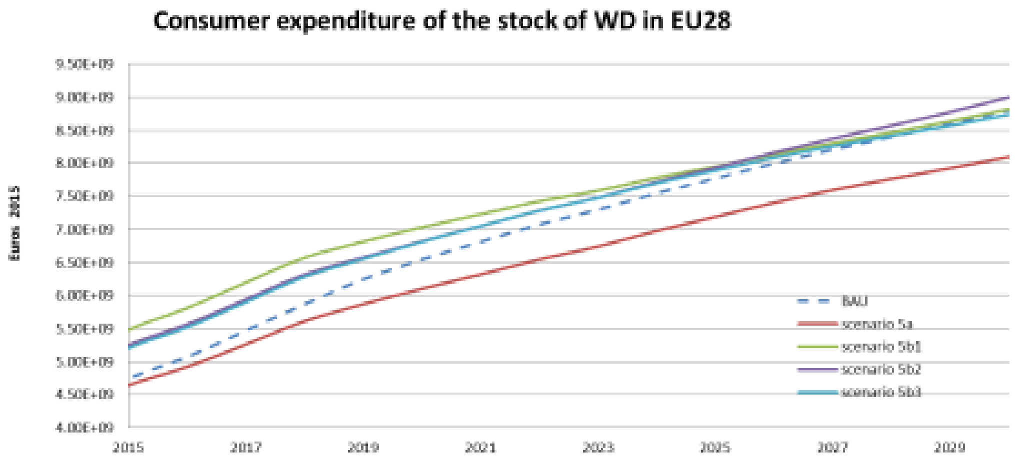


Figure7.42: Estimated consumer expenditure of the stock of washer dryers in the EU 28 for the scenarios BAU, scenario 5a, scenario 5b1, 5b2 and 5b3

7.6.3.4.4 Impacts on job creation for scenarios 5a, 5b1, 5b2 and 5b3

Finally, the impact in terms of expected job is considered. As explained in section 7.4.2.7 the job creation is estimated here on a very basic level, using the turnover and a ratio of 188000 euro/employee for the manufacturing industry and 60000 euro/employee for white good retailers. The turnover of the manufacturers and the white good retailers is calculated as the number of sold machines by the price at the manufacturer's door and the selling price, respectively (excluding VAT). The results are shown in Figure7.43 in 2030.

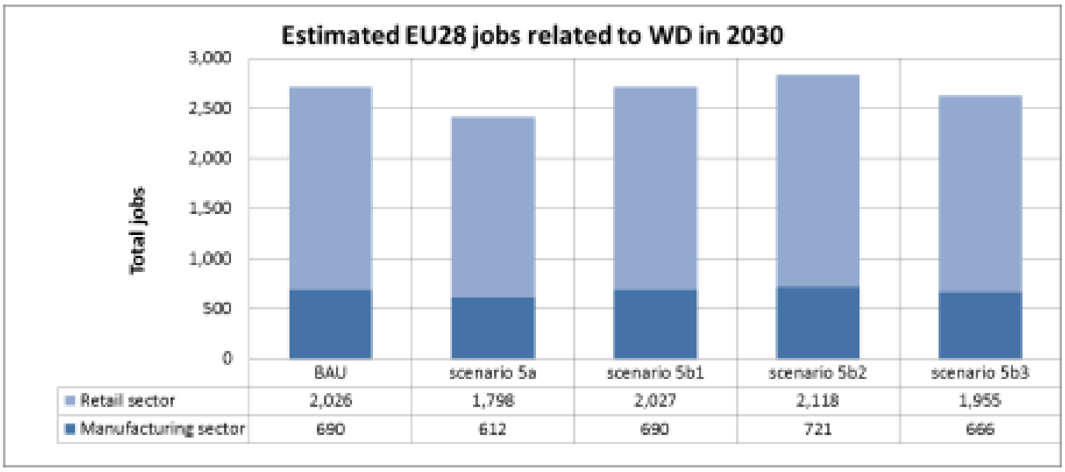


Figure7.43: Estimated number of jobs by 2030 in the EU washer-dryer sector

7.7 Summary of the scenarios for washer-dryers

The main outcomes of the ecodesign and energy label scenarios are summarized in Table 7.38.

Table 7.38: Summary of the outcomes of the scenarios BAU, 5a, 5b1, 5b2 and 5b3

Main impacts 2030			**energy label scenario**				
			BAU	**Scenario 5a**	**Scenario 5b1**	**Scenario 5b2**	**Scenario 5b3**
Environment							
	Electricity	TWh/a	2.59	2.53	2.40	2.45	2.50
	Energy	PJ/a	22.07	21.60	20.50	21.56	21.33
	GHG	Mt CO_2 eq/a	0.63	0.62	0.59	0.60	0.61
	Water (use phase)	Millions m^3/a	119.98	112.41	115.89	114.94	113.51
CONSUMER							
EU totals	Expenditure	€ bin./a*	8.11	8.10	9.16	9.31	8.74
	Purchase costs	€ bin./a	6.83	6.83	7.92	8.06	7.47
	Electricity costs	€ bin./a	0.55	0.54	0.51	0.52	0.53
	Water costs (use phase)	€ bin./a	0.03	0.02	0.02	0.02	0.02

	Consumables (detergents, etc.)	€ bin./a	0.33	0.33	0.33	0.33	0.33
	Maintenance costs	€ bin./a	0.38	0.38	0.38	0.38	0.38
Per product	Product price	€	1219.71	271.32	271.32	271.32	271.32
	Installation cost	€	0.00	1.00	2.00	3.00	4.00
	Energy costs	€/a	54.21	57.55	57.55	57.55	57.55
BUSINESS							
EU Turnover	Manufacturers	€ bin./a	0.26	0.23	0.27	0.28	0.25
	Retailers	€ bin./a	0.51	0.45	0.53	0.55	0.49
EMPLOYMENT							
Employment (job creation)	Industry EU (inclu OEM)	'000	689.78	611.98	726.93	754.43	665.68
	Retailers	'000	2026.22	1797.69	2135.35	2216.15	1955.43
	TOTAL	'000	2715.99	2409.67	2862.28	2970.58	2621.10

Scenario 5 assesses the benefits of implementing jointly Ecodesign and Energy label regulations as well as the re-scaling of the label. From the resource saving perspective, scenarios 5b1 and 5b2 achieve the largest savings, although these scenarios result in an increase of the overall consumer expenditure.

8. Annexes

8.1. Annex I – Examples of further EU Ecodesign regulations or Ecolabels with resource criteria implemented

The following EU Ecodesign Regulations or Ecolabels are not directly linked to the product groups household washing machines and washer-dryers, but might serve as examples of implemented resource and material efficiency criteria.

8.1.1. EU Ecodesign Regulation 1194/2012/EU on directional lamps, light emitting diode lamps and related equipment

The Ecodesign Regulation 1194/2012 sets specific functionality requirements which include different functionality parameters on the lifetime of lamps (European Commission 2012a):

- Lamp survival factor at 6,000 h (for LED lamps only). Lamp survival factor (LSF) means the defined fraction of the total number of lamps that continue to operate at a given time under defined conditions and switching frequency. Test procedure: The test shall end when the required number of hours is met, or when more than two lamps fail, whichever occurs first. Compliance: a maximum of two out of every 20 lamps in the test batch may fail before the required number of hours. Non-compliance: otherwise.
- Number of switching cycles before failure. Test procedure: The test shall end when the required number of switching cycles is reached, or when more than one out of every 20 lamps in the test batch have reached the end of their life, whichever occurs first. Compliance: at least 19 of every 20 lamps in the batch have no failure after the required number of switching cycles is reached. Non-compliance: otherwise.
- Premature failure rate which means when a lamp reaches the end of its life after a period in operation which is less than the rated life time stated in the technical documentation. Test procedure: The test shall end when the required number of hours is met, or when more than one lamp fails, whichever occurs first. Compliance: a maximum of one out of every 20 lamps in the test batch fails before the required number of hours. Non-compliance: otherwise.
- Rated lamp lifetime in hours at 50% lamp survival. 'Lamp lifetime' means the period of operating time after which the fraction of the total number of lamps which continue to operate corresponds to the lamp survival factor of the lamp under defined conditions and switching frequency. For LED lamps, lamp lifetime means the operating time between the start of their use and the moment when only 50% of the total number of lamps survive or when the average lumen maintenance of the batch falls below 70%, whichever occurs first
- Product information requirements to be visibly displayed to end-users prior to their purchase on the packaging and on free access websites: Nominal lifetime of the lamp in hours (no longer than the rated lifetime); number of switching cycles before premature failure

8.1.2. EU Ecodesign Regulation 666/2013/EU on vacuum cleaners

The Ecodesign Regulation on vacuum cleaners sets specific requirements on durability from 1 September 2017 (European Commission 2013a):

- Durability of the hose: The hose, if any, shall be durable so that it is still useable after 40,000 oscillations under strain. Measurement and test method: The hose shall be considered useable after 40,000 oscillations under strain if it is not visibly damaged after those oscillations. Strain shall be applied by means of a weight of 2.5 kg.
- Operational motor life-time: The operational motor lifetime shall be greater than or equal to 500 hours. Measurement and test method: The vacuum cleaner shall run with a half-loaded dust receptacle intermittently with periods of 14 minutes and 30 seconds on and 30 seconds off. Dust receptacle and filters shall be replaced at appropriate time intervals. The test may be discontinued after 500 hours and shall be discontinued after 600 hours. The total run-time shall be recorded and included in the technical documentation. Air flow, vacuum and input power shall be determined at appropriate intervals and values shall, along with the operational motor lifetime, be included in the technical documentation.

According to (Bundgaard et al. 2015), implementing these specific requirements on resource efficiency was enabled by the existence of measurement and test standards so that the requirements can be monitored when the product are put on the market.

Further, the Ecodesign Regulation vacuum cleaners sets information requirements on resource efficiency from 1 September 2017 (European Commission 2013a):

The technical documentation and a part for professionals of the free access websites of manufacturers, their authorised representatives, or importers shall contain the following elements:

- Information relevant for non-destructive disassembly for maintenance purpose, in particular in relation to the hose, suction, inlet, motor, casing and cable.
- Information relevant for dismantling, in particular in relation to the motor and any batteries, recycling, recovery and disposal at end-of-life.

8.1.3. Draft EU Ecodesign Regulation on electronic displays

At the end of 2014, a Consultation Forum meeting with regard to possible Ecodesign and Energy Labelling requirements for electronic displays has taken place. In this context, the European Commission provided draft proposals for the Ecodesign and Energy Label Regulations on electronic displays as well as related explanatory notes. The draft Ecodesign Regulation includes a comprehensive set of end-of-life requirements.

NOTE: The following information presented is taken from the documents that have been published so far and are still under discussion; thus they will be refined at a later project stage to take into account the latest versions of the documents available.

According to the explanatory notes of the possible Ecodesign and Energy Labelling requirements for electronic displays (European Commission 2014c),

> *"The proposed measure sets specific requirements for manufacturers to (1) disclose information relevant for disassembly, recycling and/or recovery at end-of-life, (2) mark plastic parts, (3) declare the recyclability rate of plastic parts, and (4) label for mercury and presence of brominated flame retardants (BFR).*

These requirements are devised to help recyclers to better comply with the WEEE Directive (2012/19/EU) by providing information relevant for the depollution, disassembling and/or shredding operations. These requirements are in line with the approach taken in the Ecodesign regulations that were adopted so far and with the Commission Communication "Towards a circular economy: a zero waste programme for Europe" aimed at establishing a common and coherent EU framework to promote the circular economy. The proposed requirements should result in marginal costs to manufacturers with possibly relevant cost reduction and improved efficiency for the recycling industry."

Following end-of-life requirements were proposed for electronic displays (European Commission 2014a):

- Design for recovery of electronic displays
- Marking of plastic parts of electronic displays
- Declaration of the recyclability index for plastic parts
- Mercury free logo
- Brominated fire retardants logo
- Documentation for recycling at end of life of displays

<u>Design for recovery of electronic displays</u>

Manufacturers shall ensure that electronic displays are designed so that the following four types of components (when present) can be dismantled:

- Printed circuit boards assembly (larger than 10 cm^2);
- Thin-film-transistor liquid-crystal display (larger than 100 cm^2);
- PMMA board;
- Mercury containing backlighting lamps;

This shall be ensured by:

- Documenting the sequence of dismantling operations needed to access the targeted components, including for each of these operations: type of operation, type and number of fastening technique(s) to be unlocked, and tool(s) required;
- Describing the design strategies / innovations implemented to facilitate the disassembly, recycling and/or recovery of the electronic display;
- Providing a video showing the dismantling operations and the indicative time needed to extract the targeted components.

<u>Marking of plastic parts of electronic displays</u>

1. Plastic parts larger than 25g, other than the Polymethyl Methacrylate Board (PMMA) and display optical plastics, shall be marked by specifying the type of plastic using the symbols as specified in EN 11469 and EN 1043, set between the marks “>” and “<”. The marking shall be legible and located in a visible position.

Exemptions are made in the following cases:

(i) Where the marking would impact on performance or functionality of the plastic part

(ii) Where marking is technically not possible due to the production methods; or

(iii) Where the marking could cause defect rates under quality inspection, leading to unnecessary wastage of materials

Each exemption shall be justified in the 'end-of-life report'.

2. Plastic parts larger than 25g, other than the PMMA board and display optical plastics, containing Brominated Fire Retardants (BFR) shall be marked in the following way:

(i) >x-FR-y<

where:

x= plastic polymer

FR = Fire Retardant

y= brominated fire retardant coding, according to EN 1043.

3. Plastic parts larger than 25g, other than the Polymethyl Methacrylate board (PMMA) and display optical plastics may include information related to the presence of fillers and fire retardants other than BFR in plastic parts. When the information is added voluntarily, this shall be presented in the following way:

(i) the presence of fillers as: 'x-y'

where:

x = plastic polymer

y = abbreviated term for the fillers.

(ii) the presence of fire retardant in plastic parts as: 'x-FR-y'

where:

x= plastic polymer

FR = Fire retardant

y= type of the fire retardant coding.

<u>Declaration of the recyclability index for plastic parts</u>

The recyclability index of plastic parts (heavier than 25 g) in electronic displays shall be determined in accordance with the following equation:

$$R_{plastic} = \frac{\sum (m_i \times RCR_i)}{m_{tot}} \times 100 \qquad [\%]$$

Where:

$R_{plastic}$ = recyclability index of plastic parts [%]

m_i = mass of the ith plastic part heavier than 25 g

m_{tot} = total mass of plastic parts heavier than 25 g

RCR_i = recyclability rate of the ith plastic part heavier than 25 g [%] as specified in the table.

Plastic parts lighter than 25 g, Printed Circuit Boards (PCB), wiring and speakers are excluded from the calculation.

The manufacturer shall declare in the instruction booklet for users the value of the recyclability index of plastic parts (heavier than 25 g) in the electronic display. The manufacturer shall illustrate in the 'end-of-life report' the calculation of the recyclability index for plastic parts ($R_{plastic}$) based on some generic default values set for assessing the recyclability rate of plastics (RCR_i).

Table 8.1: Recyclability rate of plastics (RCR_i); source: (European Commission 2014a)

Material	Recyclability rate
Acrylonitrile Butadiene Styrene (ABS)	94%
Acrylonitrile Butadiene Styrene (ABS) with any additives	94%
High impact polystyrene (HIPS)	94%
High impact polystyrene (HIPS) with any additive	94%
Polyamide (PA)	94%
Polycarbonate (PC)	94%
Polycarbonate/ Acrylonitrile Butadiene Styrene (PC-ABS)	94%
Polycarbonate/Acrylonitrile Butadiene Styrene (PC-ABS) with any additives	94%
Polymethyl methacrylate (PMMA)	94%
Polypropylene (PP)	94%
Polypropylene (PP) with natural fibres	0%
Polypropylene (PP) with other additive	94%
Co-injected plastics	0%
Other plastics	0%

If the manufacturer has evidence that the recyclability rate is actually higher (e.g. based on tests) then the manufacturer can use the determined recyclability rate.

Mercury free logo

Electronic displays shall be labelled with the "Mercury inside" or the "Mercury free" logo. The logo shall be immediately and clearly visible on the back of the electronic display without the removal of a cover. The logo shall be in the form of the following graphic.

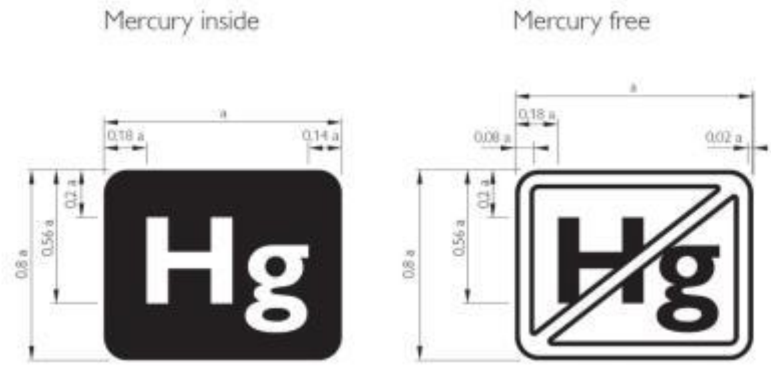


Figure 8.1: Mercury free logo as proposed in the draft Ecodesign Regulationfor displays; source: (European Commission 2014a)

The dimension of “a” shall be greater than 9 mm and the typeface to be used is ‘Gill Sans serif’. The logo shall be visible, durable, legible and indelible.

Brominated fire retardants logo

Electronic displays having plastic parts larger than 25g (other than PMMA board and display optical plastics) containing Brominated Fire Retardants (BFR) shall be labelled with the "BFR plastics inside" logo. Electronic displays with plastic parts larger than 25g (other than PMMA board and display optical plastics) not containing BFR shall be labelled with the “BFR-free plastics" logo.

The logo shall be immediately and clearly visible on the back of the electronic display without the removal of a cover. The logo shall be in the form of the following graphic.

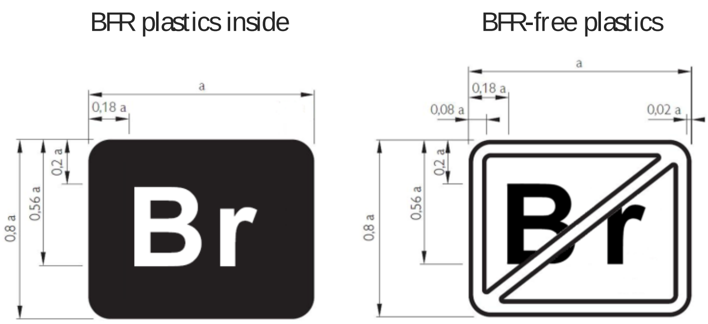


Figure 8.2: Brominated fire retardants logo as proposed in the draft Ecodesign Regulationfor displays; source: (European Commission 2014a)

The dimension of “a” shall be greater than 9 mm and the typeface to be used is ‘Gill Sans serif’. The logo shall be visible, durable, legible and indelible.

Documentation for recycling at end of life of displays

From 24 months after the publication of the Regulation in the Official Journal of the European Union, manufacturers, and/or importers in the European Union shall provide the following product information on every equivalent electronic display model in a freely accessible websites and kept available for 10 years from the day of the last model placed on the market:

- An 'end-of-life report' containing information relevant for disassembly, recycling and/or recovery at end-of-life. The report shall include at least the following:
  - the exploded diagram of the product labelling the targeted components defined, when present, together with a documentation of the sequence of the dismantling operations needed to access to these components. Each of these operations shall be described in terms of type of operation (e.g. unscrewing, removing, levering, positioning), type and number of fastening techniques to be unlocked (e.g. M3 screw, snap-fit) and tool(s) required;
  - the description of the design strategies / innovations implemented to facilitate disassembly, recycling and/or recovery of the displays;
  - the rationale for each exemption, if some plastic parts are not marked as set out;
  - the declared value of the recyclability index for plastic parts larger than 25 g, accompanied by a description of the calculations (including at least: the list of the plastic parts; their material composition; the considered recyclability rates for each plastic type, plus a justification in case the values differ from the ones presented.
- A video showing the dismantling operations and the indicative time needed to extract the four types of targeted components, when present.

The value of the 'recyclability index of plastic parts' in the electronic display shall be declared in the instruction booklet for users.

The following generic measurement methods were proposed, accompanied with a standardization request of the European Commission to the European standardization organisations (ESOs) to develop generic methodologies related to material efficiency, such as durability, reusability, recyclability and recoverability (cf. section 1.3.3.2):

- Extraction of key components: Measurements of the extraction time of key components shall be made using a reliable, accurate and reproducible measurement procedure, which takes into account the generally recognised state of the art measurement methods, including the provision by manufacturers (through e.g. DVD, website) of the information necessary for the measurement, such as: technical documentation illustrating the dismantling sequence and a supporting video-recording that shows the compliance to the requirement.
- Measurements of marking of plastic parts of electronic displays: Measurements of marking of plastic shall be made using a reliable, accurate and reproducible measurement procedure, which takes into account the generally recognised state of the art measurement methods.
- Minimum recyclability rate index for certain plastic parts: Measurements of minimum recyclability rate index shall be made using harmonised standards, the reference numbers of which have been published in the Official Journal of the European Union, or using other reliable, accurate and reproducible methods which take into account the generally recognised state of the art, and produce results deemed to be of low uncertainty.
- Mercury free logo: Measurements and checks of backlighting systems of electronic displays for mercury content shall be made using harmonised standards, the reference numbers of which have been published in the Official Journal of the European Union, or using other reliable, accurate and reproducible methods which

take into account the generally recognised state of the art, and produce results deemed to be of low uncertainty.

8.1.4. Review of Regulation 327/2011 with regard to ecodesign requirements for fans

Currently, the Ecodesign Regulation 327/2011 with regard to ecodesign requirements for fans is under revision. The working document presented to stakeholders relating to a meeting of the Ecodesign Consultation Forum on the review of the Regulation 327/2011 on fans on 30 April 2015 includes information requirements for the use of permanent magnet motors for fans:

- Manufacturers shall indicate the total weight per fan of the permanent magnets, if any, used in the motor, in kg with 2 digit precision.
- To the knowledge of the authors of that preparatory study, this is the first and only regulation which implements marking criteria for permanent magnets and might be a model for other regulations.

The related explanatory notes further explain that the use of Rare Earth Elements (REE) in Electronically Commutating (EC) motors which are used e.g. in fans are expected to be become a noticeable part of the waste stream. Most types contain permanent magnets with on average 18% Neodymium and smaller fractions of other REE. As these REE are regarded as 'critical raw materials' due to their ever increasing prices and dependence on supply from a single country it may be useful to indicated the weight of the magnets on the nameplate of the fan.

Discussions at the Consultation Forum meeting for fans, however, proposed to change the requirement into information about the type of rare earths the motor is composed of rather than the weight of the permanent magnets.

8.1.5. EU: Draft Commission Decision establishing the criteria for the award of the EU Ecolabel for personal, notebook and tablet computers

Currently, the EU Ecolabel criteria for "Personal, notebook and tablet computers" are under revision with the final draft of the EU Ecolabel criteria published to be voted in the Regulatory Committee on 17 April 2015.

The criteria include rather detailed requirements on the product lifetime extension (such as durability testing for portable computers, rechargeable battery quality and lifetime, data storage drive reliability and protection, as well as upgradeability and repairability). Further, the requirements on design, material selection and end-of-life management (material selection and compatibility with recycling as well as design for dismantling and recycling) have been updated and detailed. Finally, a new criterion on sourcing of 'conflict-free' minerals has been introduced.

Although the product categories of personal, notebook and tablet computers are not directly comparable to large household appliances, this approach shall be listed as most current example for defining durability and end-of-life criteria which might be partly applicable also to other electrical and electronic equipment.

In the following, the proposed criteria are listed detailed (European Commission 2015b):

Criteria on product lifetime extension of personal, notebook and tablet computers

- Durability testing of portable computers (mainly based on test procedures of IEC 60068)
  - Mandatory durability test specification for notebook computers:
  - Resistance to shock
  - Resistance to vibration
  - Accidental drop
  - Additional durability test specifications for notebook computers
  - Temperature stress
  - Screen resilience
  - Water spill ingress
  - Keyboard lifespan
  - Screen hinge lifespan (Specification: The screen shall be fully opened and then closed 20,000 times. Functional requirement: The screen shall then be inspected for any loss of stability and hinge integrity.)
  - Mandatory durability test specification for tablet and two-in-one notebook computers
  - Accidential drop
  - Screen resilience
- Rechargeable battery quality and lifetime (not relevant for large household appliances)
- Data storage drive reliability and protection (not relevant for large household appliances)
- Upgradeability and Repairability: For the purpose of upgrading older components or undertaking repairs and replacements of worn out components or parts, the following criteria shall be fulfilled:
  - <u>Design for upgrade and repair</u>: The following components of computers shall be easily accessible and exchangeable by the use of universal tools (i.e. widely used commercially available tools such as a screwdriver, spatula, plier, or tweezers):
  - Data storage (HDD, SSD or eMMC),
  - Memory (RAM),
  - Screen assembly and LCD backlight units (where integrated),
  - Keyboard and track pad (where used)
  - <u>Rechargeable battery replacement</u>: The rechargeable battery pack shall be easy to extract by one person (either a non-professional user or a professional repair service provider) according to the steps defined below. Rechargeable batteries shall not be glued or soldered into a product and there shall be no metal tapes, adhesive strips or cables that prevent access

in order to extract the battery. In addition, the following requirements and definitions of the ease of extraction shall apply:

- For notebooks and portable all-in-one computers it shall be possible to extract the rechargeable battery manually without tools;
- For sub-notebooks it shall be possible to extract the rechargeable battery in a maximum of three steps using a screwdriver;
- For tablets and two-in-one notebooks it shall be possible to extract the rechargeable battery in a maximum of four steps using a screwdriver and spudger.
- Simple instructions on how the rechargeable battery packs are to be removed shall be marked on the base cover of the product or provided in the user instructions.
- <u>Repair manual</u>: The applicant shall provide clear disassembly and repair instructions (e.g. hard or electronic copy, video) to enable a non-destructive disassembly of products for the purpose of replacing key components or parts for upgrades or repairs. This shall be made publicly available or by entering the products unique serial number on a webpage. Additionally, a diagram shall be provided on the inside of the casing of stationary computers showing the location of the components listed above can be accessed and exchanged. For portable computers a diagram showing the location of the battery, data storage drives and memory shall be made available in pre-installed user instructions and via the manufacturer's website for a period of at least five years.
- <u>Repair Service / Information</u>: Information should be included in the user instructions or on the manufacturer's website to let the user know where to go to obtain professional repairs and servicing of the computer, including contact details. During the guarantee period referred to above this may be limited to the applicant's Authorised Service Providers.
- <u>Availability of spare parts</u>: The applicant shall ensure that original or backwardly compatible spare parts, including rechargeable batteries (if applicable), are publicly available for at least five years following the end of production for the model.
- <u>Commercial Guarantee</u>: The applicant shall provide at no additional cost a minimum of a three year guarantee effective from purchase of the product during which time they shall ensure the goods are in conformity with the contract of sale. This guarantee shall include a service agreement with a pick-up and return option for the consumer. This guarantee shall be provided without prejudice to the legal obligations of the manufacturer and seller under national law.

Criteria on design, material selection and end-of-life management of personal, notebook and tablet computers

- Material selection and recyclability
  - <u>Improving the recyclability of plastic casings, enclosures and bezels</u>: Parts shall not contain molded-in or glued-on metal inserts unless they can be removed with commonly available tools. Disassembly instructions shall

show how to remove them; for parts with a weight greater than 25 grams for tablet computers and 100 grams for all other computers, the following treatments and additives shall not result in recycled resin with a >25% reduction in the notched izod impact when tested according to ISO 180:

- Paints and coatings
- Flame retardants and their synergists
- Existing test results for recycled resin shall be accepted provided that the recycled resin is derived from the same input material as described above.
- Material information to facilitate recycling: Plastic parts with a mass greater than 25 grams for tablet computers and 100 grams for all other computers shall be marked in accordance with ISO 11469 and ISO 1043, sections 1-4. The markings shall be large enough and located in a visible position in order to be easily identified. Exemptions are made in the following cases:
- Printed circuit boards, Polymethyl Methacrylate Board (PMMA) and display optical plastics forming part of display units;
- Where the marking would impact on the performance or functionality of the plastic part;
- Where the marking is technically not possible due to the production method; or
- Where the marking causes defect rates under quality inspection, leading to an avoidable wastage of materials.
- Where parts cannot be marked because there is not enough appropriate surface area available for the marking to be of a legible size to be identified by a recycling operator.
- Minimum recycled plastic content: The product shall contain on average a minimum 10% content post-consumer recycled plastic measured as a percentage of the total plastic (by weight) in the product excluding Printed Wiring Boards and display optical plastics. Where the recycled content is greater than 25% a declaration may be made in the text box accompanying the Ecolabel. Tablets, subnotebooks, two-in-one notebooks and products with a metal casing are exempt from this sub-criterion.

- Design for dismantling and recycling:
  For recycling purposes computers shall be designed so that target components and parts can be easily extracted from the product. A disassembly test shall be carried out according to the test procedure in Appendix 1 to the Decision. The test shall record the number of steps required and the associated tools and actions required to extract the target components and parts identified under the following points.
  - The following target components and parts, as applicable to the product, shall be extracted during the disassembly test:
  - All products: Printed Wiring Boards relating to computing functions >10 cm^2
  - Stationary computer products: Internal Power Supply Unit; HDD drives
  - Portable computer products: Rechargeable battery

   - Displays (where integrated into the product enclosure): Printed Circuit Boards >10 cm^2; Thin Film Transistor unit and film conductors in display units >100 cm^2; LED backlight units
   - At least two of the following target components and parts, selected as applicable to the product, shall also be extracted during the test, following-on in the test from those above:
   - HDD drive (portable products)
   - Optical drives (where included)
   - Printed circuit boards ≤ 10 cm^2 and > 5 cm^2
   - Speaker units (notebooks, integrated desktops and portable all-in-one computers)
   - Polymethyl Methacrylate (PMMA) film light guide (where the screen size is >100 cm^2)

The test procedure, i.e. protocol for a product disassembly test, inter alia specifies following aspects:

- Operating conditions for the extraction:
   - Personnel: The test shall be carried out by one person.
   - Tools for extraction: The extraction operations shall be performed using manual or power-driven standard commercially available tools (i.e. pliers, screw-drivers, cutters and hammers as defined by ISO 5742, ISO 1174, ISO 15601).
   - Extraction sequence: The extraction sequence shall be documented and, where the test is to be carried out by a third party, information provided to those carrying out the extraction.
- Recording of the test conditions and steps
   - Documentation of steps: The individual steps in the extraction sequence shall be documented and the tools associated with each step shall be specified.
   - Recording media: Photos shall be taken and a video recorded of the extraction of the components. The video and photos shall enable clear identification of the steps in the extraction sequence.

Criteria on sourcing of 'conflict-free' minerals

The applicant shall support the responsible sourcing of tin, tantalum, tungsten and their ores and gold from conflict-affected and high-risk areas by:

- Conducting due diligence in line with the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas, and
- Promoting responsible mineral production and trade for the identified minerals used in components of the product in accordance with OECD guidance within conflict-affected and high-risk areas.

8.2. Stakeholder discussions and feedback during the course of the study

The following issues represent the discussions with stakeholders at the first Technical Working Group Meeting (Sevilla, 24 June 2015) and subsequent written feedback with regard to the draft interim report including Tasks 1-4.

8.2.1. Energy efficiency and performance

8.2.1.1. Energy efficiency testing in the most commonly used programmes

Sections 1 and 3 provide evidence that the standard cotton programmes are currently not always chosen by consumers, because of their long duration and in some cases also for not reaching the indicated temperatures of 60 °C or 40 ºC. Additionally, some stakeholders indicate that the standard programmes are not always easy to find and select in the appliances, and that the standard programme indicator (an empty arrow) might not be well understood by all consumers. The ambition of the ecodesign and energy label Regulations shall be that the programmes which the consumer select most often to wash normally soiled clothes, and thus result in the largest energy consumption in the EU annually, should be the programmes tested for Ecodesign and Energy Labelling. The most used programmes are at present "normal" washing cotton loads at 40 °C and 60 °C, with a trend towards a lower temperature range (20-40 °C) enabled by the development of enzyme-based detergents.

In the current Regulation, there is a requirement to define a "standard cotton programme". This has resulted in a split between standard and non-standard cotton programmes for 40 and 60 °C. While some consumers choose the standard programmes, others do not (cf. chapter 3), resulting in an overall higher energy use in the EU than if there were only one 60 °C and one 40 °C programme per machine. One option to solve this might be to go back to what was requested in mandate M/458/EN (2010) ('European Commission Mandate to CEN, CENELEC and ETSI for Standardisation in the field of household washing machines'): *"to ensure that the prospective harmonised standard(s) includes a procedure that avoids an appliance being programmed to recognise the test cycles, and reacting specifically to them*". This might ensure that for programme testing only the cotton programme for normally soiled load will be used. Additionally, when the appliance has default programme selection, it might be requested that the programme tested (40 °C/60 °C) is selected by default by the appliance when the machine is switched on.

Stakeholders asked on their opinion about eliminating the need of an additional "standard cotton programmes", and devising a mechanism for testing the most frequently used programmes for cotton loads at 40 °C and 60 °C replied that the forthcoming ecodesign criteria should be set based on the market reality of what programmes are used but also, they should be established based on how we would like the market to evolve with the view to further shrink the environmental footprint linked to the washing machine use.

For example, one stakeholder is very much promoting that adding a 30° cycle as part of the default selection programme would be a strong sign into the direction of using overall lower wash temperature programmes. The 60 °C cotton full programme should not be skipped (for hygiene reasons), but a 30 °C full programme should be added.

One stakeholder suggested to work with a "single, standard load size" as opposed to the current testing of multiple load/temperature combinations (maximal load at 60 °C; half load at 40 °C and 60 °C), as this would make the comparison of relative efficiency easier for consumers. Testing at maximum ('Rated Capacity') could still form part of the testing scheme.

Another stakeholder undelined the need of having different programmes with the same temperature to meet the different level of soiling with different programme durations. However, he proposes to do the standard testing with the cotton programme for normally soiled textiles labelled 30 °C (which is suitable also for textiles labelled with higher temperatures), but with different load sizes, for example full load, 70% load and 30% load. According to the stakeholder's opinion, this would align testing to the programmes most used by consumers and to consumer habits as shown in market research done by AISE and University of Bonn, covering 60% of the consumer programmes as shown in the consumer surveys. Further, one single programme simplify the procedure for testing and facilitate better alignment with the testing of washer-dryers.

One stakeholder did not agree with the proposal of eliminating the need of an additional "standard cotton programme", and devising a mechanism for testing the *most frequently used* programmes for cotton loads at 40 and 60 °C as consumer behaviour changes frequently due to public discussions (e.g. hygiene), resulting in a variance and inhomogeneous consumer groups. Also, the programme application varies by the ability of a particular washing machine. Nevertheless, according to the consumer survey 2015 by University of Bonn, cotton is the most common used load.

Further, one stakeholder proposed to include a performance assessment and communication of the mandatory 20 °C wash cycle, as so far they very much differ (some of these cycles are short, others long, some refresh, others are performance cycles).

Another stakeholder states that end-users need more or better information about the most efficient programme. Today, this programme is indicated by the arrow on the control panel. Based on consumer feedback, the symbol is not really understood by users and can therefore hardly contribute to identify the most energy saving programme. Other signs like "eco" seem to be better known, e.g. from the campaign of the washing temperature reduction from 90 °C to 60 °C in the 1990's. Thus, from the stakeholder's point of view, the formerly used eco concept would applicable also for the future, due to its link with environmental (ecological) aspects and also supported by the dishwasher regulation, which is using "Eco" and not the arrow for indicating the standard programme.

Generally asked if the same testing approach should be applied also for the washing cycle of washer-dryers, all stakeholders providing feedback agreed to this position.

8.2.1.2. Default programme setting

Stakeholders asked if they agree with the proposal of requesting default programme selection of the standard programme tested, remarked that this option is in principle only possible for appliances with electronic displays whereas some washing machines/washer-dryers still have mechanical programme selection which cannot offer the possibility yet for automatic default programme selection. Further, based on the currently two standard programmes for 60 °C and 40 °C, one stakeholder remarked that there can only be one default selection.

One stakeholder expressed its concerns regarding that proposal as from his view, consumers should have the choice of the programme that they want to use when starting their appliance. Washing machines offer a wide range of programmes because textiles need to be treated differently based on fabric, colour, degree of soil, etc. To his opinion, a mandatory standard programme as default setting would cause inconvenience to consumers as they would have to change programme every time they would use the appliance for other purposes than washing cotton textiles. Consumer data show consumer using typically and often more than one program. Further, consumers who are washing lightly soiled laundry might choose programmes which need less resource (energy and water) than the default standard cotton programme for normally soiled cotton.

To set functional or technical constraints on product functionality in a regulation is not agreed by another stakeholder due to the different implementations of control panels. For manufacturers, for example, such requirement would take freedom away to design the temperature selection.

Finally, one stakeholder remarks that for washer-dryers, default programme selection would be even more difficult as the drying part of the WD cannot be default.

8.2.1.3. Protocol for testing: temperatures (40 °C / 60 °C) and loading (full, half or partial loads)

The ATLETE testing (see section 2.2.5) concludes that the EN60456:2012 is well applicable and it does not yield any technical problems. The protocol of the test standard seems thus fit for the purpose of describing a reproducible, comparable level playing field.

However, following the information on user behaviour described in Chapter 3, some elements of the performance measurement protocol could be changed, as for instance:

- the number of full loads and half loads (see also discussion point on capacity below)
- the temperature of the programme(s).

It seems from the data collected that the testing might continue to be based on the 40 and 60 °C cotton programmes, as those are the most widely chosen.

At the first Technical Working Group Meeting (Sevilla, 24 June 2015), the study team discussed with stakeholders if it could be an option to change the 60 °C cotton full programme to a 40 °C cotton full programme and to leave the half load programmes as it is currently (see also discussion on capacity and loads below). In consequence, it is assumed that the total average energy consumption would be lower.

One stakeholder agrees with the proposal of the study team as 40 °C full load (rated capacity) as well as 40 °C and 60 °C half load or partial load still play a major role in laundry washing.

Some stakeholders replied that they are not in favour of changing the 60 °C cotton programme in the test cycle to a 40 °C cotton programme. Although 40 °C is suitable for many cotton and cotton blend items, the bleaching capacity of a 60 °C cotton cycle is still needed. One stakeholder argued that the primary goal of a washing machine is not to save energy and water, but to deliver clean laundry, at the best with the lowest possible energy and water consumption. However there is some support for changing the 40 °C cotton cycle to a 30 °C cotton cycle, but maintaining the 60 °C programme and a mix of full and half load cycles in the testing procedure. To use 30 °C wash is possible as detergent products are available and the energy reduction will be much higher in EU.

One stakeholder agreed to change the 60 °C cotton full programme to a 40 °C cotton full programme; also keeping partial loads in the test procedure is supported as it is more related to consumer habits. Also, this would reflect testing the capability of appliances to adapt to the actual amount of load in the machine (cf. below, section on capacity measurement). Furthermore, testing might be done using only 40 °C (for full and half loads) programme or better also at lower temperature like 30 °C as the main way to reduce energy in washing is to reduce the temperature of washing according to the view of one stakeholder.

As alternative testing procedure, the study team proposed at the first Technical Working Group meeting in Seville the idea of testing a programme (“Cotton Eco Programme”) to be used for all textiles labelled 40 °C and higher temperatures together at temperatures of around 40 °C, i.e. not damaging 40 °C labelled textiles. This would allow combining loads which are otherwise washed separately at 40, 50, 60 or 90 °C and to utilise the large load capacity of modern washing machines. This Cotton Eco Programmes at 40 °C is offering a cleaning level of a 60 °C programme and therefore supposed to replacing it. Thus, the energy saving is coming from the temperature reduction from 60 °C to 40 °C.

One stakeholder stresses the need for educational programmes to explain to consumers that full loads are more energy efficient. He believes that both the household appliance industry and civil society actors, like consumer associations and NGOs, have a role to play in educating consumers.

8.2.1.4. Capacity measurement

Currently, the capacity of a washing machine is declared by the manufacturer (the so-called "rated capacity"), as requested in the Ecodesign regulation. However, some stakeholders claim that different capacities can be declared for identical washing machines depending on which country they are sold. Harmonisation could be achieved by requiring the measurement of the capacity according to the already existing standard IEC 60456.

Sales data indicate that the rated capacity of appliances has increased in the last decade, but that the amount of laundry loaded in practice is on average <4kg cotton. The current measurement and calculation methods make use of half loads to address this divergence. However, for a 10 kg machine this means 5 kg and for a 13 kg machine this means 6.5 kg. These half load-capacities resemble more to a fully loaded «normal» washing machine and are in a contrast with the European average load, which is around 3-3.5 kg. This average load shall remain the reference for testing, so that it reasonably reflects real practice. Thus, it seems relevant to discuss if to adapt and increase the share of half-loads in the standard testing.

It is additionally an issue for discussion how to address the testing of automatic load detection programmes, in case these provide an additional energy saving potential. Some stakeholders indicate that there are washing machines on the market which use the same amount of energy and water for a half load as for a full load using the standard programme. It may thus be required that half load tests deliver realistic energy and water saving compared to full load tests. As the correlation of load to energy use is not linear, reference saving rates compared to full load may be required, e.g. 25-30%. As technology progresses, 30-35% might be achievable.

Additionally, the Standard Annual Energy Consumption (SAE_C), which constitutes the denominator for the determination of the Energy Efficiency Index used in the Energy label and Ecodesign regulations, is calculated based on the lowest between the rated capacities "c" declared for the standard 60 °C cotton programme at full load and the standard 40 °C cotton programme at full load. SAE_C is calculated in kWh/year (and rounded to two decimal places) according to the formula $SAE_C = 47.0 \times c + 51.7$. Apparently, the SAE_C calculation is not based on real use conditions and it would be interesting to deepen the fundaments of its determination and to understand if it should be updated and how.

It has also been noticed that US legislation refers to drum volume. On the one hand, reference to volume makes requirements independent of the textile type. On the other hand, it is more difficult to address issues like half-load, or the dependency of wetting (and water consumption), spinning and drying on the textile type. According to stakeholder feedback, this is just habits: the Europeans are used to understand kg as a capacity figure, whereas US costumers better understand volume in cubic feet. In USA the understandable parameter for the consumer is the volume in cubic feet no mentioned load, the tests are done with standard loads, and not measuring the washing performances at all, thus the two testing standards of EU and USA are based on a completely different approach.

Stakeholders asked about the issue of the influence of capacity measurement declare that the application of different technologies (e.g. motors) and intelligent treatment techniques allow treating different load amounts in the same drum volume, meaning that a mechanically similar model can be sold with different capacities, e.g. 6 and 7 kg, but electronics and programmes would be adjusted to account for the different maximum load sizes (as correctly labelled). Meaning that there is no direct correlation, because the load capacity is not only determined by the drum volume, but also by other features of the machine (e.g. motor size and power, size and weight of counterweights, cycle design etc.). Furthermore, the load capacity must be chosen in a way that all safety requirements are fulfilled. Thus, even though the current existing standard provides instructions on how to measure the drum volume, this latter is not the only element determining the capacity. Other components of the washing machine or washer-dryer also have to be suitable for the claimed capacity. For example, a washing machine with 1000 revolutions per minute (rpm) and a washing machine with 1600 rpm final spin speed may have the same drum volume but have different drive systems (motor). A different motor will enable a different rated capacity. Thus, according to stakeholders, the declared washing efficiency, resp. water and energy consumption should be always measured using the rated capacity and not predetermined by a calculation formula.

One stakeholder is in favour of further including partial loads when calculating the energy efficiency index. The current EN standard provides means to test partial loads. Considering the IEC EN 60456 the standard cotton load should still be used 5 times within a label measurement test series. Thus, for washing machines, the topic of half load testing is already covered by the current test procedure.

The proposal of adjusting the share of half-loads based on a quantitative assessment of the average loads (obtained from user survey) is in general supported by the responding stakeholders; simplification of the testing procedure should be kept in mind. One stakeholder however pointed out that today half load is not visible for the end-user, due to the average figure of calculating the energy efficiency.

One stakeholder proposed to increase the share of partial loads and to differentiate by declared nominal loads, e.g. to prescribe two quarter loads (25%) instead of one half load with machines from a particular nominal load (e.g. 8 kg). Two full loads (nominal load) should remain to prevent unrealistic declarations.

According to one stakeholder, there are practically no appliances left in the market without automatic load detection, but with half load button to adjust for smaller loads. On the question how automatic load detection can be dealt within the test procedure stakeholders remarked that the test protocol already today covers different load amounts. But it is not yet required to show the load adaptation. Different treatments for one program could be selected: e.g. full, half, EU-average, small. The current evaluation method using average values calculated out of results from full and half load is not suitable to show the load adaptation function. It is proposed that the different treatments with different load amounts are evaluated separately.

On the other hand, the idea of introduction of minimum energy saving rates for half-load (e.g. 25%) compared to full load is not supported by stakeholders. Minimum energy saving rates might be difficult to achieve due to necessary basic consumption with any load independent from load size. Thus, prescription of savings could lead to higher energy consumptions with full loads to fulfil such regulations.

Instead, as an information requirement (saving percentage) it might be accepted. Stakeholders pointed out that, in order to reach energy savings, it is important that consumers are well informed that full load is more energy efficient than half load. With transparency on one hand (consumer information with the message of washing full loads if possible) and competition on the other hand to reach greater saving rates is supposed to help reaching improvement of energy efficiency for real life load sizes. According to one stakeholder, bad management of partial loads results in a lower energy label class, which is already regulated by the energy label;

Asked if the formula for the calculation of the SAE_C should be updated, for instance to reflect real use conditions or the evolution of the market, stakeholders recommended that the SAE_C should be aligned with the new test portfolio and current market figures.

In this context, one stakeholder points out that the market analysis shows that there has been a tendency over the last years to sell larger capacity machines whereas on the other hand, this does not reflect the data observed in terms of average composition of households and is thus preventing many consumers from using full loads. According to the stakeholder's view, as the main target of the ED/EL directives is to lower the energy/water consumption, it is extremely critical that – for both temperatures and water – the supposedly "linear" reduction of water/energy when using such saving programmes at partial loads is secured.

For washer-dryers it is generally agreed by all stakeholders that the approach for testing the washing programmes in a washer dryer should follow the washing machine regulation due to consistency.

However, one stakeholder remarked that for washer-dryers the partial load testing is a new issue and it has an impact on partial drying. Testing washer-dryers with partial load would require that the standard is updated, both for the washing and for the drying part.

Also on these issues, no stakeholder disagreed with having the same approach also for the washing part of washer-dryers; ideas for the inclusion of the drying part still need to be developed.

8.2.1.5. Temperature testing

Recent tests of appliances on the market (e.g. ATLETE project, see Chapter 2) concludes that the standard 60 °C and 40 °C programmes achieve actually maximum temperatures of respectively 35 °C and 25 °C.

While 5-10 °C differences may be insignificant for consumers at nominal temperatures around 40 °C, provided that the washing performance is the same, larger deviations can be a problem at nominal temperatures around 60 °C, as this temperature is normally selected purposefully to address hygiene or specific soiling of textiles. Certain pathogenic microorganisms or soiling is removed indeed only if exposed to this temperature. According to the feedback from one stakeholder, 5 °C may be the maximum difference from the declared temperatures.

Using the standard cotton 60 °C programme commonly provided in many washing machines on the market today will provide the complete opposite effect of a hygienic wash – it will incubate pathogens at 35 to 40 °C – exactly the temperature at which they multiply most rapidly. Some stakeholders argue in this respect that low temperature standard programmes would normally require running additional regular maintenance cycles at high (e.g. 90 °C) temperature to remove bacterial growth, and this should be included in the EEI calculation.

Whilst it is recognised that manufacturers are obliged to include a statement explaining that claimed temperatures may not be achieved in practice, the statement itself is too vague to give the user a proper understanding of the situation.

This issue could be handled for instance through:

- the removal of the standard 60 °C cotton programme from the test procedure linked to the Regulations.
- a requirement to declare the maximum temperature (± 2 °C) of each programme in the booklet of instructions.
- a requirement to reach a minimum temperature for a certain amount of time for some specific programmes.

The method for temperature testing (e.g. exact placement in the machine, duration of the measurement) shall also be part of the standard.

Some stakeholders have additionally indicated that the availability of cold wash programmes (i.e. 20 °C), which is required by the Ecodesign regulation, offer great energy saving potential. However, their performance is not tested, measured and regulated, especially with respect to the washing function.

Stakeholders were asked on their opinion of the proposals outlined to address the differences between declared and actual temperatures. There was no support for removing the standard 60 °C cotton programme from the test procedure linked to the Regulations. According to one stakeholder, using from time to time and in certain occasions a reliable 60 °C cycle with a powder detergent is needed. According to another stakeholder, the consumer behaviour study 2015 shows that a significant number of consumers are using programmes with temperatures of 60 °C and above. These consumers are using these programmes for maintenance of the machine, disinfection of machine and textiles. One stakeholder assumes that in case the 60 °C cotton programme is removed from the test protocol it is very likely that the temperature will be "back".

The proposal for introducing a requirement to declare in the booklet of instructions the maximum temperature (e.g. ± 2 °C) reached in all the programmes was in principle supported. However, according to one stakeholder, in case temperature requirements like declaration in the manual are introduced, it has to be ensured that the repeatability and the reproducibility of the measurement method are available and considered. The effort to verify such requirements should be considered as any declaration requires physical verification by market surveillance authorities

The proposal of a required minimum temperature for a certain amount of time for some specific programmes was not unanimously supported. Stakeholders mention that washing temperature is one of the design parameter for washing cycles and should be left free to manufacturers to decide if higher temperatures and shorter cycles using more energy or the opposite should be used in order to achieve the energy reduction targets. One stakeholder would rather like to see increased promotion in the use of lower temperatures to decrease energy consumption without compromising the results. In any case, if minimum temperatures are seen as declarations, the point of how these temperatures have to be measured (according to one stakeholder, this has to be combined with a temperature measurement method inside the laundry to be developed in the standardisation bodies; for professional machines a measurement method has already been developed which might be a basis for the development of a measurement method for household appliances), the repeatability and the reproducibility of the measurement method and the verification of such a declaration need to be considered. Currently, there is no a common agreed method to measure the washing temperature. Further the temperature of the wash is very variable inside the drum and no standard method exists. The initial definition of washing temperature was related to the capability of washing clothes without damaging them and following the recommendation of the clothes label not to the real washing temperature. However, there are proposals under discussion in standardization working groups.

Stakeholders were also asked if they are in favour of requirements for the testing of performance of the cold wash programmes.

Stakeholders recommend to better define the programme with regard to what it should deliver (refreshment vs cleanliness and for which types of stains). The same test procedures for low temperature cycle or "normal" temperature cycles should be applied. But the requirement cannot be to deliver the same performance as a 60 °C cotton programme thus the performance of such a cold programme needs to be discussed.

On the other hand, concerning high temperature programmes in relation to appliance hygiene, according to stakeholders there would be no need to regulate them as no general usage pattern can be defined and the need for hygiene cycles also depends on user behaviour (e.g. keeping the porthole open to dry out the machine, keeping the dispenser drawer open, ambient conditions of the room where the machine is used,…). In any case the consumer will experience when a high temperature cycle is needed (e.g. smell). One stakeholder argues that in case such programmes would be included in the EEI calculation, there would also be the need for microbiological analysis of the efficiency of these programmes, which currently does not exist as general standard.

In general, on these topics, the same approach should be followed for washer-dryers.

8.2.1.6. Inclusion of rinsing performance and measurement of hygiene

Rinsing is reportedly needed to ensure a sufficient elimination of the detergent and soil components from the wash load, which have been lately linked to the development of allergies. The data collected on standardisation activity (also internationally) and on rinsing performance of the most energy-efficient washing machines currently on the European market indicates that it might be advisable to include rinsing performance testing in the testing procedure associated to the ecodesign and energy labelling.

So far, the existing test procedures for rinsing efficiency did not provide sufficient reproducibility and repeatability. A new procedure for measuring the rinsing performance with sufficient reproducibility and repeatability is under investigation within the standardisation working group CLC/TC 59X/SWG 1.8. Some stakeholders indicate that there should be requirements on a minimum of two rinsing cycles in the regulation.

It seems also advisable to pursue alignment with international standardisation (e.g. IEC rinsing method under development). It seems that the US and Australia are following this line in their requirements.

Moreover, IEC59D has decided to limit its standardisation activities for washing machines to the measurement of the microbial contamination reduction on textiles. SC 59D decided to develop a globally acceptable Publicly Available Specification (PAS) to respond to the increase in consumer complaints regarding odour from washed laundry caused by the presence of microorganisms. This IEC/PAS 62958 Ed.1: "Clothes washing machines for household use – Method for measuring the microbial contamination reduction" was published in 2015. There is not much experience and no information on measurement uncertainty on the use of PAS 62958. Nevertheless, this measure may be seen as a complementary measure to the washing performance, as lower wash temperature may affect the microbial contamination reduction on textiles.

Stakeholders were asked if they agree with the proposal of including rinsing in the standard and the regulations. This was unanimously supported because it is an important consumer requirement. It can be done however only if a recognized measurement standard method is available. It is recommended not to further reduce the limits for water consumption without introducing a minimum rinsing performance. On the other hand, a method for determination the rinsing performance would even be a condition if further water restrictions would be planned as ecodesign measure. The rinsing performance should not be classified on the label but a required minimum performance. The minimum value should depend on the new standard and its repeatability and reproducibility. The current work of standardisation bodies from CENELEC and IES on this issue (see above) is supported by stakeholders. A possible circumvention method might be based on bad rinsing leaving detergent in the load for the next run, increasing the performances by accumulated detergent.

One stakeholder proposed that to progress this topic, a joint workshop with appliance, detergent and academia experts having worked on the topic should be organized, e.g. for defining minimum rinsing volume per load and minimum rising time, whilst taking into account the fact that both liquid detergent and powder detergents exist on the market (with a majority of liquid detergent being used, and those, not containing an active oxygen bleach system to date); also the fact to use for the performance cycle a modern reference detergent matching the reality of the market use (and thus, notably liquid), should be taken into account.

Regarding the developing of an approach for measuring and reducing the residual microbial contamination of the laundry, there is seen no need by stakeholders; one stakeholder argues that consumers need to be better informed that there are washing cycles up to 90 °C available for contamination problems. Further it is mentioned by stakeholders that developing such a standard would imply too high test effort. Further, there are fewer experiences, as there is up to now no international standard and the repeatability and reproducibility of draft methods (PAS) needs to be checked first.

With regard to the inclusion of rinsing performance and measurement of hygiene, for the washing cycle of of washer-dryers the same approach as for washing machines should be applied. Due to higher temperatures in the drying phase, hygiene and additional germ killing is even seen as less of an issue in washer-dryers.

8.2.1.7. Streamlining low power requirements

Following the prescriptions of Regulation 1275/2008 as amended by Regulation 801/2013/EU on standby, washing machines and washer-dryers are equipped with power management systems since 2013. This limits substantially the annual energy consumption of standby and off modes (cf. section 1.2.1.2), which contribute minimally (up to 2.5%) to the annual energy consumption calculated according the EN 60456 standard (according to the results of the ATLETE project, it accounts on average for 1.8% of the annual consumption).

A remaining issue of concerns for some stakeholders is that this contribution, despite small, may be sufficient to result in different energy class categorisation of two machines with the same energy consumption for the washing cycle, but different standby mode energy use. It was indeed indicated that low power modes of e.g. 2.5% of the yearly energy consumption, represent about a fourth of the width of an energy class.

Currently, the testing of low-power modes is judged by manufacturers and testing laboratories as complicated and costly, as it needs special test set-ups to avoid failure rates beyond the measurement tolerances. This may be seen as a barrier for the testing in new laboratories.

The mandatory prescriptions for stand-by in place since 2013 by Regulation (EC) No. 1275/2008 seem to have made to some extent obsolete the measurement of some of the low power conditions required in performance tests for washing machines. Measurement of the energy consumption in low power modes may thus be excluded from the calculation of the EEI used for the revised ecodesign and the energy label.

Alternatively, low power consumption requirements may be included in the Ecodesign regulation, (if not already included in Commission Regulation (EC) No. 1275/2008), e.g. automatic switch-off of the appliance after a certain time.

Stakeholders were asked if they agree that energy consumption from low power modes barely contributes to the annual energy consumption of washing machines. Stakeholders comment that the impact of low power modes is negligible on the total consumption and is regulated anyhow. However, its relative impact can grow if lower total energy consumption of the appliances will be reached. The consumer survey as presented by UniBonn showed that the assumption that 50% of the usages the consumer does not switch off its appliance is wrong and is rather current calculation per regulation.

The use case delay start is currently not covered by the low power mode measurement. Delay start function is either used to have the washing finished at a certain time, or to shift the running of the appliance to a time when energy tarifs are low (mostly during the night). The latter use has the advantage of shifting grid load which contributes to a better energy spread on the grid. To include it in EEI is not supported by stakeholders as it does not significantly contribute to the annual energy consumption. It may be considered as a seperate ecodesing requirement under 1275/2008. One stakeholder proposes that requirements on delay start should only cover the energy consumption and not have a limitation on the time as this is depending on user behaviour and use case.

Further, as smart grid functions will be enabled in future, the appliances will have to react on signals from grid. Therefore a "delay-start" function is needed to serve this technology. Restrictions/limitations on this option will impact the realization according to stakeholder comments. Appliances with network connection have to comply with the regulations already in place.

Finally, according to one stakeholder, the measurement method for standby is complex and expensive to achieve high accuracy. Simpler measurement method with little lower accuracy might help to simplify without compromise the final result. Alternatively it is proposed that the low power mode being regulated already might be eliminated from the energy label evaluation, as not contributing in the differentiation of the products in the market.

For washer-dryers the same approach should be followed.

8.2.1.8. Specify consumption values per cycle

As the low power energy consumption has turned out to have quite a small contribution to the annual energy consumption (see above), there seems to be no longer a need to calculate average energy and water consumption on an annual basis. For consumers, consumption values have a similar representativeness if reported per year or per cycle.

On the one hand, a potential buyer can perhaps convert more easily yearly values to potential annual savings in monetary terms. On the other hand, the real annual consumption depends on the household size and on washing habits, and the annual number of washing cycles might deviate from the 220 washing cycles taken as basis for the calculation of the annual energy consumption (see Chapter 3).

Therefore, it is proposed to discuss if it is advisable to change the annual energy and water consumption reported on the label to 'consumption per cycle' (i.e. back to the format before EC 1061/2010). Alternatively, if the current annual values are kept, it is proposed to discuss if the number of washing cycles per year shall or not be updated.

Asking stakeholders if they are in favour of providing information per cycle rather than per year there is no unanimous feedback. Some prefer the information given per cycles some per year. One stakeholder feels that consumers should be provided with consumption data in a transparent way, so that they can make an informed choice when selecting their wash programme. The information should however be conveyed in a consumer-friendly and "easy-to-access" (and action-oriented) way.

Another stakeholder is rather in favour of information per year, as the consumption values (kWh and l) are already in a very low level: consequently differences between appliances will be very small in case consumption values are given per cycle. Yearly consumption values deliver greater numbers, where differences between appliances become more obvious and easier to quantify by users (in favor of energy efficient appliances). Additionally the consumers are accustomed to annual consumption values from other kinds of appliances like TV-sets, refrigerators, lamps etc., thus for better coherence it seems better to keep it that way for washing machines and washer-dryers as well as in order to guarantee a general understanding of the energy label

If information is given per year 208 or 200 cycles per year are proposed by one stakeholder, based on the results of the consumer survey 2015 by University of Bonn. For washer-dryers to be comparable with washing machines the yearly consumption values for washing should base on 208 cycles also. Additionally 104 drying cycles should be used to express the yearly consumption by the drying function is proposed by one stakeholder.

8.2.1.9. Demand-response enabled appliances

As the energy system of the future is getting more and more variable due to fluctuating energy production by wind and solar PV stations, it is necessary and helpful to have some flexibility on the demand side as well. This can be realised by appliances which offer a demand-response possibility. However, a sufficiently large number of appliances need to be in the market before such a system can be launched. It is therefore useful for a more energy efficient power supply to support the introduction of demand-enabled appliances.

Appliances which offer a demand-response function provide flexibility in the demand side to match the fluctuating energy production forecasted for the future due to the increasing number of wind and solar PV stations. However, this cannot work alone, and it is needed that the distribution system operator, or an aggregator of the smart grid, offers the consumer sufficient incentives to allow the use of the demand-response enabled power capacity. A sufficient large number of appliances need to be in the market before such a system can take off. It could therefore be useful to support the introduction of demand-response enabled appliances. Requirements to the demand-response function itself can be set up either by standardization or be introduced in the ecodesign or energy label regulation.

Therefore, it is proposed for discussion if support to the demand-response enabled appliances should be introduced, and what is the best tool to set up the general requirements, e.g. user settings, information and capabilities. Stakeholders were asked if there should be any general requirements set to handle the demand-response function (e.g. user settings, information requirements, capabilities, etc.).

One stakeholder points out that there are no standards or common functionality definitions available yet, as well as any real smart grids. To his opinion, end-users should always remain in control of the appliance and decide whether or not to activate smart functions. The intelligence should remain in the smart appliances or their systems installed in the households and should not lie with external bodies such as energy companies or energy distribution companies.

One stakeholder generally welcomes the Commission's acknowledgement of the important future role to be played by home appliances for providing flexible consumption to balance increasing intermittent generation. Smart appliances will enable the development of residential demand response. However, one prerequisite for the market development of such products is the existence of an electricity market remunerating demand response. The European Commission has launched, in fall 2014, a dedicated preparatory study on smart appliances under the ecodesign framework, which is currently in the process of setting its scope, and therefore the definition of smart appliances. To set requirements, one stakeholder argues, it is better to wait a more detailed definition of the demand response function. According to the view of another stakeholder, however, information requirements can be set and the utilization of local energy supplies by photovoltaic, solar power, wind can be supported.

Asked about the question if demand-response enabled appliances should be incentivized, e.g. by a bonus-malus in the EEI, one stakeholder rejected this with the argumentation that the availability of the feature itself will not automatically lead to any energy saving and will for sure not contribute to an improvement of the appliance's efficiency. This is related to the availability of the infrastructure and the user habit to really use this. So any incentive should be arranged only between energy supplier and customer, and not in the Energy Efficiency Index. Another stakeholder would be in favour of incentives, but not before a common standard and function is defined.

Stakeholders also were not in favour of showing information about the availability of such feature on the label. The availability of such feature should rather be part of the broshures and catalogues of the supplier, but not necessarily on the energy label as it is not saving energy. The label should be simple and easily to be understood by the consumer

Regarding this issue there is seen no difference of washer-dryers to washing machines by stakeholders.

8.2.1.10. Programme duration

Programme time is an important parameter for balancing the information on the energy efficiency of a washing machine and a washer-dryer. As described in Chapter 4, it is possible to achieve low energy consumptions by prolonging the programme time. Also, market research reveals that currently there is a trend by manufacturers to supply the market with appliances with longer average duration of the standard cotton programmes (cf. section 2.2.6.3). This effect is not so clear for washer-dryers so far. On the other hand, consumer research reveals that one of the reasons for not using the standard cotton programmes is exactly that the most accepted programme duration by average users is generally not longer than 3 hours, while an increasing number of standard cotton programmes exceed currently 4 hrs.

However, also communication plays a role. Research indicates that acceptance of (longer) "eco" programmes can increase when consumers are informed about the role of the washing cycle duration (i.e.

why "eco" programmes have long programme durations and still are the most efficient). To allow customers at the point of sale to make a well-informed purchase decision and to let them choose the most appropriate washing programme for their daily needs, stakeholders were asked which, when and how information should be provided on the programme duration.

According to one stakeholder, the principle of the Sinner Circle as described in section 4.1.1.1 ("The washing process is based on four factors: mechanics, temperature, chemistry and time. These factors depend on each other, i.e. one factor cannot be reduced without increasing one of the others (if the same washing performance has to be maintained)") has no room for "if" in the current ecodesign requirements; in order to place products on the European market, washing performances have to be maintained on A-class level while meeting a set of energy standards. Thus, according to the stakeholder, to provide more transparency to consumers, an indication of the cycle time would be an option, but there is a need to be further discussed how to come up with a relevant information about the cycle time (average time, time per treatment, time for full-load, time for half-load, etc.).

Further, it is assumed that consumers would select longer programme times if they were better informed that longer cycles can have lower energy consumption values, thus educational campaigns could play a big role in informing consumers and therefore reducing energy consumption. According to another stakeholder, there is no correlation in consumer's minds (actually even possibly the contrary), on the fact that a long cycle can be more energy efficient. This is not clear/nor not understood by "the average" consumer, thus teaching the effect of programme length and temperature is seen as important.

However, one stakeholder assumes that the consumer will accept longer programmes, but only up to 15 minutes longer.

Asked about the way of how the consumer should be informed about this aspect, one stakeholder believes that on such matters cross-sector or even multi-stakeholder campaigns help getting the message across with consumers. It is expected that if the different market players all communicate consistently in their user manual, booklet of instructions, ideally on the appliance (e.g. sticker/magnet) at the point of sale, they would have better chances to be understood by consumers. Backing such claims with external stakeholder support (e.g. authorities), on such topics provided they are true and non- (or pre) competitive is also important. Also the role of consumer organisations is seen as crucial by stakeholders to inform the end-user, as they represent the consumer and have a neutral market position.

One stakeholder proposes that information on the longest (label) programme duration should be given on the label as well as in the product fiche and in the instructions for users

8.2.1.11. Facilitate the selection of the tested programme(s)

The sections above provide evidence that the standard programmes are currently not always chosen by consumers, because of their long duration and in some cases also for not reaching the indicated temperature of 40 °C or 60 °C. Additionally, some stakeholders indicate that the standard programmes are not always easy to find and to select in the appliances, and that the standard programme indicator (an empty arrow) might not be well understood by all consumers.

The ambition of the ecodesign and energy label Regulations shall be that the set of programmes which the consumer select most often to wash normally soiled clothes, and thus result in the largest energy consumption in the EU annually, should be the programmes tested for Ecodesign and Energy Labelling. These programmes shall also be easy to identify when operating the machine. The revised requirements shall facilitate those goals.

The standard shall continue to define, in an updated manner, the conditions of testing of the programme that is associated to the attribution of the label class. On the other hand, reference to "standard programme" might create some confusion. In this respect, for dishwashers the use of the name 'Eco' has proven to help the consumers to identify the most efficient washing programme.

Stakeholdes were asked during the course of this study if the energy saving programme(s) for washing machines and washer-dryers should be called "standard programmes", "eco-programmes" or if they have a different proposal for definition and name to use? One stakeholder proposed to call the future standard programmes simply "Energy saving programme". Another stakeholder prefers "ECO", but proposed to keep / allow also the currently required arrow solution in order to avoid rework of control panels and explanations in the manuals (costs without any benefit for consumers and manufacturers). The stakeholder also points out that applying this proposal would confuse consumers who are now getting used to the current arrow symbol, i.e. changing it again would require starting new education campaigns.

Finally, another stakeholder adds that not all washing machines have control panels with text language, there are still models with only symbols on the market.

8.2.1.12. Information to the consumer about consumption values of ALL programmes

The information that consumers get about energy and water consumption values at the point of sale via the energy label is based on selected programmes, the two standard cotton programmes for 40 °C and 60 °C. To help consumers make better informed purchase choices it might be recommendable that the appliances provide information on the consumption values of other programmes as well before and after the purchase of the appliance.

Therefore, it could be recommended that the user manual contains, besides the information on the standard cotton programmes, also detailed information on energy consumption, water consumption, programme time and the preferred usage for each individual programme. Some appliance models are already providing such information. Similarly, the functioning of options could be described by figures, e.g. how much more or less energy is used compared to other programmes.

Thus, stakeholders were asked if it would be possible to indicate the consumption values of every programme available in the user manual, in a cost-effective manner.

Some stakeholders inform that it is already a current generic ecodesign requirement and is done by manufacturers to indicate the consumption values of main programmes. However, this does not include all options. Whereas on stakeholder agrees with the proposal, other stakeholders are of the opinion that there are too many possible combinations of programmes and options to be able to reference them in a cost effective manner. The number of declarations could sum up to more than 400 programme & option combinations for premium washing machines. Another stakeholder even assumes that all program-option-combinations would add more than 1000 data sets, i.e. this requirement would add reams of pages and adding costs to the user manual without added value to the consumer. Also, according to another stakeholder, any declaration requires physical verification by market surveillance authorities; thus it is recommended to only declare the values of the main programmes. However, there should be a clear definition of "main" programmes.

The proposal to indicate directly on the machine the expected consumption values before the programme starts, and the actual consumption once it finishes is seen by one stakeholder as a positive incentive to consumers if the machine screen or display would also show the effective saving in energy or water consumption. On the other hand, several stakeholders point out that not all machines are equipped with displays so far and not all products with display have the computing resources available for this calculation. Also, measuring water and energy consumption within a machine requires additional sensors and devices which will increase the costs of the units and therefore the appliance prices. Furthermore, more materials would be needed, which might be counter-productive regarding resource efficiency. Finally, according to one stakeholder, the indicated information may be wrong as it depends on load, textiles, surrounding conditions, etc.; thus, the information can lead to uncertainty and confusion.

8.2.1.13. Use of hot water

If a user has a hot water supply, especially if based on renewable energy sources, this can be used to feed the appliance. To support consumers in using alternative hot water supplies, manufacturers could include clear statements about the fitness of their appliances for a hot water connection, be it in the user manual, the energy label, or the product data sheet.

It was discussed with stakeholders whether additional communication efforts shall be made (e.g. special symbols in the energy label) indicating if the appliance can be connected to an external hot water supply, and if additional advice with specific instructions on this (e.g. maximum temperature of the how water inlet) shall be provided in the user manual.

According to stakeholders' feedback, additional warm water supply connection is a niche market only. Any benefit for energy saving mainly depends on the individual warm water supply situation. This feature should be part of the brochures and catalogues of the supplier, but not necessarily on the energy label. Adding such information would overload the label and would not have a significant impact on consumers' behaviour. For those customers looking for these types of appliances, the information of hot water supply is already available for them at the point of sale.

Asked about additional information to help the buyer/user to save energy, and protect the functioning of the appliance, stakeholders responded that a kind of guideline would be helpful to explain the use cases, where a hot/cold fill would bring additional benefit (like solar heated water, existing hot water circulation to the water supply tap or a very short supply water pipe from the boiler to the washing machine). Furthermore, one stakeholder recommends that the inlet temperature at the tap connection should not exceed 60 °C to ensure full protection of the functioning of the appliance when being connected to the installation. In order to avoid denaturation of proteins and avoid damages of textiles, normal washing machines should not be connected to hot water supply only. Additional safety devices might need to be installed to assure this temperature limit.

In addition, if a washing machine without warm water inlet is connected to a hot water supply only, this is causing additional energy wasting during the rinsing process. Another stakeholder proposed to provide as additional information to consumers that they shall wash at lower temperatures than provided with hot fill if not special purpose wash is necessary. Finally, in this case, communication support by "neutral" stakeholders deemed to be helpful.

Finally, one stakeholder sees the current infrastructures as one additional constraint to the use of external hot water supplies. To his opinion, the infrastructure (solar panels, thermos, feeding pipes) has first to be adjusted and then the demand for those appliances will increase on the market. Otherwise, hot water supply may consume even more energy compared to water heated via the appliance.

8.2.1.14. Performance of washer-dryers

The standard of measuring of performance of household clothes washer-dryers (EN 50229) is currently being updated, to align load definitions with washing machines and tumble-dryer standards.

The energy use test procedure for washer dryer described in the (old) directive on labelling of washer-dryers (Directive 96/60/EC of 1996) overrates the drying function, as it requires drying of 100% of the washed laundry. However, the evidence is that only 25% of the laundry is dried in typical household use (see chapter 3). The current version of the standard does not either reflect user behaviour regarding washing temperature and load amount (only cotton 60 °C with rated capacity against low temperature washing mainly with partial loads).

Stakeholders agree with the diagnosis above. One stakeholder proposes the following procedure:

To be prepared for any programme portfolio for the calculation of EEI, the following adjustment of the IEC 62512 when introducing the common modification for the future EN 62512 should be inserted:

- The current standard is limited to washing performance testing with non specified washing and cotton cupboard drying -> Offer and define more performance testing opportunities
- Describe the opportunity, that all washing performance tests according to EN 60456 can be applied for washer-dryers without exception
- Describe the opportunity, that all drying performance tests according to EN 61121 can be applied for washer-dryers with the special condition that the initial moisture content for the drying needs to be defined based on washing tests in related programs (cotton, easy care)
- Add the opportunity to apply the special test sequences for interrupted and continuous washing + drying cycle for other programme combinations like easy care drying and other final moisture contents than cupboard drying.

Another stakeholder states that a high convenience for consumers is given with the function continuous wash&dry which is possible with partial loads. Thus, this function should be a main part of the WD label. Finally, another stakeholder remarks that a solution has to be found regarding how washing and drying can be combined in a way that somehow reflects user behaviour.

8.2.2. Material resource efficiency

Research has shown an increasing number of examples of integration of resource efficiency matters (such as durability and facilitating end-of-life management of products) into product policy instruments like mandatory ecodesign Regulations or voluntary ecolabels.

While ecolabels such as EU Ecolabel, German Blue Angel or the Nordic Swan already have included a large range of resource-related criteria for quite a long time, the implementation of those criteria into mandatory product-specific regulations has only started a few years ago (e.g. ecodesign for vacuum cleaners, lamps, displays), apart from general directives or Regulations such as RoHS, REACH or WEEE. This is accompanied by increasing importance of research on the feasibility of implementing resource efficiency aspects into product policies, as reflected different European research studies published within the past two years.

However, it seems that there is still a gap between the already implemented requirements/criteria in product policies, and the ongoing research in this field, which focuses on the effectiveness and impacts of increased product-related resource efficiency. One of the causes of this gap is the absence of sufficient standards which are applicable for testing and measuring resource-related criteria that hinder a practicable implementation of the criteria (including procedures for verification and market surveillance).

Some stakeholders indicate additionally that any new resource efficiency requirements should be measurable, enforceable, relevant and should not hinder innovation and competitiveness. Any new requirements should have a proven environmental benefit and thus be based on robust data, methodologies and widely recognised standards that confirm this. Standards should be built on a solid foundation to ensure they reflect the technical reality (state of the art). Solid evidence for feasibility, proper measurability and environmental benefit should be taken into account when developing such standards. In the absence of these conditions, any shift from resources in use (energy, water, etc.) towards material efficiency should not be forced artificially.

Some stakeholders find it also confusing that material efficiency and end-of-life requirements, part of the same integrated product policy initiative in the early 2000's although split in the final implementation (ecodesign and energy labelling on one side, RoHS, REACH and WEEE/ELV on the other), are again re-integrated.

There are currently a number of standards related to material efficiency (e.g. safety standards for durability, recycling standards for end-of-life management), but they are primarily developed for other purposes (product safety, management at recycling operations) and are not directly transferrable for increasing resource efficiency in the design phase . For example, the EN 50625 standard series cover various aspects of the treatment of electronic waste (including collection, treatment requirements, de-pollution and preparing for re-use). However, it only deals with the handling of existing (waste) products entering the recycling stream. The European Commission will issue a standardization request to ESO to develop, in an appropriate timeframe, European standards on material efficiency aspects for energy-related products. When available, such standards might be referenced normatively in product or product group related harmonised standards where implementing measures set ecodesign requirements for material efficiency aspects.

However absent harmonized standards for resource efficiency may be, it is still possible to explore resource efficiency aspects in the preparatory study. The ESO horizontal initiative above may if deemed necessary be combined with product-specific standards which could address requirements of design that facilitate end-of-life management and resource efficiency for specific product groups.

For household washing machines and washer-dryers, the presented examples are used as a basis for the discussions.

Stakeholders were asked which kind of resource or end-of-life requirement they deem as most/least feasible for washing machines and washer-dryers. Just one stakeholder commented that all requirements which are mandated under the draft standardisation request on material efficiency aspects to CEN/CENELEC and lead to a harmonised standard, shall be accepted. He recommends leaving it to the ESO standardisation work to decide for which resource efficiency requirements standards can be developed, before deciding for which resource efficiency issue ecodesign requirements can be defined. It should be avoided that ecodesign requirements overlap with requirements in other environmental legislation (e.g. WEEE, RoHS, REACH, F-gases, etc.).

8.2.3. Additional feedback on legislation and standardisation issues

The following additional issues have been tabled by stakeholders:

1. *Washing performance should be separate for each treatment and not an average value. Industry claims that alternative measurement methods have to be developed.*
   Stakeholder feedback gives support to the first part of the statement that washing performance shall be achieved for each of the three treatments. The statement that alternative measurement methods need to be developed is challenged as the standard EN 60456 already includes the measurement method for each treatment. The regulation specifies that washing performance 1.03 must be met on average. If in future regulation this washing performance is still required, then according to one stakeholder it should be regulated for each treatment of the future programme portfolio. Additionally it is remarked that the reference for each programme must not be the required performance of the standard 60 °C cotton programme. The required performance of future programmes needs to be discussed

2. *It would be an interesting cost-saving option to streamline the existing methods for water preparation (e.g. in dishwashers, washing machines, washer-dryers, professional and household).*
   This statement is challenged by stakeholder feedback as there is just one standard EN 60734 which describes the way of water preparation for all products mentioned. The standard allows different water qualities as a starting point to be flexible and cost saving, but ensures comparability, repeatability and reproducibility

3. *The tolerances for the EMPA-certificates are too small.*
   This statement is challenged as the production of these stain strips is following the highest standards for these materials as prerequisite for low measurement uncertainty (low verification tolerances).

4. *The requirements for remaining moisture content (RMC) measurement are different for the ecodesign and labelling requirements. For labelling, the value of remaining moisture content is evaluated for a weighted mix of the standard cotton programmes, analogue to the procedure for the calculation of the energy consumption. For the product fiche, values have to be documented (and verified) for the "standard 60 °C cotton programme" at full load or the "standard 40 °C cotton programme" at partial load, whichever is the greater. Conversely in ecodesign the testing shall be done for every main washing programme at full or partial load, or both.*
   A harmonisation of the regulations is strongly supported by stakeholder comments.

5. *With respect to washer-dryers, the approach for integrating the drying function in the revised ecodesign and energy label requirements has to be discussed. For instance, two separate labels/scales might be needed (1 for the washing function and 1 for the drying function).*
   One stakeholder replies his preference to have a specific label for washer-dryers

6. With respect to the spin-drying efficiency, it is proposed by some stakeholders to introduce a minimum requirement. However this should be assessed also with respect to the market distribution of products in terms of spin-drying efficiency. Stakeholder comment that this may be discussed or the idea modified into an indication on the tumble-dryer suitability as spin dry efficiency is closely connected to the mechanical dimensioning of the appliances and offers a possibility for differentiation between types of models.

8.3. Input data ErP-EcoReport tool – Base case for Washing machines

Table 8.2: WM Inputs 'Materials extraction and production'

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Recyclable?
1	Stainless steel	17984	3-Ferro	26 -Stainless 18/8 coil	Yes
2	Steel sheet	7898	3-Ferro	22 -St sheet galv.	Yes
3	Cast iron	1779	3-Ferro	24 -Cast iron	Yes
4	Steel	866	3-Ferro	23 -St tube/profile	Yes
5	Aluminium	2347	4-Non-ferro	28 -Al diecast	Yes
6	Copper	1356	4-Non-ferro	29 -Cu winding wire	Yes
7	Copper wire (cable tree)	379	4-Non-ferro	30 -Cu wire	Yes
8	PP	2000	1-BlkPlastics	4 -PP	Yes
9	ABS	1740	1-BlkPlastics	11 -ABS	Yes
10	Elastomer EPDM	1468	1-BlkPlastics	1 -LDPE	Yes
11	Insulation (cable tree)	95	1-BlkPlastics	8 -PVC	yes
12	PET	22	1-BlkPlastics	10 -PET	yes
13	PE foil	15	1-BlkPlastics	1 -LDPE	Yes

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Recyclable?
14	Glass fibre filler for tub	6138	2-TecPlastics	19 -E-glass fibre	No
15	POM	126	2-TecPlastics	14 -PMMA	Yes
16	Talkum	121	2-TecPlastics	18 -Talcum filler	No
17	PMMA	46	2-TecPlastics	14 -PMMA	Yes
18	PA	24	2-TecPlastics	12 -PA 6	Yes
19	PUR	1	2-TecPlastics	16 -Rigid PUR	Yes
20	Circuit board	225	6-Electronics	98 -controller board	Yes
21	Concrete Weights	20186	7-Misc.	59 -Concrete	Yes
22	Glass	1870	7-Misc.	55 -Glass for lamps	Yes
23	**Packaging**				
24	Wood, Coated	2000	7-Misc.	57 -Cardboard	Yes
25	Packaging EPS	510	1-BlkPlastics	6 -EPS	Yes
26	Paper, Carton Packaging	210	7-Misc.	57 -Cardboard	Yes
27	Plastic foil PE	130	1-BlkPlastics	1 -LDPE	Yes
28	Paper	66	8-Extra	100-Office paper (from recycled paper)	Yes
	TOTAL	69603			

Table 8.3: WM Inputs 'Manufacturing and distribution'

Pos Nr	MANUFACTURING Description	Weight in g	Percentage Adjust	Category index (fixed)
201	**OEM Plastics Manufacturing** (fixed)	12438		21
202	**Foundries Fe/Cu/Zn** (fixed)	1779		35
203	**Foundries Al/Mg** (fixed)	2347		36
204	**Sheetmetal Manufacturing** (fixed)	25882		37
205	**PWB Manufacturing** (fixed)	0		54
206	**Other materials** (Manufacturing already included)	27158		
207	**Sheetmetal Scrap** **(Please adjust percentage only)**	1294	5%	38

Pos nr	DISTRIBUTION (incl. Final Assembly) Description		Answer	Category index (fixed)
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	60
209	**Is it an installed appliance (e.g. boiler)?**		NO	61
				63
210	**Volume of packaged final product in m^3**	**in m^3**	0.45	64
				65

Table 8.4: WM Inputs 'Use phase'

Pos nr	USE PHASE direct ErP impact Description		unit		Subtotals
226	ErP Product (service) Life in years	12.5	years		
	Electricity				
227	On-mode: Consumption per hour, cycle, setting, etc.	0.644	kWh	163,46	
228	On-mode: No. of hours, cycles, settings, etc. / year	220	cycles		
229	Standby-mode: Consumption per hour	0	kWh	0	
230	Standby-mode: No. of hours / year	0	#		
231	Off-mode: Consumption per hour	0	kWh	0	
232	Off-mode: No. of hours / year	0	#		
	TOTAL over ErP Product Life	1.77	MWh (=000 kWh)		66
	Heat				
233	Avg. Heat Power Output	0	kW		
234	No. of hours / year	0	hrs.		
235	Type and efficiency (Click & select)			86-not applicable	
	TOTAL over ErP Product Life	0.00	GJ		
	Consumables (excl, spare parts)			material	
236	Water	9.57	m^3/year	84-Water per m^3	
237	Auxilliary material 1 (Click & select)	16.5	kg/ year	121-Detergent - Washing machine	

238	**Auxilliary material 2** **(Click & select)**	0	kg/ year	**86 -None**
239	**Auxilliary material 3** **(Click & select)**	0	kg/ year	**86 -None**
240	**Refrigerant refill** **(Click & select type, even if there is no refill)**	0	kg/ year	**3-R404a; HFC blend; 3920**
	Maintenance, Repairs, Service			
241	**No. of km over Product-Life**	160	km / Product Life	87
242	**Spare parts** (fixed, 1% of product materials & manuf.)	696	g	1%

Table 8.5: WM Inputs 'Disposal and recycling'

Pos nr	DISPOSAL & RECYCLING Description											
253	product (stock) life L, in years	**12,5**										
		current	L years ago	period growth PG in %	CAGR in %/a							
254	unit sales in million units/year	16.6	**11.6**	43.1%	2.9%							
255	product & aux. mass over service life, in g/unit	276550	276550	0,0%	0,0%							
256	total mass sold, in t (1000 kg)	4590	3208	43.1%	2.9%							
	Per fraction (post-consumer)	1	2	3	4	5	6	7a	7b	7c	8	9

		Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc. , excluding refrigant & Hg	refrigerant	Hg (mercury), **in mg/unit**	Extra	Auxiliaries	***TOTAL (CARG avg.)***
263	EoL mass fraction to re-use, in %						**1%**			1%		**0%**	*0.2%*
264	EoL mass fraction to (materials) recycling, in %	29%	**29%**		94%		**50%**	**10%**	**30%**	**39%**	**60%**	**0%**	*9.7%*
265	EoL mass fraction to (heat) recovery, in %	15%	**15%**		0%		**0%**	**1%**	**0%**	**0%**	**0%**	**0%**	*0.8%*
266	EoL mass fraction to non-recov. incineration, in %	22%	**22%**		0%		**30%**	**0%**	**5%**	**5%**	**10%**	**0%**	*1.1%*
267	EoL mass fraction to landfill/missing/fugitive, in %	33%	**33%**		5%		**19%**	**88%**	**64%**	**55%**	**29%**	**100%**	*88.2%*
268	TOTAL	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100,0%*
269	EoL recyclability****, (click& select: 'best', '>avg', 'avg' (basecase); '< avg'.; 'worst')	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	***avg***
		0%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	

Table 8.6: WM Inputs for EU-Totals and LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**12.5**	years
B	Annual sales	17	mln. Units/year
C	EU Stock	201	mln. Units
D	Product price	€ 577.94	Euro/unit
E	Installation/acquisition costs (if any)	€ 0.00	Euro/ unit
F	Fuel rate (gas, oil, wood)	€ 0.00	Euro/GJ
G	Electricity rate	€ 0.21	Euro/kWh
H	Water rate	€ 3.98	Euro/m3
I	Aux. 1: Detergent - Washing machine	€ 2.67	Euro/kg
J	Aux. 2 :None	€ 0.00	Euro/kg
K	Aux. 3: None	€ 0.00	Euro/kg
L	Repair & maintenance costs	€ 45.00	Euro/ unit
M	Discount rate (interest minus inflation)	4%	%
N	Escalation rate (project annual growth of running costs)	4%	%
O	Present Worth Factor (PWF) (calculated automatically)	12.50	(years)

P	Ratio efficiency STOCK: efficiency NEW, in Use Phase	0.89

8.4. Input data ErP EcoReport tool – Base case for washer-dryers

Table 8.7: WD Inputs 'Materials extraction and production'

Pos Nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Recyclable?
1	Stainless steel	19369	3-Ferro	26 -Stainless 18/8 coil	Yes
2	Steel sheet	8506	3-Ferro	22 -St sheet galv.	Yes
3	Cast iron	1916	3-Ferro	24 -Cast iron	Yes
4	Steel	933	3-Ferro	23 -St tube/profile	Yes
5	Aluminium	2527	4-Non-ferro	28 -Al diecast	Yes
6	Copper	1460	4-Non-ferro	29 -Cu winding wire	Yes
7	Copper wire (cable tree)	409	4-Non-ferro	30 -Cu wire	Yes
8	PP	2155	1-BlkPlastics	4 -PP	Yes
9	ABS	1874	1-BlkPlastics	11 -ABS	Yes
10	Elastomer EPDM	1581	1-BlkPlastics	1 -LDPE	Yes
11	Insulation (cable tree)	102	1-BlkPlastics	8 -PVC	yes
12	PET	24	1-BlkPlastics	10 -PET	yes
13	PE foil	16	1-BlkPlastics	1 -LDPE	Yes
14	Glass fibre filler for tub	6611	2-TecPlastics	19 -E-glass fibre	No
15	POM	136	2-TecPlastics	14 -PMMA	Yes
16	Talkum	131	2-TecPlastics	18 -Talcum filler	No

17	PMMA	49	2-TecPlastics	14 -PMMA	Yes
18	PA	26	2-TecPlastics	12 -PA 6	Yes
19	PUR	1	2-TecPlastics	16 -Rigid PUR	Yes
20	Circuit board	225	6-Electronics	98 -controller board	Yes
21	Concrete Weights	20186	7-Misc.	59 -Concrete	Yes
22	Glass	1870	7-Misc.	55 -Glass for lamps	Yes

Pos Nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !	Recyclable?
23	**Packaging**				
24	Wood, Coated	2000	7-Misc.	57 -Cardboard	Yes
25	Packaging EPS	510	1-BlkPlastics	6 -EPS	Yes
26	Paper, Carton Packaging	210	7-Misc.	57 -Cardboard	Yes
27	Plastic foil PE	130	1-BlkPlastics	1 -LDPE	Yes
28	Paper	66	8-Extra	100-Office paper (from recycled paper)	Yes
	TOTAL	73023			

Table 8.8: WD Inputs 'Manufacturing and distribution'

Pos	MANUFACTURING	Weight	Percentage	Category index (fixed)

nr	Description	in g	Adjust	
201	**OEM Plastics Manufacturing** (fixed)	13347		21
202	**Foundries Fe/Cu/Zn** (fixed)	1916		35
203	**Foundries Al/Mg** (fixed)	2527		36
204	**Sheetmetal Manufacturing** (fixed)	27875		37
205	**PWB Manufacturing** (fixed)	0		54
206	**Other materials** (Manufacturing already included)	27358		
207	**Sheetmetal Scrap** (Please adjust percentage only)	1394	5%	38

Pos	DISTRIBUTION (incl. Final Assembly)		Answer	Category index (fixed)
nr	Description			
208	**Is it an ICT or Consumer Electronics product <15 kg ?**		NO	60
209	**Is it an installed appliance (e.g. boiler)?**		NO	61
				63
210	**Volume of packaged final product in m^3**	in m^3	0.45	64
				65

Table 8.9: WD Inputs 'Use phase'

Pos	USE PHASE direct ErP impact	unit	Subtotals
nr	Description		

226	**ErP Product (service) Life in years**	**12.5**	years		
	Electricity				
227	**On-mode: Consumption per hour, cycle, setting, etc.**	1.93	kWh	455,4	
228	**On-mode: No. of hours, cycles, settings, etc. / year**	220	cycles		
229	**Standby-mode: Consumption per hour**	0	kWh	0	
230	**Standby-mode: No. of hours / year**	0	#		
231	**Off-mode: Consumption per hour**	0	kWh	0	
232	**Off-mode: No. of hours / year**	0	#		
	TOTAL over ErP Product Life	**5.31**	**MWh (=000 kWh)**		66
	Heat				
233	**Avg. Heat Power Output**	0	kW		
234	**No. of hours / year**	0	hrs.		
235	**Type and efficiency (Click & select)**			86-not applicable	
	TOTAL over ErP Product Life	**0.00**	**GJ**		
	Consumables (excl, spare parts)			**material**	
236	**Water**	11.77	m^3/year	**84-Water per m^3**	
237	**Auxilliary material 1 (Click & select)**	16.5	kg/ year	**121-Detergent - Washing machine**	
238	**Auxilliary material 2 (Click & select)**	0	kg/ year	**86 -None**	
239	**Auxilliary material 3 (Click & select)**	0	kg/ year	**86 -None**	
240	**Refrigerant refill (Click & select type, even if there is no refill)**	0	kg/ year	**3-R404a; HFC blend; 3920**	

	Maintenance, Repairs, Service				
241	**No. of km over Product-Life**	160	km / Product Life	87	
242	**Spare parts** (fixed, 1% of product materials & manuf.)	730	g	1%	

Table 8.10: WD Inputs 'Disposal and recycling'

Pos nr	DISPOSAL & RECYCLING Description				
253	product (stock) life L, in years	12.5	Please edit values with red font		
		current	L years ago	period growth PG in %	CAGR in %/a
254	unit sales in million units/year	1	0.699	43.1%	2.9%
255	product & aux. mass over service life, in g/unit	280003	280003	0.0%	0.0%
256	total mass sold, in t (1000 kg)	280	195.7	43.1%	2.9%

Pos nr	Per fraction (post-consumer)	1	2	3	4	5	6	7a	7b	7c	8	9	
		Bulk Plastics	TecPlastics	Ferro	Non-ferro	Coating	Electronics	Misc., excluding refrigerant & Hg	refrigerant	Hg (mercury), **in mg/unit**	Extra	Auxiliaries	***TOTAL (CARG avg.)***
263	EoL mass fraction to re-use, in %	1%								1%		0%	*0.2%*
264	EoL mass fraction to (materials) recycling, in %	29%	29%	94%			50%	10%	30%	39%	60%	0%	*9.8%*
265	EoL mass fraction to (heat) recovery, in %	15%	15%	0%			0%	1%	0%	0%	0%	0%	*0.8%*

266	EoL mass fraction to non-recov. incineration, in %	22%	**22%**		0%		**30%**	**0%**	**5%**	**5%**	**10%**	**0%**	*1.1%*
267	EoL mass fraction to landfill/missing/fugitive, in %	33%	**33%**		5%		**19%**	**88%**	**64%**	**55%**	**29%**	**100%**	*88.1%*
268	TOTAL	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100.0%*
269	EoL recyclability****, (click& select: 'best', '>avg', 'avg' (basecase); '< avg'.; 'worst')	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	**avg**	***avg***
		0%	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	

Table 8.11: WD Inputs for EU-Totals and LCC

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**12.5**	years
B	Annual sales	1	mln. Units/year
C	EU Stock	8.56	mln. Units
D	Product price	€ 826.00	Euro/unit
E	Installation/acquisition costs (if any)	€ 0.00	Euro/ unit
F	Fuel rate (gas, oil, wood)	€ 0.00	Euro/GJ
G	Electricity rate	€ 0.21	Euro/kWh
H	Water rate	€ 3.98	Euro/m3
I	Aux. 1: Detergent - Washing machine	€ 2.67	Euro/kg
J	Aux. 2 :None	€ 0.00	Euro/kg
K	Aux. 3: None	€ 0.00	Euro/kg
L	Repair & maintenance costs	€ 45.00	Euro/ unit
M	Discount rate (interest minus inflation)	4%	%
N	Escalation rate (project annual growth of running costs)	4%	%
O	Present Worth Factor (PWF) (calculated automatically)	12.50	(years)

P	Ratio efficiency STOCK: efficiency NEW, in Use Phase	0.85

8.5. Full list of possible policy options for household washing machines

The following Table 8.12 provides a full list of possible policy options for household washing machines preliminarily discussed with stakeholders in the course of study. The policy instruments addressed are the Energy label (EL), generic and/or specific Ecodesign-measures (ED), standards and measurement methods (SM), as well as consumer information (CI) measures. Please note that these policy options for washing machines (WM) might also be of relevance for the washing function of washer dryers (WD).

Table 8.12: Full list of possible policy options for household washing machines

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
1a	The consumer survey reveals that the most efficient 'standard cotton 40°/60° programmes' are not used so much in real life, there are other most used programmes (mainly quick wash/short, normal 40°/60° and synthetic/easy care). One reason for this might be that the standard cotton programmes are often optimised by **increased programme duration** which is not convenient for consumers. Also, consumers don't believe that washing programmes with long cycles are energy saving (cf. 2015 survey results)	Cap for maximum **programme duration** of the standard cotton programmes (e.g. 2-4 hours? during the stakeholder meeting 2 hours were suggested, 4 hours would allow better differentiation between appliances on the market - stakeholders' views are welcome)	ED	Unrealistic cycle times will be avoided. Better acceptance: Consumers might use the standard cotton programmes more often if the cap is rather short and convenient (e.g. 2 hours). On the other hand, a more flexible cap (e.g. 3 hours) would leave enough freedom for manufacturers for differentiation. The increase of energy consumption if the programme duration is shortened (see drawbacks), however, should not have an effect under real life conditions as at the moment the (very efficient) standard cotton programmes are hardly used. It can also be an incentive for manufacturers to find other possibilities to reduce the energy consumption than just increasing the duration. Despite a cap, manufacturers still can offer longer and thus more energy saving programmes (as an extra/competitive feature). However this should not be the 'standard programme' as people are not willing to use it as 'standard' if it is too long. Therefore the standard-programme should somehow be regulated (time cap, temperature prescription, duration on label,…). Damages of laundry might decrease (cf. option 11)	If the cap of the programme duration is too strict, machines might not differ any more in their energy consumption (especially in combination with fixed temperature). Energy consumption in the standard cotton programmes would increase or maximum loading capacity will decrease. Consumers which would generally accept longer programme times would not find programmes which are really saving a lot of energy. Other short programmes will be preferred further on. New innovation / developments are possibly prevented (e.g. efficient small heat pumps need longer programme durations until they reach their stationary operating mode). The accuracy of measuring the rinsing performance has to be increased to avoid workarounds circumvention (the effect could be a shortening of rinsing cycles by increasing the washing time to reach the same washing performance at shorter cycle times, i.e. worse rinsing performance or higher water consumption).

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
1b	cf. 1a	**Information about the maximum (average) programme duration of standard cotton programmes** on the Energy Label (for example, for tumble dryers the duration of the longest label programme is indicated)	CI / EL	Consumers might use the standard cotton programmes more often; better consumer information before a purchase decision; consumers might choose WM/WD with shorter cycle times which might lead to an overall market shift / competition towards machines with shorter cycle times (even more than a cap) and thus stimulating manufacturers to reduce the time, driven by competition, i.e. with other innovations to reach better Energy efficiency classes Already in place in the Energy label for tumble dryers	Overload of label information; with this explicit information, consumers might choose machines with shorter programme durations resulting in higher energy consumption. There is a need to be further discussed, i.e. how to come up with a relevant information about the cycle time (average time, time per treatment, time for full-load, time for half-load,…). The accuracy of measuring the rinsing performance has to be increased to avoid workarounds circumvention (the effect could be a reduction of rinsing cycles to reach shorter cycle times, i.e. worse rinsing performance or higher water consumption).
1c	cf. 1a	**Adjust measurement standard so that long programme times** do no longer add benefit to reach the required average washing performance > 1,03 (may be done for instance by rearranging the test strips into separate evaluation of the five soilings)	SM	Reduction of the benefit of long runtimes in the standard measurement might lead to a reduced programme time for standard cotton programmes of today; further also better consideration of the real household soilings.	No clear evidence of this effect. Still the standard cotton programmes might not be used sufficiently in real life.
1d	cf. 1a	Better / mandatory **consumer information about the environmental benefits of a longer programme duration** in terms of energy savings (e.g. leaflets, stickers, educational campaigns, …) which also results in economic benefits for consumers when using primarily the efficient standard cotton programmes (for cotton wash).	ED/CI	Consumers might use the standard cotton programmes more often (i.e. overcome the misperception of consumers that longer programmes consume more energy)	Consumer information is difficult to be regulated by Ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer information measurements)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
2a	Standard cotton programmes are often optimised by **decreasing the wash temperature compared to the declared ones**; consumers might rather choose the 'normal' 40°/60° programmes.	**Prescribing the declared temperatures to be reached** at least for the standard cotton 60° programme for a certain time, e.g. 10 minutes. In general, the temperature prescription should not be limited to the standard programme(s) only (even though it is likely that the machines reach the declared temperatures in other than the standard programmes anyway). The same approach as decided for WM should be applied to WD	SM	Consumers might use the standard programmes more often when they can rely on the indicated temperatures. Consumer transparency: credibility and comparability increases; especially in households where besides the washing performance also hygienic aspects are relevant more often, people rely on the fact that the temperature of the 60 °C programme is reached (i.e. hygiene might be improved). This is supposed to be necessary for e.g. the proper elimination of mites, lice/lice eggs, nematodes/nematode eggs.	From a functional point of view the required washing performance level is reached by these (lower temperature) programmes as well. Machines might not differ any more in their energy consumption (especially in case of combination with a cap of the programme duration). The energy consumption of the standard cotton 40°/60° programmes would generally increase although hygienic issues requiring 60 °C for a certain time might occur rather seldomly. Temperature measurement needs to be done inside the load to ensure the real temperature is measured. However, so far no standard test method exists to measure the temperature insight the drum/load of household WM/WD, but only for the temperature of the water supply (proposals are under discussion in standardization working groups). For professional machines a measurement method has already been developed. This could be a basis for the development of a measurement method for household appliances. However, precision of data loggers has to be taken into account. In general, rather than putting constraints for the washing temperature (measurement), the use of lower temperatures to decrease the energy consumption should be promoted.
2b	cf. 2a	**Renaming of the standard cotton 40°/60° programmes** by indicating the 'true' temperatures which are maximum reached.	ED	Better transparency to consumers.	Shift in consumer thinking (definite temperatures) needed; the reduction level of temperatures might be rather different for different manufacturers / machines; also alignment to textile labelling (indicating the maximum possible temperatures the laundry may be treated), as the initial definition of washing temperature was related to the capability of washing clothes without damaging them and following the recommendation of the clothes label not to the real washing temperature.
2c	cf. 2a	Better **consumer information:** Manufacturer shall inform about the fact that real temperatures might deviate from the declared ones. Education that under 'normal' circumstances when only a certain wash performance is necessary, lower temperatures	ED/CI	Consumers might use the standard programmes more often	Consumer information is difficult to be regulated by Ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer information measurements

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		are sufficient. Clear indication which programme(s) is/are applicable especially for hygienic needs.			
3a	The consumer survey reveals that the **most efficient 'standard cotton 40°/60° programmes' are not the most used ones** in real life; these are rather the normal 40°/60° and 30° cotton, quick wash/short, and synthetic/easy care programmes. Also, there is a tendency towards use of lower temperature programmes.	Define / **keep the 'most efficient' programme(s) as ED/EL programme(s)** (business-as-usual). **Re-name it ECO** for WM/WD (as already common for dishwashers).	ED / EL / SM / CI	Clearer identification of the energy saving programme(s) for consumers; the term ECO is already introduced and common for DW.	This option is less representative for real-life usage (other programmes are per se more often used), thus the effect on real-life usage could still be minor (only ecological oriented consumers, not mainstream) due to long programme durations etc.
3b	cf. 3a	Additional requirement to avoid circumvention: **Other programmes for the same washing item & temperature** (i.e. 'normal' 40°/60° cotton programmes) **shall use not more than 20% more energy** than the standard programmes	ED / EL	Cap on energy consumption of other often used programmes	Must be verified and would thus add costs
3c	cf. 3a	Additional requirement to avoid circumvention: Prescribing that WM/WD **offer only one programme** for the same washing item & temperature	ED	Avoids the current washing machine situation where the main programmes are duplicated to reach better energy label classes	Prevents product innovation / market variety / consumer choices

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4a	cf. 3a	Define the **'most used' programme(s) as standard programme(s)** (not the 'most efficient' ones): Taking those programmes which are recommended by the manufacturer for the wash of normally soiled cotton articles at 40 °/60 °C, i.e. **todays 'normal' 40 °/60 ° cotton programmes without setting further requirements on programme duration or temperature** (cf. options 1 and 2). (=> taking those programmes which consumer already today use/want) Keep the name 'standard programme', not using the term ECO as it might not be the most efficient programme of the machine.	ED / EL / SM / CI	Better alignment to real-life conditions: The normal cotton programmes are still the most used washing programmes for 40° and 60° washes. The real life programmes for these articles would be used for declaration, i.e. skipping the approach of developing special programmes only for the energy label.	The 'most used programme' is different for each consumer. Consumer behaviour changes frequently due to public discussions/issues, i.e. variance and heterogeneous consumer groups. Programme application also varies for particular washing machines. Consumer choice of most used programmes might change in near future: the 2015 consumer survey shows the use of washing machines currently IN STOCK, which is presumably different to how people would use a NEW machine (e.g. washing machines in stock not necessarily have the arrow to indicate the standard programmes, also a 20 °C programme was mandatory only from 2014 onwards, etc.). Energy consumption on the label will be much higher as today. However, under real life conditions the consumption will not change only by increasing the declared consumption. Consumers use these programmes already today without their energy efficiency being regulated. There may be programmes which allow saving energy, but consumers may not be sufficiently informed or motivated to use them. Manufacturers may declare new programmes which the consumer may prefer to use, like 'Cotton 60 °C short'
4b	cf. 3a	**Include further wash programmes** (e.g. short/quick wash or delicate/synthetics) into the current test procedure and calculation formulae for energy and water consumption of the standard programmes.	ED / EL / SM	Better alignment to real-life conditions according to the spread of most used programmes; realizing further improvement potentials of Ecodesign/Energy labelling measures (e.g. incentive to improve the other - often used - programmes as well)	Increasing testing effort. The resulting energy/water consumption declared on the label would be an average of even more tested programmes thus diluting the 'real' consumption values of the single programmes

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4c	cf. 4a	**Change the programme selection for test cycles** (e.g. from 3:2:2 test cycles at 60 °C full : 60 °C half : 40 °C half to 3:2:2 test cycles at 40 °C full : 40 °C half : 30 °C half or, alternatively, adding further 30 °C test cycles to the current 40 °C and 60 °C cycles). For WD, the same approach as decided for WM should be applied.	ED / EL / SM	According to the 2015 consumer survey, 40 °C programmes are mostly used, 30 °C nearly the same as 60 °C programmes; i.e. better alignment to real-life user behaviour. In general, high temperature cycles should be dedicated to special purposes only.	The total average energy consumption indicated would be lower just by changing the calculation formula, not by improving the machines. The temperature and thus consumption differences between 40 °/30 °C are rather small. 60 °C is the most energy consuming programme and still used by consumers, e.g. for disinfection of machine and/or textiles. This programme might then not be energy optimised any more if taken out of the calculation, but it is still used to a certain extent (7% standard 60 °C cotton, 11% normal 60 °C cotton). 40 °C is suitable for many cotton and cotton blend items, but bleaching with today's detergents still demands for higher temperatures, best around 60 °C. Further alternative options do not seem to be justified: 40 °/20 °C would leave out the most energy consuming programme as well; 60 °/30 ° would leave out the most used 40 ° programme.
4d		Each **separate declaration of the energy consumption of the 60 ° standard cotton programme and the 40 ° standard cotton programme** instead of an average weighted mix on the Energy label	ED / EL / CI	More transparency to consumers with regard to real consumption values of the programmes at a first glance (EL, not only in the manual); ideally further shift towards use of lower temperature programmes; each programme might be optimized individually, not only the weighted average	The uncertainty of measured values might increase due to less number of test cycles per programme (compared to todays 7 total cycles); or higher test burden for manufacturers / market surveillance authorities due to increasing number of test cycles needed for each of the programmes.
5a	cf. 4a	<u>**Completely new definition of an ECO programme**</u>: Define an Eco programme for WM and the washing function of WD which can wash normally soiled cotton labelled textiles for 40 °C and 60 °C *together*. No limit on time, but indication of programme time on the label. Offering a cleaning level of a 60 °C programme and therefore replacing it. The maximum temperature (measured in the load) shall be 43 °C to ensure that 'cotton 40 °C' labelled textiles can be washed (this is the maximum temperature a textile labelled	ED / EL / SM / CI	Provides a clear option to the consumer to choose an energy saving programme. Real life saving as - it allows the use of the higher capacities, i.e. better utilizing the drum loads by combining separate loads which can be washed at 40 °C or 60 °C; - the wash temperature is lower than 60 °C (60 °C can be avoided); - by indication of the programme time on the label unrealistic cycle times will be avoided, i.e. consumers might use this programme more often - better identification for consumers: under the assumption that the consumers are willing to wash as environmental friendly as possible it makes sense to name it 'eco' to quickly identify the most efficient programme	New thinking of consumers is necessary. Temperature range for Textile Care Labels (40 °C, 60 °C) which can be washed in this programme needs to be communicated. The change in philosophy for the programme name might not be understood by consumers. To address hygienic issues it still would be necessary to guarantee that the declared temperature of other programmes, e.g. 60 °C cotton is really reached. So consumers would be able to choose between (1) wash most environmental friendly or (2) (in certain circumstances) wash hygienic and be sure to eliminate pathogenic germs and/or parasites. Precise rinsing performance measurement needed to avoid circumventions.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		for 40 °C should be washed). Call (only) this programme 'ECO' for indication of ecological benefits. Test procedure: e.g. 3 x full load + 4 times half load in Eco cycle (instead of 'half' load, a fixed low load could be possible, e.g. 4 kg). This measure should be accompanied with intensive consumer information / education of the feasibility and ecological benefits of mixing cotton clothes together, the meaning of the maximum temperature etc.			
5b	cf. 4a	**Completely new definition of an ECO SHORT programme**: Define an Eco programme for WM and the washing function of WD which can wash all **lightly soiled** cotton labelled textiles for 40 °C and 60 °C *together,* **programme duration <1h** The maximum temperature (measured in the load) shall be 43 °C to ensure that 'cotton 40 °C' labelled textiles can be washed (this is the maximum temperature a textile labelled for 40 °C should be washed). Call (only) this programme 'ECO SHORT' for indication of ecological benefits. Test procedure: e.g. 3 x full load + 4 times half load in Eco cycle (instead of 'half' load, a fixed	ED / EL / SM / CI	cf. 5a	cf. 5a Consumers may still choose other programmes, especially for non-cotton items

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		low load could be possible, e.g. 4 kg). This measure should be accompanied with intensive consumer information / education of the feasibility and ecological benefits of mixing cotton clothes together, the meaning of the maximum temperature etc.			
5c	cf. 4a	Alternative option: taking into account the **cotton programme for normal soiled textiles labelled 30 °C** (that is suitable also for textiles with higher temperatures) with **different load sizes** (for example: full load, 70% load and 30% load), in order to align testing to the most used programmes by consumer and consumer habits as shown in market research done by AISE and Bonn University	ED / EL / SM / CI	Better alignment to real-life conditions: This programme is claimed to be used frequently as shown in the studies. Detergent products for lower temperatures are available. The energy reduction might be higher in the EU (provided that consumers really use this lower temperature programme compared to todays 40 °C/60 °C programmes). The single test programme will enhance the alignment with the washer dryer testing and will simplify the overall testing procedure.	cf. 5a Consumers may choose other programmes, especially for non-cotton items

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
6a	The **most efficient** standard cotton 40°/60°C **programmes** are **often not easy to find** between the lots of programme choices	**Default setting of the future 'standard programme**' for household WM/WD equipped with automatic programme selection or any function for automatically selecting a washing programme or maintaining the selection of a programme	ED	Consumers might use the standard programmes more often	Since Jan 2014 implemented for DW; so far no evaluation on impact of this measure. For WM/WD more difficult as far more textile types / wash programmes exist (also for WM currently not one single standard programme, but 60 °C/40 °C). Making mandatory to have a standard programme as default setting would cause inconvenience to consumers as they would have to change programme every time they would use the appliance for other purposes than washing cotton textiles, i.e. consumers might try to overrule this setting easily. Some WM/WD still have mechanical programme selection. Having a standard programme as default setting would be easier for machines with electronic displays/selection while it would add design burdens for appliances with mechanical programme selection. Such requirement would also limit temperature selection. For WD, the drying cycle cannot be default.
6b	cf. 6a The most efficient programmes are today indicated by the arrow on the control panel. Based on consumer feedback, the symbol is not really understood by customers and can therefore hardly contribute to identify the most energy saving program.	**Change the current indicator symbol** (arrow, 'standard cotton...') for the standard programmes, e.g. into 'Eco' as already applied for DW Alternative: 'Energy saving programme'	ED	Consumers might find and use the standard programmes more often. Other signs/terms like 'eco' are better known from the campaign of the washing temperature reduction from 90 °C to 60 °C in the 1990's. The formerly used eco concept might be applicable for the future also, thanks to its link with environmental (ecological) aspects. This is supported by the Dishwasher regulation, which is using Eco and not the arrow.	Changing the control panels would imply large extra costs for the industry. Not all washing machines have control panels with text language to display 'ECO', there are models only with symbols. Manuals would also have to be adapted as it would require new explanations to be found. Finally, applying this proposal would confuse consumers who are now getting used to the current symbol. Changing it again would require starting new education campaigns. The term 'ECO' would only make sense if the standard programmes are the most efficient ones (cf. options 3 and 5 versus option 4)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					The currently required arrow solution might be kept / allowed additionally to avoid rework of control panels.
7a	According to the 2015 consumer survey, only 4% of consumers use the **mandatory 20 °C programmes**; one reason might be consumers suspecting lower wash performance	Inclusion of measurement of **wash performance level of 20 °C** wash programmes in performance standard and information about wash performance level of 20° wash programme (e.g. booklet, label)	SM / CI / (EL)	Consumers might trust and use the low temperature programmes more often. At the moment, it is only an alibi requirement being fullfilled formally but not used in the practice. Some of these cycles are short, others long, some refresh, others are performance cycles, so communicating clearly on what consumers can expect with the 20 °C cycle will be crucial.	In general, consumers should not expect the same washing performance as for 60 °C programmes; cold washing - even with high cycle durations - can only partly fulfill expected washing results such as removing stains, dirt, germs etc. An inclusion of 20 °C wash performance into the overall wash performance of the WM/WD would decrease the possibility to differentiate between machines. The results of the 2015 consumer survey shows the use of washing machines currently IN STOCK, which is presumably different to how people would use a NEW machine (e.g. a 20 °C programme was mandatory only from 2014 onwards, i.e. it might be that the machines of the consumers participating in the survey did not have a 20 °C programme at all etc.). Increased test burdens.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
7b	cf. 7a	Require minimum **wash performance level for 20 °C** wash programme	ED	Consumers might trust and use the low temperature programmes more often	cf. 7a Specific low temperature detergents which might enable a better wash performance at 20 °C are not included in the performance standard measurement; however: specific low temperature detergents might not use special ingredients at all (only marketing). Avoid circumvention of using detergents with chemicals more harmful than common detergents.
8a	Consumers often do not know that a certain minimum **washing performance for the standard programmes** is mandatory and might mistrust the performance especially when getting knowledge about longer times and lower temperatures in these programmes. Tests found that longer lasting programmes deliver better washing results.	**Declaration of the average washing performance (mandatory A class) for the standard cotton programmes** provided on the label again. Proposal: a classification of the washing performance / efficiency should be reintroduced only as a fixed mark on the label	CI / EL	Confirmation of good washing performance in standard programmes might lead to consumers choosing these programmes more often despite knowledge about longer duration / lower temperatures	Overload of label information
8b	cf. 8a	**Require that the washing performance of A is reached in the different programmes tested** (60 °C full/haf and 40 °C half).	ED / CI (/EL)	Better consumer transparency; the overall washing performance might improve	Uncertainty of verification might become higher as fewer number of wash cycles contribute to the measurement of each the single programmes (2 or 3 instead of 7). Level of performance needs to be determined for each programme (currently, the washing performance 1.03 must be met on average only; the reference for each programme (or a future standard programme) may not obligatory be the

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					required performance of the standard 60° cotton programme for all tested programmes).
8c	Both liquid detergent and powder detergents exist on the market (with a majority of liquid detergent being used, and those not containing an active oxygen bleach system to date)	Use of a modern **reference detergent** for the performance cycle matching the reality of the market use (and thus, notably **liquid**)	SM	Better alignment to real-life conditions	Cost and availability of standard detergents ensuring repeatability and reproducibility of tests.
9	The **quality of rinsing of residues of detergents** is important for consumers, especially for those being sensitive due to allergies. Certain requirements (e.g. caps on water consumption or on programme duration) might worsen the rinsing quality as for example the number of rinsing cycles might be reduced to save water and/or programme time. Consumer tests (e.g. OCU 03/2015) report about unsatisfactory rinsing performance in the tested appliances.	Introduce **rinsing performance** for WM/WD (possibly minimum requirement, e.g. at least 2 rinsing cycles; indication on EL), continuing the work to ensure the robustness of the rinsing standard for WM. The rinsing performance should not be classified only on the EL, but have a required minimum performance.	SM / ED / EL	Consumers get a guarantee of a certain minimum rinsing performance in the standard programmes, i.e. energy efficiency gains are not realized at the expense of rinsing performance. The so called 'LAS' standard method currently under development by CENELEC SWG 1.8 and IEC WG20 is most likely also applicable for washer-dryers, whereas the currently known alkalinity method would not be applicable for WD.	So far, no measurement standard exists (because of reproducibility reasons). Additional testing effort for manufacturers and also market surveillance authorities. Possibilities of circumvention can be achieved for instance through a wash cycle with bad rinsing which would leave detergent in the load and would thus increase the performances of the next cycle thanks to the accumulated detergent.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
10a	Complaints about **odours of laundry**, e.g. caused by frequent washing cycles at lower temperatures with liquid detergents	Introduce **hygiene performance** for washing machines (possibly minimum requirement, indication on EL; for consumer information requirements cf. also option 17a)	SM / ED / EL / CI	Important information for (sensitive) consumers; might reduce ecological 'rebound effects' that consumers start choosing additional or stronger detergents, additional rinsing cycles or similar to prevent those odours	High test effort (microbiological analysis) and less experiences, there is up to now no international standard, the repeatability and reproducibility of draft methods (PAS) would have to be checked. The germ reduction potential of washing machines is already generally high (no need for quantified evaluations). There are washing cycles available up to 90 °C. For washer-dryers, there is also additional germ killing during drying because of high temperatures.
10b	cf. 10a	**Consumer information about best practice / possibilities to avoid odours** of the laundry (using cycles at higher temperatures from time to time)	CI	cf. 10a	Consumer information is difficult to be regulated by Ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer information measurements
11	Especially during very long cycle times (e.g. 6 hours), the mechanical action (drum repeatedly turning around) might lead to increased **damage of textiles** (resource efficiency)	Introduce a '**Gentleness of Action**' for WM/WD measure to avoid too much damage of the textiles. Set a limit value	ED / EL / SM	would reduce the possible programme time	There is no clear evidence that programme length is causing damages. Textile is damaged not only by mechanical action but also by temperature and chemistry, longer cycles at lower temperature are not necessarily worse than shorter cycles at higher temperature with high detergent concentration. Cotton is a fabric that can be treated with more mechanics than other fibres. Drum washing machines are already very gentle in comparison to tub washing machines (Asian style or US-style). Additional testing cost if one more test watch is needed. Several methods exist to measure textile damages during the washing process at international level which, however, have to be updated and included in the 6th edition of the IEC 60456; repeatability / reproducibility are low. All

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					manufacturers are using these methods and are already taking care of mechanical actions and textiles protection, and machines are generally designed to take care of textiles. Thus, there might be no added value of having requirements on textile damages.
12a	The spin drying efficiency (remaining moisture content RMC) not only depends on the maximum spin speed (rpm), but also on the drum size (larger drums cause higher centrifugal forces at same spin speeds compared to lower drums). The spin drying performance is an important information to consumers for the subsequent drying process.	Introduction of a minimum requirement for **spin drying efficiency** (remaining moisture content RMC) of the standard programme(s), e.g. class A.	ED / EL / CI	The better the laundry is spun, the less water it contains and the faster goes drying - in case of a tumble dryer being used, well spun laundry is a measure to reduce the energy demand of the subsequent drying process considerably (and in general, a strong trend to tumble drying can be observed).	According to a OCU consumer test report of March 2015, models with 1,000 and 1,200 rpm eliminate half the humidity from the clothes and machines with 1,400 rpm eliminate 60% of this humidity; however, these additional rpm might not be particularly useful (if not further drying the clothes in a very humid place), but contribute to more wrinkling of the laundry. Spin drying efficiency is closely connected to the mechanical dimensioning of the appliances and offers a possibility of differentiation between types and models. A strict requirement would limit such differentiations. Still, most of the laundry is dried in the outside air / on a line, and high spin speeds are only recommended when using a tumble/washer dryer
12b	cf. 12a	**Mandatory consumer information on spin speed** depending on the subsequent drying process, e.g. within the fiche: 'For tumble-drying / washer dryers please use a higher spin speed; for outside line-drying please use a lower spinning speed.	ED / CI	cf. 12a	cf. 12a

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
12c	The requirements for remaining moisture content measurement are different for the ecodesign and labelling requirements. For labelling, the value of remaining moisture content is evaluated for a weighted mix of the standard cotton programmes, analogue to the procedure for the calculation of the energy consumption. For the product fiche, values have to be documented (and verified) for the 'standard 60 °C cotton programme' at full load or the 'standard 40 °C cotton programme' at partial load, whichever is the greater. Conversely in ecodesign the testing shall be done for every main washing programme at full or partial load, or both.	Aligning ED / EL requirements to the same basis	ED / EL	Better consistency	None

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
13a	**Trend towards increasing drum volumes vs. non-increasing size of households/loads**: The overall trend to higher capacities might offset (at least partly) the efficiency gains due to their better efficiency classes as the absolute energy consumption of larger machines might be similar compared to that of smaller ones. In addition, the situation could be worse under real life conditions as the real life loading is expected to be rather lower and different from the declared rated capacity measured under standard conditions. Also, for programmes and loads other to standard conditions, large (and hence 'efficient') WM/WD can even lead to energy wastage: if they do not adapt water and energy consumption to the effective load, for all programmes and loads, more energy is used by larger machines.	**Cap for absolute energy consumption** independent of the rated capacity	ED	More smaller machines with less absolute consumption in real life; no thrive for bigger machines just to reach a better Energy label class	No clear evidence of this effect and hard to justify any change

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
13b	cf. 13a	**Cap for absolute water consumption** independent of the rated capacity (in the current formulae, there is a dependency of the rated capacity)	ED	Higher presence on the market of smaller machines with lower absolute consumption values in real life.	Further reducing the water consumption might lead to worse rinsing performance (only a minimum washing performance is mandatory), cf. also option 9 on rinsing performance. Less water consumption is important, in particular in some countries, but as there is no requirement on rinsing performance, it may imply worse rinsing performance. This can lead to increased consumption if consumers use an extra rinse or smaller loads, and to more allergies / hypersensitivities (especially in cold climates with low indoor relative humidity in winter). Thus, a cap on the water consumption should only be done together with a minimum requirement on rinsing performance.
13c	cf. 13a	**Different calculation formulae** for smaller and larger machines, being stricter for machines with a larger rated capacity	ED / EL	Higher presence on the market of smaller machines with lower absolute consumption values in real life. Avoiding the today's effect of the linear efficiency approach that good efficiency classes can be reached more easily by increasing the capacity than by efficiency improvements that lower the machine's energy consumption.	No clear evidence of this effect
13d	cf. 13a	**Progressive (bended) curves** / calculation of EEI, i.e. stricter for machines with a larger rated capacity	ED / EL	cf. 13c	cf. 13c

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
14a	The 'standard load' being the basis for the rated capacity of the machine is difficult to reach under real life conditions (other / different kinds of laundry). Under standard test conditions, sensors (adapting energy & water consumption better to the real life conditions) have to be switched off.	Allow **sensor use in the measured standard programmes**.	ED / SM	Real life has normally less load. Machines equipped with intelligent sensors should be able to adapt the programme accordingly and realize savings.	Sensors are not measured in the standard programme performance test so far, i.e. no effect on EEI; the current evaluation method using average values calculated out of results from full and half load is not suitable to show the load adaptation function provided by sensors. To have an effect, different treatments with different load amounts must be evaluated separately. Sensor use is difficult to measure (reproducibility). Price of low cost machines might increase if sensors (with a certain quality) become mandatory. Having partial loads included in the test procedure might also give a wrong signal to consumers as it may encourage them even more to use their appliances half loaded.
14b	cf. 14a	Based on load detection / sensor use in measurement of standard programmes: **Specific requirements on energy and water consumption for half-load** of the standard programmes compared to full load (e.g. the consumption in half-load has to be at least xy% lower than full-loaded). Alternatively: **Consumer information (e.g. saving percentage)** of half-load consumption (label, fiche, …), i.e. overcome the misperception that there is a 'linear' reduction of water/energy when using	ED / EL / CI	Real life has normally less load compared to the standard load. Machines equipped with intelligent sensors should be able to adapt the programme accordingly and realize savings. Minimum requirements would lead to a minimum performance of the quality of load sensors. Consumer information will receive the message to wash full loads if possible	cf. 14a Today, half load consumption values are not visible to consumers due to the average value. Difficult to achieve due to necessary basic consumption with any load independent from load size. Prescription of savings could lead to higher energy consumptions with full loads to fulfill such regulations.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		'half load'.			
14c	cf. 14a	Direct **feedback on actual load** to consumers **via display**	ED / CI	Possibility to influence consumer behaviour / increase real-life loading	Not all appliances are equipped with a display so far; communication of such information can only be done with special displays (control panel with text language, TFT e.g.). Such indications would be subject to certain tolerances which would make to only rough estimations; the more accurate it is required to measure, the more costly would be the technology to measure. Significant raise of the appliance prices expected, especially on low range models; would not help improving resource efficiency (more materials needed for display); impact is not clear (if consumers are really changing their behaviour).
14d	cf. 14a	Measurement and declaration of energy consumption (and water) at a **fixed amount of load, e.g. 3, 3.5 or 4 kg laundry**, or introduction of a 'small-load' (2 kg or less). At least instead of 'half load' - the terminus might be replaced e.g. by 'average load'; could also be taken for all cycles (assuming that real-life 'full load' is also only filled with maximum 4 kg laundry	ED / SM / EL	Better alignment to real-life conditions - currently, the tests are based on half-load which, for very big appliances (e.g. 13 kg machines), is still far above from the known 'average' load figure of 3.5 kg. This may help to stop the trend of increasing sales of large capacity machines which are apparently more efficient at full load conditions only. It might offer an incentive to optimise machines for small loads from an energy perspective. Number of test cycles might be reduced if *all* standard programmes are measured at 4 kg instead of spread between full/half load.	No clear evidence of this effect. Loading would be underestimated if users were able to actually fill half of the rated capacity. Today, half load consumption values are not visible to consumers due to the average value.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		compared to the standard load)			
14e	cf. 14a	**Increase the share of partial load in the EEI calculations and differentiate by declared nominal loads**: e.g. to prescribe 2 quarter loads (25%) instead of 1 half load with machines from a particular nominal load (e.g. >8kg). 2 full loads (nominal loads) should however remain to prevent unrealistic declarations	ED / EL / SM	Partial loads would have higher influence in the EEI calculation for ED/EL for machines with higher loads. Better alignment to real-life conditions - currently, the tests are based on half-load which, for very big appliances (e.g. 13 kg machines), is still far above from the known 'average' load figure of 3.5 kg. This may help to stop the trend of increasing sales of large capacity machines which are apparently more efficient at full load conditions only. It might offer an incentive to optimise machines for small loads from an energy perspective.	No clear evidence of this effect. Today, half load consumption values are not visible to consumers due to the average value.
14f	There exist no normative demands on how to define and declare the capacity of a WM/WD. Thus, a mechanically similar model can be sold with different capacities (however, the electronics and programmes would be adjusted to account for the different maximum load sizes).	Require a **standard measurement of the volume** as described in the existing standard IEC 60456 and to define a clear formula with a conversion factor from volume into capacity (load in kg)	SM	The capacity has direct influence on the Energy Efficiency Index EEI. A standard definition of the capacity helps to avoid declaring same machines just with higher rated capacities to gain a better Energy label class.	US legislation refers to the drum volume. On the one hand, reference to volume makes requirements independent of the textile type. On the other hand, it is more difficult to address issues like half-load, or the dependency of wetting (and water consumption), spinning and drying on the textile type. However, the drum volume is not the only element determining the capacity. Other components of WM/WD have to be suitable for the capacity claimed. Application of different technologies and intelligent treatment techniques allow the treatment of different load amounts which can be significantly higher than the calculated capacity based on the

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					drum volume. Thus, interlinking certain drum volumes by a conversion factor to a fixed load capacity of the machine is not reasonable.
15a	**Standby consumption** is covered by Ecodesign regulations 1275/2008 and 801/2013 on standby/networked standby anyway; low contribution to total energy consumption; according to 2015 consumer survey, most consumers 73% always switch off their appliance immediately or after unloading; for additional 13% the appliance switches itself off.	**Leave standby**-values totally out of the calculation formulae	ED / EL / SM	Simplifies the measurement which saves costs for manufacturers and market surveillance authorities. The regulated modes can be eliminated from the EL evaluation as they will not contribute to the differentiation of machines on the market. Better alignment to real-life usage, as the current calculation procedure in the regulation assumes that in 50% of the cycles the consumer does not switch off its appliance.	The energy consumption of the standby modes might be enough - at the annual level - to pass from one energy efficiency class to another (if not taken into account any more)
15b	cf. 15a	**Business as usual: Keep standby-values** within the calculation formulae for the total annual energy consumption	ED / EL / SM	The energy consumption of the standby modes might be enough - at the annual level - to pass from one energy efficiency class to another (if not taken into account any more)	Test burdens

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
15c	**Delay start** is not covered by Standby-regulation as it is not an 'unlimited' mode; delay start might become more relevant in the context of smart appliances / smart-grid-ready appliances	Include **delay start mode** into standby measurement / calculation of machine's total energy consumption	ED / EL / SM	Might avoid delay start modes with high wattages. Assuming 8 hours delay for each cycle with 5 or 10 W could contribute to a relevant extent to the total annual energy consumption. If taken into account, the energy consumption of the delay start mode might be enough - at the annual level - to pass from one energy efficiency class to another	This mode is assumed to have only minor contribution to the overall energy consumption of the machine. May lead to a less acceptance of delay start-mode. Higher test burden (for manufacturers and market surveillance authorities) if measurement in an extra test cycle would be needed. Definition of a standard delay time may be challenging.
15d	cf. 15c	**Set MEPS / power cap for delay start mode** as it is the case for standby mode, e.g. a maximum of 2W.	ED	Avoids delay start modes with high wattages. Assuming 8 hours delay for each cycle with 5 or 10 W could contribute to a relevant extent to the total annual energy consumption.	This mode is assumed to have only minor contribution to the overall energy consumption of the machine. May lead to a less acceptance of delay start-mode. Higher test burden if measurement in an extra test cycle would be needed. Ideally, this mode would also be covered by the horizontal Ecodesign regulation(s) on standby (1275/2010 and 801/2013)
15e	cf. 15c	Provide **'bonus / allowances' on delay start consumption** for WM/WD with smart-grid functionality (at least for a certain time of market introduction)	ED / EL / SM	Smart-grid ready appliances are an important instrument within the total energy transition system and thus should be favoured; too strict limit values might hinder product innovations	No standards / no real smart grids available yet. Demand-response ability does not make the appliance more efficient. Allowances for certain functions should be avoided as far as possible within Ecodesign; also, using the EU Energy label for promoting these functions of smart appliances would not be compatible with the primarily role of the label (information tool for consumers on energy efficiency and selected other aspects which have a direct impact on operating costs such as water consumption, or which are relevant because of convenience issues, such as noise level). Networked standby should ideally be covered by the horizontal Ecodesign regulation on standby/networked standby; new product innovations should comply ideally with

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
					existing energy efficiency targets.
15f	cf. 15a/15c	**Set MEPS / power cap for any other standby-modes** of WM/WD (e.g. max. 2 W) in case they are not covered by existing Ecodesign regulations 1275/2008 and 801/2013 so far, e.g. in the context of smart-grid functionality	ED	The introduction of smart-grid appliances (or other functionalities) should not lead to an overall increase of the energy consumption only due to the supply of this functionality	Smart-grid ready appliances are an important instrument within the total energy transition system and thus should be favoured; too strict limit values might hinder product innovations. Ideally, these modes would also be covered by the horizontal Ecodesign regulation(s) on standby (1275/2010 and 801/2013)
16a	The 2015 consumer survey reveals that the EU **average number of use cycles for WM (229) is still near to the current 220 cycles/year; for WD it is slightly higher (240 cycles/year);** in general, these are only average and theoretical numbers for relative comparison of machines	Keep **number of annual wash cycles** (220) for WM as they are; for the washing function of WD, the number of annual wash cycles should be aligned to this for better comparison. Alternatively: take 230 cycles for both WM/WD. For WD, additionally 104 drying cycles might be used to express the yearly consumption by the drying function (to be further analysed based on the results	ED / EL	Continuity (as it is only an average value for comparison of different machines); better understandable in terms of annual savings	The EU average number of wash-cycles slightly decreased to 4.4 cycles per week. High variance for individual users. For smaller or larger households these average numbers still do not represent their individual behaviour (cf. 2015 Consumer survey results)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		of the 2015 user survey).			
16b	cf. 16a	Indication of total energy consumption **per cycle**, not annual average consumption. Alternative: to keep some differences visible, it could be declared per 100 cycles The same approach as decided for WM should be applied to WD.	ED / EL	Better understandable and scalable for consumers. The choice of the Latin expression 'kilowatt hours per annum' alleviates the burden of expressing 'yearly' in all the languages of the single market. In a survey 2012/2013 of 1,006 German consumers, more than 70% did not understand correctly (or did not understand at all) the meaning of 'per annum' on the energy label. In the 2015 consumer survey, the option of providing the consumption value 'per cycle' was reached an importance of around 60%, whereas the option 'per annum' reached an importance of around 40%. 'Per cycle' communicates more clearly that the energy consumed depends on usage.	The consumption values (kWh and l) are already at a very low level; differences between machines (decimal places) might become insignificant for consumers whereas yearly consumption values deliver greater numbers, where differences between appliances become more obvious and easier to quantify by users (in favour of energy efficient appliances). Coherence with the energy labels of other products would be omitted as for all other products the consumption is indicated per year. For washing machines this will be the consumption of a hypothetical wash cycle if the value still is derived as average from the measurement of 60 °C full, 60 °C partial load and 40 °C partial load. Thus it would not correspond to the consumption values of a certain programme as given in the booklet which might make it more difficult for consumers to understand.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
17a	Consumers do not use the appliance in its best way (programme choice, loading, detergent dosage,…)	Develop an agreed **list of Best Practice Tips for washing and for drying** and include them as, e.g., instruction leaflet / manual in each machine. Example of possible advices: - on which cycle to use for which load; loads that require special hygiene conditions; - to full load whenever possible; the right use of large capacity machines - that programmes at lower temperatures save energy; - to adjust detergent dosing with regard to the local water hardness; - to use the pre-wash programme only when needed; - on the dependencies of spinning and subsequent drying; - on the most ecological ways of drying depending on the surroundings; - on the correct installation in order to minimise the noise emitted; - on correct maintenance of the WM/WD; - on treatment advantageous for hygienic issues (such as keeping the porthole open to dry	CI	If branded by EU it will give some confidence in the best way of using the machine; improved consumer behaviour, thus realising further efficiency potentials	Additional costs, also for compliance check (cf. ATLETE II results for washing machines); overload of information might lead to no effect in the end.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		out the machine; keeping the dispenser drawer open; ambient conditions of the room etc.)			
17b	cf. 17a with regard to detergent dosage (soiling of laundry is often overestimated)	Mandatory requirement on machines being equipped with an **automatic detergent dosage system**	ED / SM	Might lead to relevant real-life savings of resources such as detergents, waste water due to better alignment of detergent consumption to the real-life conditions / programmes chosen.	Increase of appliance costs of approximately 200 EUR; i.e. long pay-back periods for consumers; only usable with fluid detergents, i.e. bleaching agents (ingredients of solid heavy-duty detergents) have to be additionally dosed manually if necessary. In the current standard test method no variation of the kind and amount of detergents is not a variable, i.e. the use of the automatic detergent dosage would not lead to an effect under current standard methods.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
18a	In general, consumer information requirements are difficult to be regulated by Ecodesign measurements (cf. ATLETE II results for washing machines with regard to (non-) compliance of consumer information measurements)	Introduce a **template for the most relevant information** requirements of the main programmes of WM/WD (e.g. recommended load, consumption per cycle / per kg of load, consumption at half load, real wash temperature, programme duration, noise…) being easily accessible online before purchase.	ED/CI	Easier to fill out, easier to check compliance; facilitates better comparability between programmes and/or appliances for consumers	Not all the consumers would consider the same pieces of information as relevant. There are (too) many possible combinations of programmes and options able to reference them in a cost effective manner (e.g. more than 400 up to 1,000 for premium WM). A clear indication of 'main programmes' is necessary. If more performance data of additional programmes are provided, they may need to be verified, thus more testing would be necessary. A way is needed to ask for declaration without verification of the values.
18b	cf. 18a	Use of a **QR code** to provide consumer information	ED/CI	Modern form of consumer information, more flexible; might address younger consumers better	Not all consumers have access to this information tool (QR-code reader necessary)
18c	cf. 18a	Compulsory **information via the display** of the appliance when the programme is chosen	ED/CI	Modern form of consumer information, direct feedback and influence possibilities	cf. 14c

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
19	Several WM/WD do have a possibility to connect the machine directly to the hot water tap; in practice, this option is rather seldom used	Mandatory consumer information on **hot fill option** (e.g. symbol on EL for hot fill connection; further consumer information under which conditions hot fill is beneficiary)	CI / EL	For WM/WD, a direct connection to the hot water tap could be beneficiary in terms of overall electricity savings; with better consumer information, this option might be used more often as consumers might not be aware of this electricity saving option.	Overload of (label) information might lead to no effect in the end; might still be difficult to understand and implemented by consumers. For washing machines, an overall trend to lower washing temperatures is already in place, i.e. hot fill might not be so effective; also rinsing with hot water would result in wastage of energy. For some washing needs (e.g. avoiding denaturation of proteins or avoiding damages of textiles) the use of hot water can be counterproductive (e.g.blood can be fixed to textiles at higher temperatures); also the temperature at the tap should not exceed 60 °C to ensure full protection of the functioning of the appliance; additional safety devices need to be installed to ensure this limit. Benefits will be realized depending on the type of heating system in the house (e.g. renewable sources, natural gas) and the length of the pipe, e.g. hot fillings linked to improper hot water systems (e.g. a circulator) can increase the energy consumption. For those consumers explicitly looking for those types of appliances, the information of hot water supply is already available in the manual at the point of sale.
20	Trend towards new kinds of washing machines	Adjust existing standard measurement method or define a new one for **innovative types of machines**, e.g. multi-drum WM	SM	Avoiding a regulatory loophole	Additional test work for (currently only) niche products

8.6. Full list of possible policy options for household washer-dryers

The table 8.13 provides a full list of possible policy options for household washer-dryers preliminarily discussed with stakeholders in the course of study. The policy instruments addressed are the Energy label (EL), generic and/or specific Ecodesign-measures (ED), standards and measurement methods (SM), as well as consumer information (CI) measures. Please note that policy options for washing machines (WM) (cf. Section 8.5) might also be of relevance for the washing function of washer dryers (WD).

Table 8.13: Full list of possible policy options for household washer-dryers (washing function and drying function)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
Washing function of Washer-dryers (WD)					
1	Washing only function as one part of regulation for WD	Apply the requirement for the new EL and ED for the washing only function	ED / EL / SM / CI	According to the 2015 consumer survey, WD are mostly used as WM. All washing performance tests according to EN60456 can be applied for washer dryers without exception	Should be done to align regulations.
2	Approaches for WM NOT applicable to the washing function of washer-dryers	*For the other policy options listed for washing machines (cf. Annex I, options 1-20), stakeholders were asked to check which can NOT be applicable for the washing function of washer-dryers*			
Drying function of Washer-dryers (WD)					
3a	Drying only function: No existing ecodesign requirements / labelling	Application of the requirements to the TD regulation: - Availability of a standard cotton programme for drying - Measurement / calculation of the Energy Efficiency Index, - Weighted condensation efficiency	ED / EL / SM / CI	Easy to adapt; better comparison with TD. All drying performance tests according to EN61121 can be applied for washer dryers with the special condition that the initial moisture content for the drying needs to be defined based on washing tests in related programmes (cotton, easy care)	Adaptations may be needed. Condensation efficiency cannot be measured. Current minimum requirements on Energy Efficiency of TD might be challenging for WD.
3b	cf 3a For tumble dryers, in regulations 932/2012 and 392/2012 the measurement and calculation of the Energy Efficiency Index is based on the weighted average of 3 full-load and 4 half-load cycles of one standard cotton programme. In the annual energy	Align the requirements of the drying function to the (future) approach which is decided to use for the wash-function (currently: 3:2:2 test cycles at 60 °C full : 60 °C half : 40 °C half-load, cf. option 4c on the sheet WM (WASH)).	ED / EL / SM / CI	Better alignment to the approach decided to use for the washing function and possibly to actual conditions of use	

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	consumption, also the standby modes are included.				
3c	cf. 3a	Alternative adaptation of requirements for the drying process from TD regulation	ED / EL / SM / CI	Possibly reflecting better the characteristics of WD	Values to be defined ad-hoc, no direct comparison with TD
3d	cf 3a According to the 2015 consumer survey, the drying-only function of WD is not used frequently	No requirements at all for the drying only function		The use of this function does not seem relevant; its regulation would create burdens without providing additional benefits compared to those that can be achieved through regulating the wash & dry function	Missed regulation of such function
4a	Wash&dry function According to the 2015 consumer survey, WD are mainly used as WM, with a broad spectrum of wash programmes used, but also to wash&dry textiles (mainly in a continuous wash&dry cycle); The Energy label Directive 96/60/EC is based on a standard 60 °C cotton cycle; the wash&dry cycle measurement procedure is based on 1x full load wash + 2 x partial load drying, measured in discontinued cycles. So far, for WD there exist no ecodesign requirements.	Business as usual; keep the existing measurement method and A-to-E Label classes, but adjusting them to the current consumption levels	ED / EL / SM	Continuity	Does not reflect knowledge of how consumers use WD (mostly wash and continuous wash/dry cycles; lower temperatures used; possible partial loads)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4b	cf. 4a	Define a new measurement method for testing the most used programmes for the continuous wash&dry cycle (different temperatures, full/partial load, taking the average of a certain number of cycles in the end): Specific information for wash & dry function can be provided by testing WD in two treatments: - Treatment 1: 60 °C cotton wash at full WD load + drying to cupboard dry status - Treatment 2: 40 °C cotton wash at half WD load + drying to iron dry status It is for example recommended to perform 7 tests, with three times treatment 1 and 4 times treatment 2 to maintain the frequency of seven cycles for the test load, as required by the measurement standard as interval between normalisation and conditioning. The specific values of these seven test runs shall be taken as absolute values or divided by the maximum rated capacity for the wash&dry process as specific consumption values. If a continuous cycle is possible this should be preferred compared to an interrupted operation (e.g. test performed at the maximum drying capacity). If no specified final drying status can be selected (time controlled drying only) the appropriate time needed to reach the final drying status shall be assessed by pre-testing.	ED / EL / SM	Better alignment to real-life conditio of use. With the proposed approach a primary function of WD is tested. All washing performance tests according to EN60456 can be applied for washer dryers without exception. Additionally, the function 'continuous wash&dry' can be tested with partial loads. This function should be a main part of the WD label to take this important function of the appliance into account.	Adaption of the measurement standard necessary; increased testing effort (tests must be performed for both washing and wash&dry functions). The current standard is limited to washing performance testing with unspecified washing and cotton cupboard drying; i.e. there is the need to offer and define more performance testing conditions. All drying performance tests according to EN61121 can be applied for washer dryers with the special condition that the initial moisture content for the drying needs to be defined based on washing tests in related programmes (cotton, easy care). The special test sequences for interrupted and continuous washing + drying cycles for other programme combinations like easy care drying and other final moisture contents than cupboard drying could be for instance applied
4c	cf 4b	Completely new definition of an ECO programme: Define a <u>most efficient</u> Eco programme for the wash/dry function of WD which can wash and dry normally soiled cotton labelled textiles for 40 °C and 60 °C *together*. (cf. option 5a in the options listed in Annex I for washing machines)	ED / EL / SM / CI	cf. 5a	cf. 3a n the sheet 'WD (WASH, DRY, GEN)') (and 5a in the sheet 'WM (WASH)')
5	Approaches for WM applicable to the drying function	*For the other policy options listed for washing machines (cf. Annex I, options 1-20), stakeholders were asked to check which of them could be applicable also to the drying / wash+dry functions of washer-dryers as well (e.g. time cap, consumer information)*			

Table 8.14: Full list of possible policy options for household washer-dryers (general approach)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
A	Common regulations for WM and WD	Include the WD into the revised Ecodesign and Energy label regulations of Washing Machines: - Washing function of WD: Same/similar requirements as for WM - Drying function of WD: Requirements for *drying only cycle and/or continuous wash&dry cycle (see above)* Energy label: - Two different label scales for the washing and for the wash&dry function (combined label as for air conditioners) - Information of potential interest for WD: Absolute energy / absolute water consumption, cycle time, rated capacity for wash&dry, noise for drying Example of possible requirements for ecodesign measures (based on in-house preliminary estimations): 1. Washing performance: >1.03 (respectively 'A' class) 2. Energy consumption: < 0.7 kWh/kg or < 4 kWh 3. Water consumption: < 15 L/kg or < 80 L	ED / EL	Fair comparison with WM and TD possible for consumers; the concept of a combined label scale on one appliance is already introduced for air conditioners. Less regulatory work compared to two separate regulations; update / revision of the WD regulation	WM/WD are different appliances, the wash&dry procedures differ from single wash procedures (e.g. thermo-spin ability). Two labels may confuse. WD will come up always to be worse than separate WM and TD - due to its limitations!
B	Split regulations for WM and WD	Separate regulations for WM and WD, each for Ecodesign and Energy label Values for interrupted or continuous wash&dry process and washing function to be assessed for EL/ED	ED / EL	Each machine (WM, WD) is rated according to its specific function, i.e. highlights better the character of a washer dryer	Will show relative high absolute energy (and water) consumption values for WD. In case of no alignment of the washing function to the WM revisions, the washing function WD will not be comparable to WM for consumers. More regulatory work; due to the small market share of WD, a separate regulatory work for this product group might be dropped at all, i.e. no revision at all.
C	Integration of WD in WM (washing function) and TD (drying function)	Split wash and dry functions of WD: - Washing function: Include requirements into the revised regulations of WM - Drying functions: Include requirements into revised regulations of tumble dryers (TD) (current EU regulations 932/2012 and 392/2012)	ED / EL	Transparency for consumers: Direct comparibility of the wash-function with WM and of the dry-function with the requirements for TD	Does not highlight the characteristics of the washer-dryer. WM/WD are different appliances, the wash-dry process differs from single wash processes (e.g. thermo-spin ability); different timelines of revisions. Confusing for consumers as WD would have two labels; continuous wash-dry cycle (which is often used, cf. 2015 consumer survey) would not be covered; handling and maintenance of regulations might have different retention periods.

8.7. Full list of possible policy options for material efficiency of washing machines and washer-dryers

The Table 8.15 provides a full list of possible policy options for material efficiency of household washing machines and washer-dryers and that have preliminarily discussed with stakeholders in the course of study. The policy instruments addressed are the Energy label (EL), generic and/or specific Ecodesign-measures (ED), standards and measurement methods (SM), as well as consumer information (CI) measures. Please note that policy options for material efficiency of household washing machines and washer-dryers are the same of those presented for dishwashers.

Table 8.15: Full list of possible policy options for material efficiency of household washing machines and washer-dryers (durability/reparability and end-of-life (EoL) management)

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
Policy measures with regard to **durability & reparability** of washing machines (WM) and washer dryers (WD)					
1a	Unsatisfactory mechanical robustness / durability of certain components and/or the whole appliance which lead to early failure rates There are standards on safety that could be used as starting point to handle such aspects.	Requirement on performing durability tests of certain components which are known to be prone for early failures	ED / SM	Decreased failure rate of appliance components	No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); high effort / costs for testing; quality of just performing tests might be variable from manufacturer to manufacturer; testing alone would not lead automatically to higher durability
1b	cf. 1a	Requirements on a minimum operational lifetime of certain components which are known to to be prone to early failures	ED / SM	Decreased failure rate of appliance components	Measurement standard needed; high effort for market surveillance authorities
1c	cf. 1a	Consumer information on the operational lifetime of certain components (e.g. motor)	ED / SM / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this as a competitive argument	Claims on operational lifetime must be backed with verifiable durability tests (not only marketing instrument); does not ensure that other components / the whole appliance are defective due to other reasons
2a	cf. 1a	Requirement on performing durability tests of the whole product (e.g. endurance tests; and/or tests for extraordinary constraints like shocks, vibratio, accidental drop, high temperatures, water,	ED / SM	Decreased failure rate of appliances	Specification of typical extreme stresses for those appliances needed; measurement standards needed; high effort / costs for testing; quality of just performing tests might be variable from manufacturer to manufacturer; testing alone may not lead automatically to higher durability

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		…)			
2b	cf. 1a	Requirements on a minimum operational lifetime of the whole appliance (e.g. machines to run a minimum number of cycles)	ED/SM	Decreased failure rate of appliances	cf. 1b; further: market intervention which might hinder/prevent innovations; few incentives for manufacturers to design the appliance beyond this mandatory minimum lifetime; disadvantage for those manufacturers providing already better quality (as market surveillance might not be effective enough to override bad quality products to a large extent); must be combined with legal rights for consumers to claim if the minimum lifetime is in practice not reached
2c	cf. 1a	Consumer information about the expected operational lifetime of the whole product (e.g. label, manual)	ED / SM / CI / EL	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this information as a competitive argument	cf. 1c
3a	Wrong user behaviour leading to defects of appliances (e.g. incorrect use, insufficient maintenance)	General consumer information about correct use and maintenance of appliances	ED / CI	Decreased misuse, decreased defects of appliances	Those consumer information is already mostly available in the manuals; is does not generally prevent consumers from misuse (precondition is that they read the information at all and act accordingly)
3b	cf. 3a	Compulsory direct feedback on necessary maintenance intervals via the machine's display	ED / CI	Possibly more regular maintenance done by consumers	Not all appliances are equipped with a display so far; communication of such information requires special displays (TFT; text to be displayed) and a sensoric which measures the next maintenance interval to be necessary (e.g. counting number of cycles); significant raise of appliances prices expected especially in the low-price segment; impact is not clear (if consumers would really change their behaviour)
3c	Early replacement of appliances due to changes in consumer preferences and needs (e.g. larger / newer products, design, …)	Consumer information about the environmental (and economic) benefits of prolonged product use (e.g. campaign, sign on the appliance etc.)	ED / CI	Might reduce early replacements by consumers	No clear evidence of the impact; consumers might have still other predominant arguments / reasons for exchanging products

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
4a	In case of a defect, appliances are increasingly discarded although a repair might have increased the lifetime; reasons might be e.g. a certain product design impeding repairs, missing and/or no access to spare parts, high costs for repairs compared to purchase of a new product etc.	Design for upgrades and repairs: components being prone to early failures should not be designed in a manner prohibiting repairs (e.g. high integration of different components)	ED	Modular design facilitates repairs in a cost-effective manner: otherwise whole component groups might have to be exchanged in case of a defect of only a single component which is more costly	Modular design might be more expensive. No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); market intervention possibly hindering innovations; highly integrated components might have advantages themselves (e.g. better quality of the whole component group due to integration)
4b	cf. 4a	Design for upgrades and repairs: components being prone to early failures should be easily accessible and exchangeable by the use of universal tools	ED	Facilitates repairs in a cost-effective manner	No clear evidence of certain components which usually fail more often (might be different from appliance to appliance); high effort / costs for testing / market surveillance; 'easily accessible' should be well defined
4c	cf. 4a	Appliance internal failure diagnosis systems to report error specific messages to the user	ED	Digital pre-diagnosis of the specific failure would reduce duration and costs of repairs	Not all appliances are equipped with such a system and display so far; communication of such information requires special displays (TFT; text to be displayed) and a system which recognizes the kind of failure; significant raise of appliances prices expected especially in the low-price segment; impact is not clear)
4d	cf. 4a	Information requirements on reparability (e.g. repair label), e.g. 1) indicating if the machine can be repaired or not; 2) indicating which components are not reparable	ED / CI / (EL)	Transparency for consumers; they might choose products being better reparable or which contain e.g. modular components	1) Manufacturers would always claim reparability; difficult to define / measure, i.e. difficult to prove non-compliance (standard needed) 2) Difficult to define; in general, most components will be reparable or exchangeable - cost factor
4e	cf. 4a	Consumer information about access to professional repairs (e.g. information in user instruction / manufacturer's website / on the appliance itself to let	ED / CI	Facilitates the possibilities for repairs	Those consumer information is already mostly available in the manuals; (precondition is that they read the information at all and act accordingly); it does not generally prevent consumers from not repairing the devices as other reasons might play a role (e.g. costs of repairs, inconvenience of long waiting times); often only authorized repair shops listed which might be more expensive than independent ones

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		the user know where to go to obtain professional repairs and servicing of the product, including contact details)			
4f	cf. 4a	Information about the availability (and price) of spare parts (current practice: from 0 to 10-15 years after production)	ED / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this information as a competitive argument	Price indications are variable and dependent on several factors; costs for spare parts is only one factor of the total costs of repair (labour costs, travel costs); indication of prices in advance might even discourage consumers from doing repairs
4g	cf. 4a	Guarantee of public availability of spare parts for a certain period following the end of the production of the model; ensure original and backwardly compatible spare parts	ED, EL, CI	Facilitates that products can be repaired for a long period and by repair centres which are not manufacturer-bound	Costly for manufacturers to hold a stock of spare parts for a long time; for longlasting large household appliances, this period might be at least 5 years to cover early breaks, but up to 10-15 years; environmental benefits not clear (if spare parts are not needed in this period, the might be destroyed without being used);
4h	cf. 4a	Repair manual: clear disassembly and repair instructions to enable non-destructive disassembly of product for the purpose of replacing key components or parts for upgrades or repairs. Information publicly available or by entering the products unique serial number on a webpage to facilitate access for recognized / independent repair centres. A diagram of the inside of the housing showing the location of the components available	ED	Might decrease of repair costs for consumers if independent repair organisations and approved re-use centres have information access and are able to perform repairs	Accountability (e.g. safety, lifetime, guarantee) and confidentiality of manufacturers might not be ensured if information is public available / non-authorized repair centres can do the repairs

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		online for at least 5 years			
4i	cf. 4a	Commercial guarantee providing a minimum of 3 years guarantee effective from the purchase of the product during which manufacturers shall ensure the goods are in conformity with the contract of sale (without passing the burden of proof to the consumer). It includes service agreement with a pick-up and return option.	ED	Manufacturers might improve the quality of their products to prevent claims	Costly for manufacturers; risk that costs are transferred to the total product purchase price; risk that appliances (especially low-cost) would be replaced by a new model instead of being repaired; for the long-lasting large household appliances, 3 years are quite a short time.
4j	cf. 4a	Mandatory consumer information about commercial guarantees, i.e. the number of years the producer guarantees the full functioning of the appliance for free and without passing the burden of proof to the consumer	ED / CI	Transparency to consumers; they might choose higher quality products; manufacturers can actively use this information as a competitive argument	
Policy measures with regard to **End-of-life (EoL) management** of machines					
5a	The design of appliances can influence the practicability of recycling facilities at the EoL according to WEEE requirements (dismantling of certain PCBs, displays, refrigerant containing components like heat pumps etc.) or to recover valuable resources (e.g. rare earth elements in	Design for recovery and recycling which allows better / easier access to dismantle / separate WEEE relevant components or components containing valuable resources	ED	These requirements are devised to help recyclers to better comply with the WEEE directive by providing information relevant for depollution, disassembly and or shredding operations	Measurement standard needed otherwise it would be too generic; high effort for manufacturers and market surveillance authorities

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
	permanent magnets of motors)				
5b	cf 5a	Clear marking of special components and/or identification of appliances with heat-pumps (recyclers of category 1 waste (large household appliances') are not always certified to also treat appliances with refrigerants)	ED	Better transparency for recycling facilities to treat separately refrigerant-containing appliances	New WEEE categories will be introduced from August 2018 which restructures large household appliances with refrigerants into another category (temperature exchange equipment)
5c	cf 5a	Clear marking of appliances with permanent magnet motors containing rare earth elements	ED	A clear marking would facilitate the motors being manually removed before a subsequent shredding process and separately treated to improve the recycling potential of the rare earths which would otherwise be lost	Might have no relevance if not or nearly not applied to a large extent to motors of WM/WD/DW; only effective if such motors are treated separately in the recycling facility
5d	cf 5a	Marking of plastic parts containing hazardous substances (e.g. halogenated flame retardants); example: brominated fire retardants logo as proposed in the ED draft for electronic displays	ED	Might improve to get recyclates without hazardous substances (avoid contamination)	Effective only if it is possible to separate the recycled plastic streams (those free from hazardous substances)
5e	cf 5a	'End-of-life report' for recyclers containing information relevant for disassembly, recycling and recovery at end-of-life at least on exploded diagram of the product labelling the targeted components defined together with a	ED	These requirements might help recyclers to better comply with the WEEE directive by providing information relevant for depollution, disassembly and or shredding operations	In the daily recycling practice such documents might not be used at all.

No.	Rationale	Possible Policy Measures	Addressed policy instrument	Expected benefits	Potential disadvantages, challenges and/or drawbacks
		documentation of the sequence of dismantling operations needed to access to the components			
5f	cf 5a	Declaration of the recyclability index for products indicating the share of recyclable materials, as for example proposed in the ED draft for electronic displays	ED	Transparency, market differentiation of machines	Well developed and widely accepted procedures needed; so far only a theoretical number as the real treatment of the specific appliances and thus their recyclability depends of further factors; does not help to improve the real recycling process
6a	Effectiveness of EoL efforts only if proper collection and treatment of appliances after use is ensured. Ongoing standardization activity within CENELEC in collaboration with recyclers that covers collection, transport, storage, separation and recycling of the product	Require the mandatory application of the standard that CENELEC is developing	ED	Activity supported by industry	A standard is not yet available
6b	cf 6a	Require the mandatory presence of a code / chip to track the appliance	ED	Possible track of the appliance	Availability of tools and infrastructures; does not solve the issue alone

8.8. Level of integration of specific technologies

Table 8.16: Estimated integration of technologies used for the washing process

Options for Washing (WM/WD)	Integration in 2015 WM models (%)	Expected market penetration by 2030(%)
Brushless, inverter driven asynchronous DC motors (CIM) Brushless, permanent magnet synchronous DC motors (PMSM) (BPM)	33% 33%	50% 50%
Extension of programme duration and lowering of washing temperature - moderate scenario (e.g. 4 hours) Extension of programme duration and lowering of washing temperature - extreme scenario (e.g. 6 hours)	30% 10%	Dependent on policy strategy Dependent on policy strategy
Heat pump technology for the washing function Heat-fed machines Hot/cold fill	0% 0% 1%	5% 0% 10%
Improved drenching systems (Internal water circulation; EcobubbleTM, Spray-technology)	10%	30%
Automatic load detection which adapts the water consumption and thus the energy demand to partial load: - Water drenching-based pressure sensors - Balance and electronic sensors - Automatic detergent dosage systems which is supposed to lead to reduced mis-dosing (under- or overdosing)	 90% 30% 10%	 100% 50% 40%
Displaying the actual loading Displaying a detergent dosage recommendation Indication of the energy and water demand of the chosen programme	5% 5% 5%	30% 30% 20%
Electronic update of the programmes	10%	20%
Diagnostics in case of failures Smart grid ready products	10%	20%
Diagnostics in case of failures Smart grid ready products	5%	15%
Increased durability of materials and components	5%	25%

Table 8.17: Estimated integration of technologies used for the drying phase

Options for Drying (WD)	Market penetration in 2015 WM sales (%)	Expected market penetration in by 2030 (%)
Air condensing systems	40%	50%
Heat pump technology (for the drying function)	10%	50%
Smart design of combined wash&dry programmes	90%	100%
Heat pumps for washing and for drying	0%	Not possible / Uncertain
Energy storage systems	0%	10%?

Table 8.18: Energy saving potential estimated for different product groups

Product group	Estimated savings in terms of primary energy[a] (PJ/yr.)	% normalised to total
Electric motors	1215	37%
Domestic Lighting	351	11%
Street & Office Lighting	342	10%
Standby	315	10%
Fans	306	9%
Televisions	252	8%
Circulators	207	6%
Air conditioners and comfort fans	99	3%
External power supplies	81	2%
Simple set top boxes	54	2%
Domestic refrigerators	36	1%
Domestic dishwashers	18	1%
Domestic washing machines	14	0%
Total	3294	

(a) In-house calculation based on the values reported in http://ec.europa.eu/DocsRoom/documents/5187/attachments/1/translations/en/renditions/native (1 PJ of power considered equivalent to 2.5 PJ of primary energy)

8.9. Stock and sales

8.9.1. Stock

The stock figures are based on the penetration rate and the number of households. The penetration rate is taken from Euromonitor International Passport database (http://www.euromonitor.com/passport) for washing machines and (TIG 2015b) for washer dryers and the number of households comes from Eurostat, extracted on 22/4/2016, last update 8/2/2016. The stock values for 1990-2004 are taken from VHK 2014 for washing machines and from sales data from GfK data in combination with the VKH 2014 f for washer dryers. Sales of washer-dryers in the EU were above 700,000 in 2012 based on GfK data. According to (VHK et al. 2014), this corresponds to about 4% of the 16 million unit washing machine market used as market data in that study.

Table 8.19: Washing machines and washer dryers stock figures derived from penetration rate and number of households.

Year	EU28 Number of households (mil)	EU28 Washing machine penetration rate	Washing machines units in EU28 stock (mil)	EU28 Washer dryer penetration rate	Washer dryers units in EU28 stock (mil)
1990	167.48	82%	136.61	3%	5.46
1991	169.32	82%	139.07	3%	5.56
1992	171.16	83%	141.56	3%	5.66

Year	EU28 Number of households (mil)	EU28 Washing machine penetration rate	Washing machines units in EU28 stock (mil)	EU28 Washer dryer penetration rate	Washer dryers units in EU28 stock (mil)
1993	173.01	83%	144.07	3%	5.76
1994	174.85	84%	146.60	3%	5.86
1995	176.69	84%	149.15	3%	5.97
1996	178.54	85%	151.38	3%	6.06
1997	180.38	85%	153.63	3%	6.15
1998	182.22	86%	155.89	3%	6.24
1999	184.06	86%	158.17	3%	6.33
2000	185.91	86%	160.45	3%	6.42
2001	187.75	87%	163.47	3%	6.54
2002	189.59	88%	166.51	4%	6.66
2003	191.44	89%	169.58	4%	6.78
2004	193.28	89%	172.68	4%	6.91
2005	195.12	90%	175.81	4%	7.03
2006	199.03	90%	179.71	4%	7.19
2007	200.97	90%	181.85	4%	7.27
2008	203.07	91%	184.12	4%	7.36
2009	208.86	91%	189.77	4%	7.59
2010	209.49	91%	190.75	4%	7.63
2011	211.96	91%	193.39	4%	7.74
2012	213.30	91%	195.02	4%	7.80
2013	214.14	92%	196.19	4%	7.85
2014	216.75	92%	199.00	4%	7.96
2015	218.91	92%	201.40	4%	8.06
2016	219.61	92%	202.04	4%	8.08
2017	220.31	92%	202.68	4%	8.11
2018	221.00	92%	203.32	4%	8.13
2019	221.70	92%	203.96	4%	8.16
2020	222.40	92%	204.60	4%	8.18
2021	222.84	92%	205.01	4%	8.20

Year	EU28 Number of households (mil)	EU28 Washing machine penetration rate	Washing machines units in EU28 stock (mil)	EU28 Washer dryer penetration rate	Washer dryers units in EU28 stock (mil)
2022	223.28	92%	205.41	4%	8.22
2023	223.72	92%	205.82	4%	8.23
2024	224.16	92%	206.22	4%	8.25
2025	224.60	92%	206.63	4%	8.27
2026	225.04	92%	207.03	4%	8.28
2027	225.48	92%	207.44	4%	8.30
2028	225.92	92%	207.84	4%	8.31
2029	226.36	92%	208.25	4%	8.33
2030	226.80	92%	208.65	4%	8.35

8.9.2. Weibull parameters

The idea of working with a Weibull distribution to estimate the washing machines or the washer dryers sales is taken from US EERE (2014a). The Weibull distribution is a probability distribution commonly used to measure failure rates. Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion.

The equation for the Weibull cumulative distribution function takes the form:

$$P(j) = e^{-\left(\frac{j-\theta}{\alpha}\right)^{\beta}}$$

Where:

P(j) is the probability that the appliance is still in use at age j

j is the appliance age

α is the scale parameter, which would be the decay length in an exponential distribution

β is the shape parameter, which determines the way in which the failure rate changes through time, and

θ is the delay parameter, which allows for a delay before any failures occur.

When β=1, the failure rate is constant over time giving the distribution form of cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances are getting old.

The Weibull function is a memoryless function. This means that the probability of survival for the next year depends on the probability of survival for this year.

$$P\ (next\ year) = \frac{P(j+1)}{P(j)}$$

The lifetime (LT) of the machine is calculated as

$$LT = exp^{GammaLn\left(\frac{\alpha+1}{\alpha}\right)}\ \beta + \theta$$

The parameters α and β and the corresponding lifetime are given in Table 8.20 for the years 1990-2015 and correspond with parameters found in Baldé et al. (2015) for the years 1981-2014. For years before 1981 the same parameters are assumed as in 1981. For years after 2014 the parameters are set according to the assumptions in the scenario which can be found in sections 7.4.2 (

Using the Weibull parameters shown in Figure 8.3 result in an estimation of the total sales different from the values estimated by VHK (2014 / status 2013) and CLASP (2013). It should be noted that in CLASP (2013) a standard distribution has been used rather than a Weibull distribution to estimate the fall out of machines.

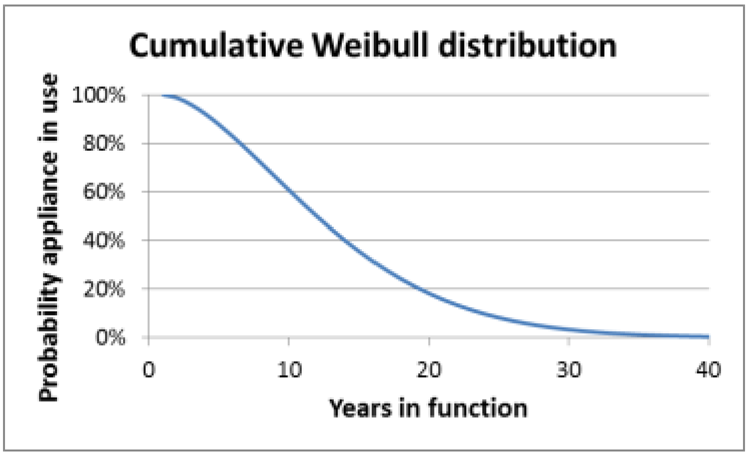


Figure 8.3: Weibull cumulative distribution function for α = 13.72, β = 1.64 and θ = 1.

Table 8.20: Weibull parameters used for estimating the replacement sales according to Baldé et al. (2015) for 1981-2014, for the years 2015-2030 based on assumptions that can be found in section 7.5.3.2.

	Washing machines			Washer dryers		
Year	α	β	Average lifetime (years)	α	β	Average lifetime (years)
1981	1.64	14.00	12.53			
1982	1.64	14.00	12.53			
1983	1.64	14.00	12.53			
1984	1.64	14.00	12.53			
1985	1.64	14.00	12.53			
1986	1.64	14.00	12.53			
1987	1.64	14.00	12.53			
1988	1.64	14.00	12.53			
1989	1.64	14.00	12.53	1.64	14.00	12.53
1991	1.64	14.00	12.53	1.64	14.00	12.53
1992	1.64	14.00	12.53	1.64	14.00	12.53
1993	1.64	14.00	12.53	1.64	14.00	12.53

	Washing machines			Washer dryers		
1994	1.64	14.00	12.53	1.64	14.00	12.53
1995	1.64	14.00	12.53	1.64	14.00	12.53
1996	1.64	16.78	15.01	1.64	14.00	12.53
1997	1.64	16.52	14.78	1.64	14.00	12.53
1998	1.64	16.27	14.56	1.64	14.00	12.53
1999	1.64	16.02	14.33	1.64	14.00	12.53
2000	1.64	15.77	14.11	1.64	14.00	12.53
2001	1.64	15.52	13.88	1.64	14.00	12.53
2002	1.64	15.26	13.66	1.64	14.00	12.53
2003	1.64	15.01	13.43	1.64	14.00	12.53
2004	1.64	14.76	13.21	1.64	16.78	15.01
2005	1.64	14.51	12.98	1.64	16.52	14.78
2006	1.64	14.26	12.75	1.64	16.27	14.56
2007	1.64	14.00	12.53	1.64	16.02	14.33
2008	1.64	13.75	12.30	1.64	15.77	14.11
2009	1.64	13.50	12.08	1.64	15.52	13.88
2010	1.64	13.46	12.04	1.64	15.26	13.66
2011	1.64	13.42	12.01	1.64	15.01	13.43
2012	1.64	13.38	11.97	1.64	14.76	13.21
2013	1.64	13.34	11.93	1.64	14.51	12.98
2014	1.64	13.30	11.90	1.64	14.26	12.75
2015	1.64	13.26	11.86	1.64	14.00	12.53
2016	1.64	13.22	11.83	1.64	13.75	12.30
2017	1.64	13.18	11.79	1.64	13.50	12.08
2018	1.64	13.14	11.76	1.64	13.46	12.04
2019	1.64	13.10	11.72	1.64	13.42	12.01
2020	1.64	13.06	11.68	1.64	13.38	11.97
2021	1.64	13.02	11.65	1.64	13.34	11.93
2022	1.64	12.98	11.61	1.64	13.30	11.90
2023	1.64	14.00	12.53	1.64	13.26	11.86
2024	1.64	14.00	12.53	1.64	13.22	11.83
2025	1.64	14.00	12.53	1.64	13.18	11.79
2026	1.64	14.00	12.53	1.64	13.14	11.76
2027	1.64	14.00	12.53	1.64	13.10	11.72
2028	1.64	14.00	12.53	1.64	13.06	11.68
2029	1.64	14.00	12.53	1.64	13.02	11.65
2030	1.64	14.00	12.53	1.64	12.98	11.61

7.7.1.1 Sales

Table 8.21: Calculated sales figures including new sales (leading to an increase in penetration rate), replacement sales and total sales for scenarios BAU, 1 and 2.

	Washing machine				Washer dryers			
Year	Stock (mil units)	New sales (mil units)	Replacement sales (mil units)	Total sales (mil units)	Stock (mil units)	New sales (mil units)	Replacement sales (mil units)	Total sales (mil units)
1993	144.07	2.51	0.68	3.19	5.76	0.10	0.68	0.78
1994	146.60	2.53	2.49	5.02	5.86	0.10	0.71	0.81
1995	149.15	2.55	4.33	6.88	5.97	0.10	0.60	0.70
1996	151.38	2.23	5.65	7.89	6.06	0.09	0.56	0.65
1997	153.63	2.25	6.73	8.98	6.15	0.09	0.54	0.63
1998	155.89	2.26	7.63	9.89	6.24	0.09	0.53	0.62
1999	158.17	2.27	8.39	10.67	6.33	0.09	0.51	0.60
2000	160.45	2.29	9.04	11.33	6.42	0.09	0.50	0.60
2001	163.47	3.02	9.60	12.61	6.54	0.12	0.50	0.62
2002	166.51	3.04	10.07	13.12	6.66	0.12	0.49	0.61
2003	169.58	3.07	10.49	13.56	6.78	0.12	0.49	0.61
2004	172.68	3.10	10.87	13.97	6.91	0.12	0.49	0.61
2005	175.81	3.13	8.42	11.55	7.03	0.13	0.37	0.49
2006	179.71	3.90	9.06	12.95	7.19	0.16	0.39	0.54
2007	181.85	2.14	9.67	11.80	7.27	0.09	0.41	0.49
2008	184.12	2.28	10.25	12.53	7.36	0.09	0.42	0.52
2009	189.77	5.65	10.80	16.45	7.59	0.23	0.44	0.67
2010	190.75	0.97	11.32	12.30	7.63	0.04	0.46	0.50
2011	193.39	2.64	11.86	14.50	7.74	0.11	0.48	0.58

	Washing machine				Washer dryers			
2012	195.02	1.63	12.36	14.00	7.80	0.07	0.50	0.56
2013	196.19	1.17	12.85	14.02	7.85	0.05	0.51	0.56
2014	199.00	2.81	13.31	16.12	7.96	0.11	0.53	0.64
2015	201.40	2.40	13.75	16.15	8.06	0.10	0.55	0.64
2016	202.04	0.64	14.19	14.83	8.08	0.03	0.56	0.59
2017	202.68	0.64	14.64	15.28	8.11	0.03	0.58	0.61
2018	203.32	0.64	15.06	15.71	8.13	0.03	0.60	0.63
2019	203.96	0.64	15.09	15.73	8.16	0.03	0.60	0.63
2020	204.60	0.64	15.13	15.77	8.18	0.03	0.60	0.63
2021	205.01	0.40	15.18	15.59	8.20	0.02	0.61	0.62
2022	205.41	0.40	15.24	15.64	8.22	0.02	0.61	0.62
2023	205.82	0.40	15.30	15.71	8.23	0.02	0.61	0.63
2024	206.22	0.40	15.37	15.77	8.25	0.02	0.61	0.63
2025	206.63	0.40	15.44	15.84	8.27	0.02	0.62	0.63
2026	207.03	0.40	15.51	15.91	8.28	0.02	0.62	0.64
2027	207.44	0.40	15.58	15.99	8.30	0.02	0.62	0.64
2028	207.84	0.40	15.65	16.06	8.31	0.02	0.63	0.64
2029	208.25	0.40	15.73	16.13	8.33	0.02	0.63	0.65
2030	208.65	0.40	15.81	16.21	8.35	0.02	0.63	0.65

8.9.3. Real lifetime of washing machines

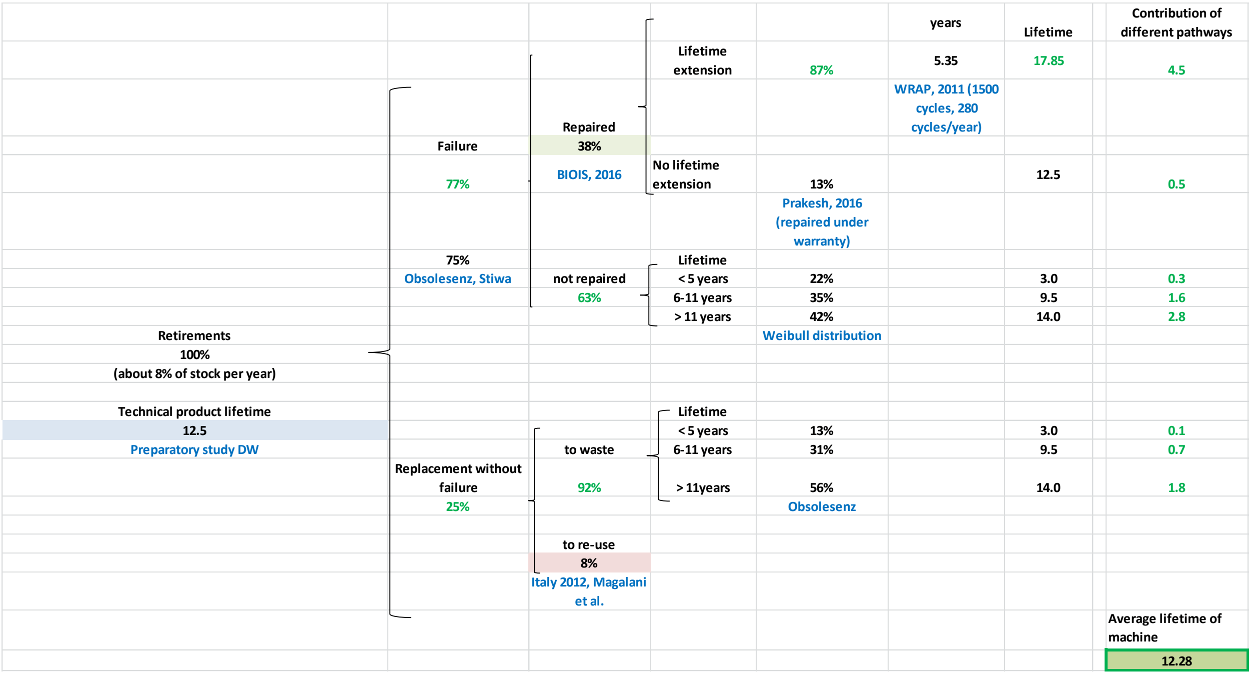


Figure 8.4: Representation of the model that has been used to define the average lifetime of washing machines on the market.

8.9.4. Prices for electricity and water

The EU28 household electricity price is taken from the Reference Scenario 2016 (European Commission 2016) (i.e. average price of electricity in final demand sectors scaled to $Euro_{2015}$). For the water price, 2011 is used as reference year with an escalation rate of 2.5% in accordance with COWI and VHK (2011b) (see section 2.3.4).

Table 8.22: Household electricity and water prices.

Year	Household electricity price (EUR_{2015}/kWh)	Household water price (EUR_{2015}/m^3)
1998	0.089	2.68
1999	0.093	2.75
2000	0.097	2.82
2001	0.101	2.89
2002	0.105	2.96
2003	0.109	3.04
2004	0.114	3.11
2005	0.118	3.19
2006	0.121	3.27
2007	0.125	3.35
2008	0.129	3.44
2009	0.133	3.52
2010	0.137	3.61
2011	0.138	3.70

Year	Household electricity price (EUR_{2015}/kWh)	Household water price (EUR_{2015}/m^3)
2012	0.140	3.79
2013	0.141	3.89
2014	0.143	3.98
2015	0.145	4.08
2016	0.146	4.19
2017	0.148	4.29
2018	0.150	4.40
2019	0.152	4.51
2020	0.154	4.62
2021	0.154	4.74
2022	0.155	4.85
2023	0.156	4.98
2024	0.157	5.10
2025	0.158	5.23
2026	0.159	5.36
2027	0.159	5.49
2028	0.160	5.63
2029	0.161	5.77
2030	0.162	5.92

8.9.5. Carbon intensity indicators

European related carbon dioxide emissions have decline in the recent past. This trend has been led by emissions reductions in the electric power sector. The power sector has become less carbon intensive (measured as CO_2 emitted per kWh of generation).

The power sector has become less carbon intensive for two reasons: the substitution of less-carbon-intensive natural-gas-fired generation, displacing coal and petroleum generation and the growth in non-carbon generation, especially from renewable sources.

The trends of electric power generation for the coming years are very different depending on the assumption under consideration. Even though there is a common agreement that the electricity and steam generation sector will undergo a decarbonisation process, some authors consider that it will be faster than others. This means that the forecast of the future carbon intensity of the electricity for the coming years is quite different depending on the sources.

For this study electricity emission factors are taken from the Reference scenario 2016 (European Commission 2016) and calculated as the division between the total CO_{2eq} emissions of the power sector divided by the gross electricity generation. The reference scenario 2016 provides data or estimations every five years. The interpolated figures are shown inTable 8.23.

Table 8.23: Electricity emission factors

year	g CO_2/kWh	year	g CO_2/kWh

year	g CO_2/kWh	year	g CO_2/kWh
1990	558.9	2010	403.3
1991	551.1	2011	395.1
1992	543.3	2012	386.9
1993	535.4	2013	378.7
1994	527.6	2014	370.5
1995	519.8	2015	362.3
1996	511.9	2016	352.9
1997	504.1	2017	343.5
1998	496.3	2018	334.1
1999	488.4	2019	324.7
2000	467.9	2020	315.3
2001	464.7	2021	310.2
2002	461.5	2022	305.1
2003	458.3	2023	300.0
2004	455.1	2024	294.9
2005	451.9	2025	289.8
2006	442.2	2026	280.9
2007	432.5	2027	272.0
2008	422.7	2028	263.1
2009	413.0	2029	254.2
		2030	245.3

8.9.6. Primary energy factors

The primary energy is defined as the energy that has not been subjected to any conversion or transformation process (i.e. fossil fuels). The secondary energy originates from the primary energy, through conversion or transformation processes (i.e. electricity). The purpose of the primary energy factors (PEF) is to weigh the different energy carriers, comparing them to the corresponding energy sources. The PEF are numerical coefficients determined as the inverse of the ratio between one unit of energy delivered and n units of primary energy expected to deliver it. Therefore the PEF takes into account the energy expenditure per energy carrier's distribution and transmission, and also takes into account the efficiency of conversion or transformation processes form primary to secondary energy.

An average European reference value of the electricity PEF is given in the Directive 2006/32/EC and equals 2.5. In the recent past, a decrease in the PEF values has been observed. This fact is due to mainly two reasons: the replacement of coal and petroleum by natural gas fired combustion plants and the increasing penetration of the renewable sources in the generation of electricity. The forecast of the PEF values are influenced by technical progress and political decisions, as well as the methodology followed for its calculation, therefore different authors report different values.

Based on a technical methodology, the Reference Scenario 2016 (European Commission 2016) reports an increase in the efficiency of the power generation, this aspect has been considered as forecast for the PEF values at EU level. To estimate the future values of the

PEF at EU level, the inverse of the power generation efficiency. This calculation reports a value of 2.49 in the year 2015, which is in line with the value of 2.5 for 2015 as suggested by Directive 2006/32/EC. The reference scenario reports value every 5 years. The interpolated figures are shown in table 8.24

Table 8.24: Primary energy factors (PEF)

year	PEF	year	PEF
1990	2.84	2010	2.59
1991	2.83	2011	2.57
1992	2.82	2012	2.55
1993	2.81	2013	2.53
1994	2.80	2014	2.51
1995	2.79	2015	2.49
1996	2.78	2016	2.49
1997	2.77	2017	2.48
1998	2.76	2018	2.48
1999	2.75	2019	2.48
2000	2.69	2020	2.48
2001	2.68	2021	2.46
2002	2.66	2022	2.45
2003	2.65	2023	2.44
2004	2.64	2024	2.43
2005	2.62	2025	2.42
2006	2.62	2026	2.41
2007	2.61	2027	2.40
2008	2.60	2028	2.39
2009	2.60	2029	2.38
		2030	2.37

8.9.7. Energy and water consumption of washing machine stock

Table 8.25: Estimated total EU28 electricity consumption of washing machine stock 2015-2030 (part 1)

Year	EU28 total electricity consumption washing machine stock (TWh/year)				
	BAU	SCENARIO 1a	SCENARIO 1b	SCENARIO 1c	SCENARIO 1d
2015	36.43	35.10	36.88	35.20	31.71
2016	35.56	34.26	36.00	34.36	30.97
2017	34.94	33.67	35.37	33.76	30.46
2018	34.39	33.13	34.81	33.23	30.00
2019	33.80	32.57	34.22	32.66	29.51
2020	33.26	32.05	33.67	32.14	29.05
2021	32.68	31.49	33.08	31.58	28.56
2022	32.15	30.98	32.55	31.07	28.12
2023	31.65	30.49	32.04	30.58	27.69

Year	EU28 total electricity consumption washing machine stock (TWh/year)				
2024	31.16	30.03	31.55	30.11	27.27
2025	30.70	29.58	31.08	29.67	26.88
2026	30.26	29.15	30.63	29.24	26.50
2027	29.83	28.74	30.20	28.83	26.13
2028	29.43	28.35	29.79	28.43	25.78
2029	29.03	27.97	29.39	28.05	25.44
2030	28.65	27.61	29.01	27.69	25.11

Table 8.26: Estimated total EU28 electricity consumption of washing machine stock 2015-2030 (part 2)

Year	EU28 total electricity consumption washing machine stock (TWh/year)				
	BAU	SCENARIO 2a	SCENARIO 2b1	SCENARIO 2b2	SCENARIO 2b3
2015	36.43	36.49	36.59	36.38	34.94
2016	35.56	35.72	35.86	35.64	34.43
2017	34.94	35.23	35.38	35.12	34.14
2018	34.39	34.82	34.95	34.66	33.83
2019	33.80	34.41	34.48	34.14	33.43
2020	33.26	34.04	34.08	33.69	33.01
2021	32.68	33.65	33.61	33.17	32.51
2022	32.15	33.33	33.19	32.66	32.03
2023	31.65	33.07	32.76	32.15	31.55
2024	31.16	32.84	32.35	31.64	31.07
2025	30.70	32.64	31.94	31.12	30.59
2026	30.26	32.50	31.54	30.58	30.11
2027	29.83	32.38	31.15	30.04	29.63
2028	29.43	32.30	30.77	29.49	29.16
2029	29.03	32.25	30.40	28.93	28.69
2030	28.65	32.24	30.03	28.35	28.17

Table 8.27: Estimated total EU28 water consumption of washing machine stock 2015-2030 (part 1)

Year	EU28 total water consumption washing machine stock (billion m^3/year)				
	BAU	SCENARIO 1a	SCENARIO 1b	SCENARIO 1c	SCENARIO 1d
2015	1594.29	1570.21	1628.67	1457.12	1554.44
2016	1654.39	1629.39	1690.06	1554.44	1613.03
2017	1725.98	1699.91	1763.20	1613.03	1682.84
2018	1792.96	1765.87	1831.62	1682.84	1748.14
2019	1847.84	1819.93	1887.69	1748.14	1801.66
2020	1896.41	1867.76	1937.30	1801.66	1849.01
2021	1933.46	1904.25	1975.15	1849.01	1885.13
2022	1966.89	1937.18	2009.30	1885.13	1917.73
2023	1994.87	1964.73	2037.88	1917.73	1945.00
2024	2017.97	1987.48	2061.48	1945.00	1967.53

Year	EU28 total water consumption washing machine stock (billion m³/year)				
2025	2036.76	2005.99	2080.68	1967.53	1985.85
2026	2051.77	2020.78	2096.01	1985.85	2000.48
2027	2063.49	2032.32	2107.99	2000.48	2011.91
2028	2072.37	2041.06	2117.05	2011.91	2020.57
2029	2078.80	2047.40	2123.63	2020.57	2026.84
2030	2083.16	2051.69	2128.08	2026.84	2031.09

Table 8.28: Estimated total EU28 water consumption of washing machine stock 2015-2030 (part 2)

Year	EU28 total water consumption washing machine stock (billion m³/year)				
	BAU	SCENARIO 2a	SCENARIO 2b1	SCENARIO 2b2	SCENARIO 2b3
2015	1594.29	1595.83	1605.86	1592.80	1611.83
2016	1654.39	1658.70	1669.66	1656.89	1675.74
2017	1725.98	1733.95	1745.41	1731.25	1750.96
2018	1792.96	1805.15	1815.10	1800.60	1818.82
2019	1847.84	1865.06	1872.87	1857.52	1873.85
2020	1896.41	1918.08	1924.65	1908.30	1921.03
2021	1933.46	1960.36	1964.33	1946.70	1956.22
2022	1966.89	1999.42	1999.99	1980.70	1987.36
2023	1994.87	2033.96	2029.72	2008.43	2012.66
2024	2017.97	2063.92	2054.55	2030.91	2033.21
2025	2036.76	2089.79	2074.63	2048.29	2049.16
2026	2051.77	2112.72	2090.67	2061.12	2061.44
2027	2063.49	2132.71	2103.20	2069.90	2070.58
2028	2072.37	2150.50	2112.66	2075.13	2077.05
2029	2078.80	2166.25	2119.48	2077.23	2081.20
2030	2083.16	2180.49	2124.05	2076.15	2080.15

8.9.8. Total GHG emissions from electricity use of washing machine stock

Table 8.29: Estimated GHG emissions from electricity use of washing machine stock 2015-2030

Year	EU28 GHG emissions from electricity use of washing machine stock (million ton $CO_{2eq.}$/year)				
	BAU	SCENARIO 1a	SCENARIO 1b	SCENARIO 1c	SCENARIO 1d
2015	13.20	12.72	13.36	13.36	12.75
2016	12.55	12.09	12.70	12.70	12.13
2017	12.00	11.56	12.15	12.15	11.60
2018	11.49	11.07	11.63	11.63	11.10
2019	10.97	10.57	11.11	11.11	10.60
2020	10.49	10.10	10.62	10.62	10.13
2021	10.14	9.77	10.26	10.26	9.80

Year	EU28 GHG emissions from electricity use of washing machine stock (million ton $CO_{2eq.}$/year)				
2022	9.81	9.45	9.93	9.93	9.48
2023	9.49	9.15	9.61	9.61	9.17
2024	9.19	8.86	9.30	9.30	8.88
2025	8.90	8.57	9.01	9.01	8.60
2026	8.50	8.19	8.60	8.60	8.21
2027	8.12	7.82	8.22	8.22	7.84
2028	7.74	7.46	7.84	7.84	7.48
2029	7.38	7.11	7.47	7.47	7.13
2030	7.03	6.77	7.12	7.12	6.79

Year	EU28 GHG emissions from electricity use of washing machine stock (million ton $CO_{2eq.}$/year)				
	BAU	SCENARIO 2a	SCENARIO 2b1	SCENARIO 2b2	SCENARIO 2b3
2015	13.20	13.22	13.26	13.18	12.66
2016	12.55	12.61	12.65	12.58	12.15
2017	12.00	12.10	12.15	12.06	11.73
2018	11.49	11.63	11.68	11.58	11.30
2019	10.97	11.17	11.20	11.09	10.86
2020	10.49	10.73	10.75	10.62	10.41
2021	10.14	10.44	10.43	10.29	10.08
2022	9.81	10.17	10.13	9.97	9.77
2023	9.49	9.92	9.83	9.65	9.47
2024	9.19	9.69	9.54	9.33	9.16
2025	8.90	9.46	9.26	9.02	8.86
2026	8.50	9.13	8.86	8.59	8.46
2027	8.12	8.81	8.47	8.17	8.06
2028	7.74	8.50	8.10	7.76	7.67
2029	7.38	8.20	7.73	7.35	7.29
2030	7.03	7.91	7.37	6.96	6.91

8.9.9. Primary energy from electricity use of washing machine stock

Table 8.30: Estimated primary energy use from electricity use of washing machine stock 2015-2030

Year	EU28 primary energy from electricity use of washing machine stock (PJ/year)				
	BAU	SCENARIO 1a	SCENARIO 1b	SCENARIO 1c	SCENARIO 1d
2015	326.24	314.34	330.25	315.25	283.93
2016	318.14	306.53	322.05	307.42	277.10
2017	312.28	300.88	316.12	301.75	272.22
2018	307.04	295.84	310.81	296.69	267.86
2019	301.48	290.48	305.19	291.32	263.19
2020	296.38	285.57	300.03	286.40	258.90

Year	EU28 primary energy from electricity use of washing machine stock (PJ/year)				
2021	289.93	279.35	293.49	280.16	253.40
2022	284.01	273.64	287.50	274.44	248.35
2023	278.32	268.16	281.74	268.94	243.48
2024	272.86	262.90	276.21	263.66	238.79
2025	267.61	257.85	270.90	258.60	234.28
2026	262.63	253.04	265.86	253.78	229.99
2027	257.83	248.42	261.00	249.14	225.84
2028	253.21	243.97	256.32	244.68	221.84
2029	248.75	239.68	251.81	240.37	217.97
2030	244.44	235.52	247.45	236.20	214.23

Year	EU28 primary energy from electricity use of washing machine stock (PJ/year)				
	BAU	SCENARIO 2a	SCENARIO 2b1	SCENARIO 2b2	SCENARIO 2b3
2015	326.24	326.82	327.70	325.81	312.89
2016	318.14	319.57	320.79	318.82	308.02
2017	312.28	314.84	316.21	313.90	305.13
2018	307.04	310.93	312.06	309.45	302.06
2019	301.48	306.95	307.59	304.56	298.21
2020	296.38	303.32	303.69	300.24	294.15
2021	289.93	298.56	298.22	294.25	288.43
2022	284.01	294.44	293.15	288.53	282.96
2023	278.32	290.85	288.14	282.77	277.47
2024	272.86	287.57	283.26	277.02	272.03
2025	267.61	284.55	278.44	271.24	266.61
2026	262.63	282.05	273.78	265.46	261.30
2027	257.83	279.82	269.24	259.64	256.06
2028	253.21	277.95	264.79	253.77	250.89
2029	248.75	276.35	260.44	247.86	245.78
2030	244.44	275.05	256.16	241.85	240.35

8.9.10. Energy and water consumption of washer dryer stock

Table 8.31: Estimated total EU28 electricity consumption of washer dryer stock 2015-2030

Year	EU28 total electricity consumption washer dryer stock (TWh/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	2.78	2.18	2.39	2.28	2.11
2016	2.77	2.22	2.40	2.29	2.16
2017	2.78	2.28	2.46	2.35	2.21
2018	2.78	2.32	2.52	2.40	2.25
2019	2.78	2.36	2.56	2.44	2.29

Year	EU28 total electricity consumption washer dryer stock (TWh/year)				
2020	2.78	2.38	2.56	2.45	2.31
2021	2.76	2.39	2.58	2.46	2.32
2022	2.75	2.40	2.59	2.48	2.33
2023	2.73	2.40	2.60	2.48	2.33
2024	2.71	2.40	2.61	2.49	2.33
2025	2.70	2.39	2.59	2.48	2.32
2026	2.68	2.38	2.59	2.47	2.31
2027	2.65	2.37	2.58	2.47	2.30
2028	2.63	2.36	2.57	2.46	2.29
2029	2.61	2.34	2.56	2.45	2.27
2030	2.59	2.33	2.55	2.43	2.26

Year	EU28 total electricity consumption washer dryer stock (TWh/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	2.78	2.78	2.78	2.78	2.78
2016	2.77	2.76	2.75	2.76	2.76
2017	2.78	2.76	2.74	2.76	2.76
2018	2.78	2.76	2.74	2.76	2.75
2019	2.78	2.74	2.73	2.75	2.74
2020	2.78	2.74	2.72	2.74	2.72
2021	2.76	2.72	2.70	2.73	2.70
2022	2.75	2.71	2.69	2.71	2.68
2023	2.73	2.69	2.67	2.69	2.66
2024	2.71	2.66	2.65	2.67	2.63
2025	2.70	2.64	2.63	2.65	2.61
2026	2.68	2.62	2.60	2.63	2.59
2027	2.65	2.59	2.58	2.61	2.57
2028	2.63	2.57	2.56	2.58	2.54
2029	2.61	2.55	2.53	2.56	2.52
2030	2.59	2.53	2.51	2.54	2.50

Table 8.32: Estimated total EU28 water consumption of washer dryer stock 2015-2030

Year	EU28 total water consumption washer dryer stock (million m^3/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	91.58	71.73	72.65	69.49	72.80
2016	93.74	75.33	75.10	71.82	76.46

Year	EU28 total water consumption washer dryer stock (million m³/year)				
2017	96.76	79.62	79.53	76.05	80.81
2018	99.78	83.76	83.89	80.20	85.02
2019	102.38	87.36	87.73	83.86	88.67
2020	104.80	90.66	90.47	86.47	92.02
2021	106.77	93.42	93.49	89.35	94.82
2022	108.71	96.04	96.39	92.10	97.47
2023	110.51	98.42	99.05	94.64	99.89
2024	112.17	100.57	101.50	96.97	102.08
2025	113.70	102.54	103.35	98.72	104.07
2026	115.13	104.32	105.42	100.69	105.88
2027	116.46	105.96	107.34	102.51	107.54
2028	117.71	107.46	109.12	104.20	109.06
2029	118.88	108.84	110.77	105.77	110.47
2030	119.98	110.12	112.31	107.24	111.77

Year	EU28 total electricity consumption washer dryer stock (TWh/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	91.58	72.83	73.31	73.06	73.01
2016	93.74	76.40	77.30	76.89	76.83
2017	96.76	80.68	81.97	81.41	81.38
2018	99.78	84.85	86.39	85.75	85.78
2019	102.38	88.49	90.17	89.49	89.64
2020	104.80	91.84	93.54	93.01	93.18
2021	106.77	94.68	96.35	95.85	96.15
2022	108.71	97.42	99.02	98.54	98.95
2023	110.51	99.94	101.45	100.98	101.48
2024	112.17	102.27	103.66	103.19	103.77
2025	113.70	104.43	105.67	105.32	105.82
2026	115.13	106.38	107.53	107.14	107.68
2027	116.46	108.14	109.26	108.80	109.35
2028	117.71	109.72	110.89	110.31	110.87
2029	118.88	111.14	112.42	111.69	112.26
2030	119.98	112.41	113.88	113.21	113.51

8.9.11. Total GHG emissions from electricity use of washer dryer stock

Table 8.33: Estimated GHG emissions from electricity use of washer dryer stock 2015-2030

Year	EU28 GHG emissions from electricity use of washer dryer stock (million ton $CO_{2eq.}$/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	1.01	0.79	0.87	0.83	1.01
2016	0.98	0.78	0.85	0.81	0.98
2017	0.95	0.78	0.85	0.81	0.95
2018	0.93	0.78	0.84	0.80	0.93
2019	0.90	0.76	0.83	0.79	0.90
2020	0.88	0.75	0.81	0.77	0.88
2021	0.86	0.74	0.80	0.76	0.86
2022	0.84	0.73	0.79	0.76	0.84
2023	0.82	0.72	0.78	0.75	0.82
2024	0.80	0.71	0.77	0.73	0.80
2025	0.78	0.69	0.75	0.72	0.78
2026	0.75	0.67	0.73	0.69	0.75
2027	0.72	0.65	0.70	0.67	0.72
2028	0.69	0.62	0.68	0.65	0.69
2029	0.66	0.60	0.65	0.62	0.66
2030	0.63	0.57	0.63	0.60	0.63

Year	EU28 GHG emissions from electricity use of washer dryer stock (million ton $CO_{2eq.}$/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	1.01	1.01	1.01	1.01	1.01
2016	0.98	0.97	0.97	0.97	0.97
2017	0.95	0.95	0.94	0.95	0.95
2018	0.93	0.92	0.91	0.92	0.92
2019	0.90	0.89	0.89	0.89	0.89
2020	0.88	0.86	0.86	0.86	0.86
2021	0.86	0.84	0.84	0.85	0.84
2022	0.84	0.83	0.82	0.83	0.82
2023	0.82	0.81	0.80	0.81	0.80
2024	0.80	0.79	0.78	0.79	0.78
2025	0.78	0.77	0.76	0.77	0.76
2026	0.75	0.73	0.73	0.74	0.73
2027	0.72	0.71	0.70	0.71	0.70

Year	EU28 GHG emissions from electricity use of washer dryer stock (million ton $CO_{2eq.}$/year)				
2028	0.69	0.68	0.67	0.68	0.67
2029	0.66	0.65	0.64	0.65	0.64
2030	0.63	0.62	0.61	0.62	0.61

8.9.12. Primary energy from electricity use of washer dryer stock

Table 8.34: Estimated primary energy use from electricity use of washer dryer stock 2015-2030

Year	EU28 primary energy from electricity use of washer dryer stock (PJ/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	24.88	19.51	21.40	18.98	18.92
2016	24.77	19.89	21.49	20.14	19.29
2017	24.81	20.35	22.01	20.43	19.74
2018	24.85	20.75	22.47	20.52	20.12
2019	24.81	21.01	22.80	21.01	20.39
2020	24.74	21.21	22.84	21.45	20.58
2021	24.51	21.22	22.90	21.76	20.58
2022	24.28	21.19	22.92	21.81	20.56
2023	24.03	21.12	22.89	21.86	20.49
2024	23.77	21.00	22.82	21.88	20.38
2025	23.50	20.86	22.61	21.85	20.24
2026	23.22	20.69	22.48	21.78	20.07
2027	22.94	20.50	22.32	21.58	19.89
2028	22.65	20.29	22.15	21.46	19.69
2029	22.36	20.07	21.96	21.31	19.48
2030	22.07	19.84	21.76	21.14	19.25

Year	EU28 primary energy from electricity use of washer dryer stock (PJ/year)				
	BAU	SCENARIO 1	SCENARIO 2a	SCENARIO 2b	SCENARIO 2c
2015	24.88	24.88	24.88	24.24	24.88
2016	24.77	24.71	24.59	24.75	24.69
2017	24.81	24.68	24.49	24.88	24.64
2018	24.85	24.61	24.42	24.68	24.58
2019	24.81	24.45	24.32	24.65	24.45
2020	24.74	24.39	24.23	24.62	24.28
2021	24.51	24.15	23.98	24.54	23.97
2022	24.28	23.91	23.73	24.44	23.67

Year	EU28 primary energy from electricity use of washer dryer stock (PJ/year)				
2023	24.03	23.63	23.47	24.18	23.36
2024	23.77	23.33	23.19	23.93	23.06
2025	23.50	23.01	22.90	23.67	22.76
2026	23.22	22.70	22.61	23.39	22.46
2027	22.94	22.40	22.31	23.10	22.17
2028	22.65	22.12	22.00	22.82	21.88
2029	22.36	21.85	21.69	22.53	21.60
2030	22.07	21.60	21.37	22.24	21.33

References

A.I.S.E (2008). Laundry and wash habits study. Unpublished.

A.I.S.E (2013). I prefer 30° - The case for the "A.I.S.E. low temperature washing" initiative: Substantiation Dossier / June 2013. Available at http://www.iprefer30.eu/component/attachments/attachments?task=download&id=244, last accessed on 15 Nov 2015.

A.I.S.E (April 2015). Market sizes 2012-2014 of different laundry detergent types. Research Sources: Home Care: Euromonitor from trade sources/national statistics by © Euromonitor International (Stakeholder Questionnaire).

A.I.S.E. ([n.d.]). Product Environmental Footprint (PEF). Available at http://www.aise.eu/our-activities/sustainable-cleaning-78/contributing-to-the-eu-agenda/product-environmental-footprint-pef.aspx, last accessed on 25 Apr 2015.

A.I.S.E. (2011a). CHARTER 2010: Advanced Sustainability Profiles for Household Fabric Conditioners. Available at http://www.sustainable-cleaning.com/content_attachments/documents/ASPsFCCharterupdate2010products10February2011.pdf, last accessed on 26 Apr 2015.

A.I.S.E. (ed.) (2011b). CHARTER 2010: Advanced Sustainability Profiles for Household Liquid Laundry Detergents. Available at http://www.sustainable-cleaning.com/content_attachments/documents/ASPsLLDCharterupdate2010products10February2011.pdf, last accessed on 26 Apr 2015.

A.I.S.E. (2011c). Laundry and wash habits study. Unpublished.

A.I.S.E. (ed.) (2012). Charter update 2010: Advanced Sustainability Profiles for Household Solid Laundry Detergents: 1st Revision - 30 MAY 2012. Available at http://www.sustainable-cleaning.com/content_attachments/documents/ASPsSLD_revision_30May2012.pdf, last accessed on 26 Apr 2015.

A.I.S.E. (ed.) (2015). Product Environmental Footprint Category Rules (PEFCR): Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash. First draft PEFCR – First version.

Adrian Porter (2013). Washing machines - Should I wash at 60°C? Available at http://www.which.co.uk/reviews/washing-machines/article/should-i-wash-at-60-c, last accessed on 20 Dec 2015.

AEA (ed.) (2009). Discussion Report: EU Ecolabel for Washing Machines. Available at http://www.endseurope.com/docs/90922a.pdf, last accessed on 05 May 2015.

AEG (n.d.). Lave-linge ÖKOMix. Available at http://www.aeg.be/fr-be/conseils/series/okomix-lave-linge/, last accessed on 17 Dec 2015.

AEG (2014a). AEG introduce the first ever washer dryer with heat pump technology: ÖKOKombi Plus | Electrolux Newsroom UK. Available at http://newsroom.electrolux.com/uk/2014/05/21/aeg-introduce-the-first-ever-washer-dryer-with-heat-pump-technology-okokombi-plus/, last accessed on 29 Apr 2015.

AEG (ed.) (2014b). User manual L 89495 FL. Available at http://www.electrolux-ui.com//DocumentDownLoad.aspx?DocURL=2014\132\913691umEN.pdf, last accessed on 21 May 2015.

AEG (2015a). Product Fiche AEG L77695WD. Available at http://www.aeg.co.uk/products/laundry/freestanding/washer_dryers/l77695wd, last accessed on 05 May 2015.

AEG (2015b). User Manual washer dryer L77695WD. Available at http://www.aeg.co.uk/products/laundry/freestanding/washer_dryers/l77695wd, last accessed on 05 May 2015.

Alborzi, F.; Schmitz, A. & Stamminger, R. (2015). Washing behaviour of European consumers 2015.

Amazon (2015). Offer AEG L77685WD Waschtrockner. Available at http://www.amazon.de/AEG-L77685WD-Waschtrockner-1600-Waschen/dp/B00DYWX0M6, last accessed on 21 May 2015.

Ardente, F. & Mathieux, F. (2012). Integration of resource efficiency and waste management criteria in European product policies – Second phase: Report n° 2: Application of the project's methods to three product groups (final). Available at http://sa.jrc.ec.europa.eu/uploads/ecodesign-Application-of-the-projects-methods-to-three-product-groups-final.pdf, last accessed on 23 May 2015.

Ardente, F. & Talens Peirò, L. (2015). Environmental Footprint and Material Efficiency Support for Product Policy: Report on benefits and impacts/costs of options for different potential material efficiency requirements for Dishwashers. Available at http://publications.jrc.ec.europa.eu/repository/bitstream/JRC95187/lb-na-27200-en-n.pdf, last accessed on 15 May 2015.

AREA (ed.) (2014). AREA F-Gas GUIDE: A practical guide on the application of the new F-Gas Regulation to refrigeration, air conditioning & heat pump contractors. Available at https://www.fluorocarbons.org/uploads/Modules/Library/area-guidelines-fgas-master-2-final.pdf, last accessed on 09 Apr 2015.

Assemblé Nationale (2015). TEXTE ADOPTÉ n° 575, Projet de Loi - relatif à la transition énergétique pour la croissance verte, Article 99 (22.7.2015). Available at http://www.assemblee-nationale.fr/14/ta/ta0575.asp, last accessed on 03 Dec 2015.

Australian Government (2012). Australia's Greenhouse and Energy Minimum Standards (Clothes Washing Machines) Determination 2012 under section 23 of the Australian Greenhouse and Energy Minimum Standards Act 2012 (25.10.2012). Available at http://www.comlaw.gov.au/Details/F2012L02117, last accessed on 25 Mar 2015.

Australian, State and Territory and New Zealand Governments (2014a). High Energy Performance Standards – Energy Star. Available at http://www.energyrating.gov.au/about/what-we-do/labelling, last accessed on 15 Sep 2016.

Australian, State and Territory and New Zealand Governments (2014b). Star Rating Calculations - Clothes Washers. Available at http://www.energyrating.gov.au/products-themes/washing-drying/clothes-washers/star-rating/, last accessed on 25 Mar 2015.

Australian, State and Territory and New Zealand Governments (2014c). The Energy Rating Label. Available at www.energyrating.gov.au, last accessed on 25 Mar 2015.

Bachl, T. & Koll, O. (2013). E-commerce, The potential for retailing? In ECR - Efficient Consumer Response . Brussels.

Bio by Deloitte (ed.) (2015). Study on Socioeconomic impacts of increased reparability – DG ENV: Questionnaire 1. Available at http://www.google.de/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=1&cad=rja&uact=8&ved=0CCgQFjAA&url=http%3A%2F%2Fwww.energimyndigheten.se%2FGlobal%2

FF%25C3%25B6retag%2FEkodesign%2FEkodesign%2FBIO_ENV_Impacts_of_reparability_questionnaire_1.docx&ei=yydFVcl8iOJom42A-AM&usg=AFQjCNFe73PSl_Stf8yWADqGFHRAA5VKiA, last accessed on 02 May 2015.

BIO Intelligence Service (ed.) (2013). Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP): Part 1: Material Efficiency for Ecodesign – Draft Final Report. Prepared for: European Commission - DG Enterprise and Industry. Available at http://www.google.de/url?sa=t&rct=j&q=&esrc=s&frm=1&source=web&cd=2&cad=rja&uact=8&ved=0CCwQFjAB&url=http%3A%2F%2Fec.europa.eu%2FDocsRoom%2Fdocuments%2F105%2Fattachments%2F1%2Ftranslations%2Fen%2Frenditions%2Fpdf&ei=iSRFVc-SFYi67gbnmoDQCw&usg=AFQjCNHSiyvwigeFrVdPMSo5FjtgldpvZQ, last accessed on 02 May 2015.

Blepp, M. & Gensch, C.-O. (2013). Einsparpotenziale durch automatische TwinDos Dosierung bei Waschmaschinen, last accessed on 14 Apr 2015.

Börjesson, P. & Tufvesson, L. (2011). Agricultural crop-based biofuels – resource efficiency and environmental performance including direct land use changes. Journal of Cleaner Production, (19), pp. 108–120.

Braun, V. & Stamminger, R. (2011). Using Fabric Softeners, Drying and Ironing in Germany: A non-representative Census of Consumer Behaviour. Tenside Surfactants Detergents (submitted and accepted), (48(3)), pp. 210–220.

Brückner, A. (2013). Consumer-relevant Assessment of automatic dishwashing machines by a new testing procedure for 'automatic' programmes. (Doctor thesis). Rheinische Friedrich-Wilhelms-Universität, Bonn, Germany.

BSH (2015). Refrigerants in heat-pump tumble dryers (E-mail; phone).

BSH Bosch und Siemens Hausgeräte GmbH (ed.) (2013). Creating Transparency: Group Sustainability Report 2013.

BSI Group ([n.d.]). Design MADE simple: Shedding light on the BS 8887 series of standards and their influence on sustainable design in the UK and beyond. Available at https://www.bsigroup.com/documents/standards/case-studies/BSI-maximizing-performance-BS-8887-design-for-manufacture-assembly-disassembly-and-end-of-life-processing-case-study-UK-EN.pdf, last accessed on 27 Feb 2014.

Buchert, M.; Manhart, A. & Sutter, J. (2014). Untersuchung zu seltenen Erden: Permanentmagnete im industriellen Einsatz in Baden-Württemberg. Available at http://www.oeko.de/oekodoc/2053/2014-630-de.pdf, last accessed on 12 Apr 2015.

Buchholz, T.; Luzadis, V. & Volk, T. (2009). Sustainability criteria for bioenergy systems: results from an expert survey. Journal of Cleaner Production, (17), S86–S98.

Bundgaard, A.; Remmen, A. & Overgaard Zacho, K. (2015). Ecodesign Directive version 2.0: From Energy Efficiency to Resource Efficiency. Available at http://www2.mst.dk/Udgiv/publications/2015/01/978-87-93283-56-5.pdf, last accessed on 08 Apr 2015.

Bush, E. & Nipkow, J. (2005). Energie- und Kostenoptimierungen bei Waschmaschinen und Geschirrspülern: Kriterien für Warmwasseranschluss: Pilotprojekt im Auftrag des Amts für Hochbauten der Stadt Zürich.

Capgemini Consulting (ed.) (2012). White goods distribution in the spotlight - Sustainable distribution networks: what can be learned? (https://www.capgemini.com). https://www.capgemini.com/resource-file-access/resource/pdf/White_goods_distribution_in_the_spotlight.pdf.

CECED (2014). Database.

CELC - China Energy Label Centre ([n.d.]a). Background and Significance of the China Energy Label. Available at http://www.energylabel.gov.cn/en/Introduction/ChinaEnergyLabel/, last accessed on 25 Mar 2015.

CELC - China Energy Label Centre ([n.d.]b). Maximum Allowable Values of Energy Consumption and Energy Efficiency Grades for Household Electric Washing Machines: GB12021.4-2004. Summary. Available at http://www.energylabel.gov.cn/en/EnergyEfficiencyStandards/FormulationandRevisionofStandards/detail/733.html, last accessed on 25 Mar 2015.

CENELEC ([n.d.]). European Mandates. Available at http://www.cenelec.eu/aboutcenelec/whatwestandfor/supportlegislation/europeanmandates.html, last accessed on 21 Apr 2015.

CENELEC (ed.) (2012). European Committee for Electrotechnical Standardization: Eu-ropean Standard EN 50574 – Collection, transport & treatment requirements for end-of-life household appliances containing volatile fluorocarbons of volatile hydrocarbons.

Center for Testmaterials BV ([n.d.]). Industry Standards. Available at http://www.cftbv.nl/industry_standards.php, last accessed on 06 May 2015.

ChinaFAQs, The Network for Climate and Energy Information (2010). Appliance Energy Efficiency Standards. Available at http://www.chinafaqs.org/files/chinainfo/ChinaFAQs_Appliance_Energy_Efficiency_Standards_0.pdf, last accessed on 25 Mar 2015.

Chinese Government (ed.) (2006). China Environmental Labelling Program: The Technical Requirement for Environmental Labeling Products - Household Electric Washing Machines. HJ/T 308-2006. Available at http://kjs.mep.gov.cn/hjbhbz/bzwb/other/hjbz/200611/W020111221567848638521.pdf, last accessed on 31 Mar 2015.

Claridge, J. (2015). Using Rainwater in Your Home. Available at http://www.goselfsufficient.co.uk/using-rainwater-in-your-home.html.

Computeruniverse (2015). Offer AEG Lavamat ÖKOKOMBI PLUS L99695HWD Waschtrockner. Available at http://www.computeruniverse.net/products/90548651/aeg-lavamat-oekokombi-plus-l99695hwd.asp, last accessed on 21 May 2015.

COWI and VHK (ed.) (2011). Methodology for Ecodesign of Energy-related Products MEErP 2011: Methodology Report. Part 1: Methods. Available at http://ec.europa.eu/enterprise/policies/sustainable-business/ecodesign/methodology/files/meerp_methodology_part1_en.pdf, last accessed on 07 Apr 2015.

Dalhammar, C.; Machacek, E.; Bundgaard, A.; Overgaard Zacho, K. & Remmen, A. (2014). Addressing resource efficiency through the Ecodesign Directive: A review of opportunities and barriers. Available at http://norden.diva-portal.org/smash/get/diva2:710881/FULLTEXT01.pdf, last accessed on 08 Apr 2015.

Deloitte (2016). Study on socioeconomic impacts of increased reparability: Final Report. Prepared for the European Commission DG ENV. Available at http://bookshop.europa.eu/en/study-on-socioeconomic-impacts-of-increased-reparability-of-increased-reparability-pbKH0216507/, last accessed on 08 Jun 2016.

DENA (ed.) (2006). Revision of the Energy Labelling System: Final Report.

Deloitte (2016). Study on socioeconomic impacts of increased reparability: Final Report. Prepared for the European Commission DG ENV. Available at http://bookshop.europa.eu/en/study-on-socioeconomic-impacts-of-increased-reparability-of-increased-reparability-pbKH0216507/, last accessed on 08 Jun 2016.

Deloitte (2017), Study to support Ecodesign measures to improve reparability of products. Interim Report. Follow up study

Deutschlandfunk (2006). Tolle Idee! – Was wurde daraus? Available at http://www.deutschlandfunk.de/tolle-idee-was-wurde-daraus.676.de.html?dram:article_id=23543, last accessed on 16 Apr 2015.

Digital Europe et al. (ed.) (2013). Guidance document on measuring all WEEE flows and establishing WEEE treatment standards under the WEEE recast implementation. Available at http://www.digitaleurope.org/DocumentDownload.aspx?Command=Core_Download&EntryId=514.

Doll, P., Kaspar, F. & Lehner, B. (2003). A global hydrological model for deriving water availability indicators: model tuning and validation. Journal of Hydrology, (270), pp. 105–134.

dolphi (2015). Dolfi: Next Gen Washing Device zu unterstützen. Available at https://www.indiegogo.com/projects/dolfi-next-gen-washing-device, last accessed on 16 Apr 2015.

Ecofys (ed.) (2014). Impacts of the EU's Ecodesign and Energy/Tyre Labelling Legislation on Third Jurisdictions: Appendices. Available at https://ec.europa.eu/energy/sites/ener/files/documents/201404_ieel_third_jurisdictions_appendices.pdf, last accessed on 25 Mar 2015.

ECOS, EE and UK SNS (ed.) (2015). ECOS, EEB and UK SNS discussion paper on the draft standardisation request on material efficiency aspects for Ecodesign products. Available at http://ecostandard.org/wp-content/uploads/ECOS-EEB-UKSNS-Discussion-Paper-on-Material-Efficiency-Mandate.pdf, last accessed on 27 Feb 2015.

Electrical and Mechanical Services Department (EMSD) (2014). Code of Practice on Energy Labelling of Products 2014. Available at http://www.energylabel.emsd.gov.hk/en/doc/2014%20MEELS%20Code%20of%20Practice%20(Eng)%20(Final).pdf, last accessed on 25 Mar 2015.

Electrolux (2015a). Product Fiche Electrolux WTSL6E200. Available at http://www.aeg.co.uk/Products/Laundry/Freestanding/Washer_dryers/L99695HWD, last accessed on 05 May 2015.

Electrolux (2015b). User manual washer dryer WTSL6E200 (heat pump). Available at http://www.aeg.co.uk/Products/Laundry/Freestanding/Washer_dryers/L99695HWD, last accessed on 05 May 2015.

EMSD (ed.) (2013). The Hong Kong Voluntary Energy Efficiency Labelling Scheme: Washing Machines. Available at http://www.emsd.gov.hk/emsd/e_download/pee/veels_washing_machine.pdf, last accessed on 25 Mar 2015.

Energy Efficient Strategies (EES) (2010). Appliance Energy Consumption in Australia: Equations for Appliance Star Ratings. Available at http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/General/Labelling_and_MEPS/appliance-star-ratings.pdf.

Energy Saving Trust (ed.) (2013). At Home with Water: The biggest ever review of domestic water use in Great Britain. Analysis from the Energy Saving Trust's Water Energy Calculator. Available at http://www.energysavingtrust.org.uk/sites/default/files/reports/AtHomewithWater%287%29.pdf, last accessed on 21 May 2015.

Energy Saving Trust (n.d.). Certification. Available at http://www.energysavingtrust.org.uk/businesses/certification, last accessed on 28 Apr 2015.

Euromonitor International (2014). Passport database. Available at http://www.euromonitor.com/passport, last accessed on 21 May 2015.

Europe Economics (ed.) (2015). The Economic Impact of the Domestic Appliances Industry in Europe: Report for the European Committee of Domestic Equipment Manufacturers (CECED), last accessed on 24 Jan 2016.

European Commission (1996). Commission Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to energy labelling of household combined washer-driers (OJ L 266, pp. 1–27). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31996L0060&from=EN, last accessed on 19 May 2015.

European Commission (ed.) (2007 / modif. 2012). Guidelines on the application of Directive 2006/95/EC (Electrical equipment designed for use within certain voltage limits). August 2007; last modified January 2012. Available at http://ec.europa.eu/enterprise/sectors/electrical/files/lvdgen_en.pdf, last accessed on 28 Apr 2015.

European Commission (ed.) (2007). Report from the Commission to the Council and the European Parliament Pursuant to Article 16 of Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents, concerning the use of phosphates. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0234:FIN:EN:PDF, last accessed on 28 Apr 2015.

European Commission (2008). Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off mode electric power consumption of electrical and electronic household and office equipment (OJ L 339, pp. 45–52). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:339:0045:0052:en:PDF, last accessed on 07 Mar 2015.

European Commission (2008b) Commission staff working document, proposal for a commission regulation implementing directive 2005/32/EC with regard to dishwashers Full Impact Assessment.

European Commission (2010a). Commission Delegated Regulation (EU) No 1061/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household washing machines (OJ L 314, 2010, pp. 47–63). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1061&from=en, last accessed on 24 Feb 2015.

European Commission (2010b). Commission Regulation (EU) No 1015/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household washing machines

(OJ L 293, 2010, pp. 21–30). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1015&from=en, last accessed on 24 Feb 2015.

European Commission (2010c). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy 2020 - A strategy for competitive, sustainable and secure energy. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:EN:PDF, last accessed on 19 May 2015.

European Commission (2010d). Guide to application of the Machinery Directive 2006/42/EC (2010). Available at http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide_application_directive_2006-42-ec-2nd_edit_6-2010_en.pdf, last accessed on 24 Feb 2015.

European Commission (2011). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy Efficiency Plan 2011. Available at http://eur-lex.europa.eu/resource.html?uri=cellar:441bc7d6-d4c6-49f9-a108-f8707552c4c0.0002.03/DOC_1&format=PDF, last accessed on 19 May 2015.

European Commission (2012a). Commission Regulation (EU) No 1194/2012 of 12 December 2012 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for directional lamps, light emitting diode lamps and related equipment (Text with EEA relevance) (OJ L 342, pp. 1–22), last accessed on 28 Feb 2015.

COMMISSION DELEGATED REGULATION (EU) No 392/2012 of 1 March 2012 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household tumble driers. OJ L 123 (European Commission 9.5.2012b).

European Commission (2013a). Commission Regulation (EU) No 666/2013 of 8 July 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for vacuum cleaners (OJ L 192, pp. 24–34). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0666&from=EN, last accessed on 27 Feb 2015.

European Commission (2013b). Commission Regulation (EU) No 801/2013 of 22 August 2013 amending Regulation (EC) No 1275/2008 with regard to ecodesign requirements for standby, off mode electric power consumption of electrical and electronic household and office equipment, and amending Regulation (EC) No 642/2009 with regard to ecodesign requirements for televisions (OJ L 225, pp. 1–12). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0801&from=EN, last accessed on 04 May 2015.

European Commission (ed.) (2013c). Digital Agenda Scoreboard 2013: Commission staff working document. Available at https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/DAE%20SCOREBOARD%202013%20-%20SWD%202013%20217%20FINAL.pdf, last accessed on 03 May 2015.

European Commission (ed.) (2013d). Mandate M/518 EN to the European Standardisation Organisations for standardisation in the field of waste electrical and electronic equipment (Directive 2012/19/EU (WEEE)). Available at ftp://ftp.cencenelec.eu/CENELEC/EuropeanMandates/M_518.pdf, last accessed on 21 Apr 2015.

European Commission (ed.) (2014a). Commission Regulation (EU) No …/2015 of XXX implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for electronic displays and repealing Regulation 642/2009 with regard to ecodesign requirements for televisions: Possible requirements for electronic displays.

European Commission (2014b). Guidelines accompanying Commission Regulation (EC) No 1275/2008 of 17 December 2008 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for standby and off-mode electric power consumption of electrical and electronic household equipment: (October 2009/with up-date November 2014). Available at https://ec.europa.eu/energy/sites/ener/files/documents/guidelines%20for%20SMEs%201275_2008_oct_09.pdf.

European Commission (ed.) (2014c). Possible Ecodesign and Energy Labelling requirements for electronic displays: Explanatory Notes.

European Commission (ed.) (2014d). Revised EU Ecolabel Performance Test for Laundry Detergents. Available at http://ec.europa.eu/environment/ecolabel/documents/Performance%20Test%20Laundry%20Detergents.pdf, last accessed on 06 May 2015.

European Commission (ed.) (2015a). Commission Implementing Decision of 7.1.2015 on a standardisation request to the European standardisation organisations pursuant to Article 10(1) of Regulation (EU) No 1025/2012 of the European Parliament and of the Council in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements on material efficiency aspects (recyclability, recoverability and reusability indexes, durability, reversible disassembly and end of life extraction time).

European Commission (ed.) (2015b). Draft Commission Decision of XXX establishing the criteria for the award of the EU Ecolabel for personal, notebook and tablet computers: Annex: EU Ecolabel criteria and assessment and verification requirements. Final criteria proposal for voting on 17th April 2015.

European Commission (ed.) (2015c). M/543 - COMMISSION IMPLEMENTING DECISION of 17.12.2015 on a standardisation request to the European standardisation organisations as regards ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council. Available at http://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=564#, last accessed on 25 Jan 2016.

European Commission (2015d). Stakeholder workspace: PEFCR pilot Household liquid laundry detergents. Available at https://webgate.ec.europa.eu/fpfis/wikis/display/EUENVFP/Stakeholder+workspace%3A+PEFCR+pilot+Household+liquid+laundry+detergents.

European Committee for Standardization (2011). CEN/TC 411-Bio-based products. Executive Summary of the Business Plan. Available at https://standards.cen.eu/BP/874780.pdf, last accessed on 25 Nov 2016.

European Parliament (2004). Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents (OJ L 104, pp. 1–35). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32004R0648&from=EN, last accessed on 17 Apr 2015.

European Parliament (2006a). Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (OJ L 157, pp. 24–86). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF, last accessed on 24 Feb 2015.

European Parliament (2006b). DIRECTIVE 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast) (2006). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:EN:PDF, last accessed on 24 Feb 2015.

European Parliament (2008). Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (OJ L 312, pp. 3–30). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0098&from=EN, last accessed on 20 May 2015.

European Parliament (2009a). Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (recast) (OJ L 285, pp. 10–35). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN, last accessed on 19 Mar 2015.

European Parliament (2009b). Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (OJ L 140, pp. 16–62). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en, last accessed on 03 May 2015.

European Parliament (2010). Directive 2010/30/EU of the European Parliament and of the Council on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products (OJ L 153, pp. 1–12). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:153:0001:0012:en:PDF, last accessed on 19 May 2015.

European Parliament (2011). Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (OJ L 174, pp. 88–110). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0065&from=EN, last accessed on 15 Apr 2015.

European Parliament (2012a). Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE) (OJ L 197, pp. 38–71). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN, last accessed on 13 Mar 2015.

European Parliament (2012b). Regulation (EU) No 259/2012 of the European Parliament and of the Council of 14 March 2012 amending Regulation (EC) No 648/2004 as regards the use of phosphates and other phosphorus compounds in consumer laundry detergents and consumer automatic dishwasher detergents (OJ L 94, pp. 16–21). Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:094:0016:0021:en:PDF, last accessed on 17 Apr 2015.

European Parliament (2014a). Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (OJ L 96, pp. 79–106). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0030&from=DE, last accessed on 12 Mar 2015.

European Parliament (2014b). Directive 2014/35/EU of the European Parliamant and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits (OJ L 96, pp. 357–374). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0035&from=EN, last accessed on 12 Mar 2014.

European Parliament (2014c). Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006 (OJ L 150, pp. 195–230). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0517&from=EN, last accessed on 09 Apr 2014.

Eurostat ([n.d.]). Prodcom. Available at http://ec.europa.eu/eurostat/web/prodcom/data/database.

Eurostat (ed.) (2013). Waste statistics – electrical and electronic equipment. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics_-_electrical_and_electronic_equipment#Database, last accessed on 18 Mar 2015.

Eurostat (2014). Household characteristics by type of household. Available at http://ec.europa.eu/eurostat/web/products-datasets/-/hbs_car_t313, last accessed on 16 Dec 2015.

Eurostat (ed.) (2015a). Statistics on the production of manufactured goods: Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data. Extraction for household dishwashers (Prodcom Code 27511200). Available at http://ec.europa.eu/eurostat/web/prodcom/data/database, last accessed on 30 Mar 2015.

Eurostat (ed.) (2015b). Traditional international trade database (ComExt): EU Trade Since 1988 by CN8. Extraction for dishwashing machines of the household type (CN Code 84221100). Available at http://epp.eurostat.ec.europa.eu/newxtweb/, last accessed on 30 Mar 2015.

Eurostat (2016). Number of private households by household composition, number of children and age of youngest child (1 000). Available at http://ec.europa.eu/eurostat/en/web/products-datasets/-/LFST_HHNHTYCH, last accessed on 14 Jun 2016.

Financial Times (2015). Xeros reinvents the washing machine. Available at http://www.ft.com/cms/s/2/b22b17bc-ad2e-11e4-a5c1-00144feab7de.html?utm_campaign=Investors&utm_source=hs_email&utm_medium=email&utm_content=16678054&_hsenc=p2ANqtz--aocLHtMqdqw1Ua4Kt8utCpIU7eRjdKJDOo2Joxl8-yrAcQ0MQ4X7C-o3o6LsClnC92bgSFWRs97qTBOZKenQow0pvNlN-6HWYyFKKG62-UhlHjy0&_hsmi=16678054#axzz3UuYRTXZ7, last accessed on 20 Apr 2015.

Fiorentino, G.; Ripa, M.; Mellino, S.; Fahd, S. & Ulgiati, S. (2014). Life cycle assessment of Brassica carinata biomass conversion to bioenergy and platform chemicals. Journal of Cleaner Production, (66), pp. 174–187.

Freescale Semiconductor (ed.) (2012). Household washing machines: Freescale MCUs provide smart solutions for home appliances. Available at http://cache.freescale.com/files/32bit/doc/brochure/BBHHWSHMCHNART.pdf?fasp=1&WT_

TYPE=Brochures&WT_VENDOR=FREESCALE&WT_FILE_FORMAT=pdf&WT_ASSET=Documentation&fileExt=.pdf, last accessed on 23 Apr 2015.

French Government (2014). Décret n° 2014-1482 du 9 décembre 2014 relatif aux obligations d'information et de fourniture concernant les pièces détachées indispensables à l'utilisation d'un bien (2014, p. 20707). Available at http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000029881868&dateTexte=&categorieLien=id, last accessed on 15 Apr 2015.

FTC (2012). EnergyGuide label templates for manufacturers. Available at https://www.ftc.gov/tips-advice/business-center/guidance/energyguide-labels-templates-manufacturers, last accessed on 25.3.2914.

Gensch, C.-O.; Baron, Y.; Blepp, M.; Bunke, D. & Moch, K. (2014). Study for the review of the list of restricted substances under RoHS 2 - Analysis of impacts from a possible ban of several new substances under RoHS 2: Analysis of Impacts from a Possible Restriction of Several New Substances under RoHS 2. Available at http://rohs.exemptions.oeko.info/fileadmin/user_upload/RoHS_Substance_Review/20140806_Substance_Review_revised_version_final_plus_Dossier.pdf, last accessed on 15 Apr 2015.

Gensch, C.-O.; Brommer, E. & Weber, A. (2009). Einsparpotenziale durch Warmwassernutzung und andere technologische Entwicklungen bei Geschirrspülmaschinen: Ermittlung typischer Randbedingungen in Haushalten: Endbericht im Auftrag der BSH Bosch und Siemens Hausgeräte GmbH.

Gensch, C.-O.; Liu, R. & Grießhammer, R. (2010). Einsparpotentiale durch eine neu entwickelte Waschmaschine mit Dosierautomatik: Studie im Auftrag der BSH Bosch und Siemens Hausgeräte GmbH, last accessed on 14 Apr 2015.

Gensch, C.-O. & Rüdenauer, I. (2004). Ökologische und ökonomische Betrachtung von Wäschetrocknungssystemen. Hauswirtschaft und Wissenschaft, 8, pp. 12–19.

GfK (2013).

GfK (2014).

Gorenje ([n.d.]). description for washing machine model W9865E. Available at http://www.gorenje.de/produkte/hausgerate/waschepflege/modelle/waschmaschinen/356674, last accessed on 06 May 2015.

Government of the Republic of China (Taiwan): Environmental Protection Administration (ed.) (2014). Green Mark Criteria for Clothes Washers: Seventh revision of November 2014. Available at http://greenliving.epa.gov.tw/GreenLife/uploadfiles/Criteria/23/98ef8d44-0194-4dcb-874d-618683e90536.pdf, last accessed on 27 Mar 2015.

Graulich, K.; Blepp, M.; Brommer, E.; Gensch, C.-O.; Rüdenauer, I.; Mudgal, S.; Cervantes, R.; Faninger, T. & Lyons, L. (2011). Preparatory Studies for Eco-design Requirements of Energy-using Products Lot 24: Professional Washing Machines, Dryers and Dishwashers: Part: Washing Machines and Dryers, Task 1: Definition. Available at http://www.eup-network.de/fileadmin/user_upload/Produktgruppen/Lots/Working_Documents/EuP_Lot24_Wash_T1_Report_ENER_clean.pdf, last accessed on 24 Feb 2015.

Griffin, A. (2015). CES 2015: Samsung, LG and Whirlpool announce wifi-enabled washing machines. Available at http://www.independent.co.uk/life-style/gadgets-and-tech/news/ces-2015-samsung-lg-and-whirlpool-announce-wifienabled-washing-machines-9961189.html, last accessed on 18 May 2015.

Groß, R.; Bunke, D.; Gensch, C.-O.; Zangl, S. & Manhart, A. (2008). Study on Hazardous Substances in Electrical and Electronic Equipment, Not Regulated by the RoHS Directive. Available at http://ec.europa.eu/environment/waste/weee/pdf/hazardous_substances_report.pdf, last accessed on 15 Apr 2015.

HEA ([n.d.]). Fachwissen - Waschmaschinen. Available at http://hea.de/service/fachwissen/waschmaschinen/index.php, last accessed on 08 Apr 2015.

Henkes, W. (2012). Schärfere Optionsregeln. Recycling Magazin, (16/2012).

Hennies, L. & Stamminger, R. (2015). An empirical survey on obsolescence of appliances in households.

Hong Kong Green Council (ed.) (2010a). Hong Kong Green Label Scheme Product Environmental Criteria for Dishwashers (GL-007-004). Available at http://www.greencouncil.org/hkgls/GL007004_rev3.pdf, last accessed on 25 Mar 2015.

Hong Kong Green Council (ed.) (2010b). Hong Kong Green Label Scheme Product Environmental Criteria for Washing Machines (GL-007-002). Available at http://www.greencouncil.org/hkgls/GL007002_rev3.pdf, last accessed on 25 Mar 2015.

Honisch, M.; Stamminger, R. & Bockmühl, D. (2014). Impact of wash cycle time, temperature and detergent formulation on the hygiene effectiveness of domestic laundering. Journal of Applied Microbiology, (117(6)), pp. 1787–1797.

Hu B.; Zheng T.; Li J. & Zeng L. (2013). Market analysis for China energy efficient products. Available at http://proceedings.eceee.org/papers/proceedings2013/6-186-13_Hu.pdf?returnurl=http%3A%2F%2Fproceedings.eceee.org%2Fvisabstrakt.php%3Fevent%3D3%26doc%3D6-186-13, last accessed on 25 Mar 2015.

Huisman, J.; Magalini, F.; Kuehr, R.; Maurer, C.; Ogilvie, S.; Poll, J.; Delgado, C.; Artim, E.; Szlezak, J. & Stevels, A. (2007). 2008 Review of Directive 2002/96 on Waste Electrical and Electronic Equipment (WEEE): Final Report. Available at http://ec.europa.eu/environment/waste/weee/pdf/final_rep_unu.pdf, last accessed on 20 Mar 2015.

Huisman, J.; van der Maesen, M. & Eijsbouts, R. (2012). The Dutch WEEE Flows. Bonn, Germany. Available at http://www.weee-forum.org/system/files/2012_the_dutch_weee_flows_unu.pdf, last accessed on 09 Apr 2015.

IBM (ed.) (2002). AISE Code of Good Environmental Practice: Final Report to the European Commission 1996 – 2001. Brussels.

IEC (ed.) (2012). IEC/TR 62635 Technical Report: Guidelines for end-of-life information provided by manufacturers and recyclers and for recyclability rate calculation of electrical and electronic equipment. Available at www.webstore.iec.ch/preview/info_iec62635(ed1.0)en.pdf, last accessed on 27 Feb 2015.

IKW (ed.) (2009). Nachhaltigkeitsbericht Wasch- und Reinigungsmittelbranche in Deutschland: Berichtsjahre 2007 und 2008. Available at http://www.ikw.org/fileadmin/content/downloads/Haushaltspflege/HP_Nachhaltigkeitsbericht07-08.pdf, last accessed on 22 Jan 2016.

IKW (ed.) (2011). Nachhaltigkeit in der Wasch-, Pflege- und Reinigungsmittelbranche in Deutschland im Industrieverband Körperpflege- und Waschmittel e.V. (IKW): Nachhaltigkeit 2009/2010. Available at http://www.ikw.org/fileadmin/content/downloads/Haushaltspflege/HP_Nachhaltigkeitsbericht09-10.pdf, last accessed on 21 May 2015.

Indensit Company (ed.) (2014). Sustainability Report 2013. Available at http://www.indesitcompany.com/pages/_saved_files/content/link/en_GB/1622_IndesitCo_CSR_2013_ENG.PDF, last accessed on 19 Mar 2015.

International Energy Agency IEA (2012). Energy Efficiency Policies and Measures Databases: Energy Efficiency Label and Standard Program, Republic of Korea. Available at http://www.iea.org/policiesandmeasures/energyefficiency/index.php, last accessed on 27 Mar 2015.

International Energy Agency IEA (2014). Energy Efficiency Policies and Measures Databases: Equipment Energy Efficiency Program (E3), Australia. Available at http://www.iea.org/policiesandmeasures/energyefficiency/index.php, last accessed on 27 Mar 2015.

International Energy Agency IEA (2015). Energy Efficiency Policies and Measures Databases: Energy Efficiency Labeling Program, Indonesia. Available at http://www.iea.org/policiesandmeasures/energyefficiency/index.php, last accessed on 27 Mar 2015.

ISIS (ed.) (2007a). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 1: Definitions. Draft final report. Available at https://circabc.europa.eu/sd/a/48b885cf-3bf6-47cc-aea6-e7d071291734/Task%201%20Definitions.pdf, last accessed on 12 Mar 2015.

ISIS (ed.) (2007b). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 3: Consumer behaviour and local infrastructure. Final Report, last accessed on 21 May 2015.

ISIS (ed.) (2007c). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 5: Definition of Base Case. Task Final Report. Available at http://www.eup-network.de/fileadmin/user_upload/Task_5_Definition_of_Base_Case.pdf, last accessed on 19 Mar 2015.

Jakobi, G. & Löhr, A. (1987). Detergents and textile washing: principles and practice: VCH Publishers.

Josephy, B.; Bush, E.; Nipkow, J. & Attali, S. (2011). Washing Machines: Key Criteria for Best Available Technology BAT: EEDAL.

Josephy, B.; Bush, E.; Nipkow, J.; Kleeli, K. & Glanzmann, S. (2013). Cold wash—Do prejudices impede high energy savings.

JRC IPTS (ed.) (2014a). Revision of European Ecolabel Criteria for Laundry Detergents: Preliminary report for the revision of ecological criteria for laundry detergents: Domestic and industrial and institutional. Available at http://susproc.jrc.ec.europa.eu/detergents/docs/LD%20Preliminary%20Report.pdf, last accessed on 25 Apr 2015.

JRC IPTS (ed.) (2014b). Revision of European EU Ecolabel Criteria for Detergents for Dishwashers: Preliminary report for the revision of European ecological criteria for detergents for dishwashers: domestic and industrial and institutional. Available at http://susproc.jrc.ec.europa.eu/detergents/docs/DD%20Preliminary%20Report.pdf, last accessed on 25 Apr 2015.

JRC IPTS (ed.) (2015a). Revision of European Ecolabel Criteria for laundry detergents, dishwasher detergents, industrial and institutional automatic dishwasher detergents, industrial and institutional laundry detergents, hand dishwashing detergents and all-purpose cleaners and sanitary cleaners. Available at http://susproc.jrc.ec.europa.eu/detergents/docs/ELS-DP_2_15-01-2015.pdf, last accessed on 25 Apr 2015.

JRC IPTS (ed.) (2015b). Revision of EU Ecodesign and Energy/Resource Label for household washing machines and washer-dryers: Stakeholder consultation - 1st questionnaire. Available at http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/docs/1st_Questionnaire_WASH.doc, last accessed on 19 May 2015.

Kashiv, P. (2015). Haier Duo is the world's first dual-drum washing machine. Available at http://www.homecrux.com/2015/09/12/34607/haier-duo-worlds-first-dual-drum-washing-machine.html.

Kates, R. (2000). Population and consumption - What we know, what we need to know. Environment, (42), pp. 10–19.

Kemna, R. & Stamminger, R. (2003). Energy Consumption of Domestic Appliances in European Households - Results from Stock Model Calculations. In 3rd Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL) .

Korea Environmental Industry & Technology Institute KEITI (ed.) (2011). Ecolabel certification criteria for washing machines. Available at http://el.keiti.re.kr/enservice/enpage.do?mMenu=2&sMenu=1, last accessed on 27 Mar 2015.

Kruschwitz, A.; Karle, A.; Schmitz, A. & Stamminger, R. (2014). Consumer laundry practices in Germany. International Journal of Consumer Studies, 38(3), pp. 265–277.

Kutsch, T.; Piorkowsky, M.-B. & Schätzke, M. (1997). Einführung in die Haushaltswissenschaft: Haushaltsökonomie, Haushaltssoziologie, Haushaltstechnik: UTB.

Laitala, K.; Boks, C. & Klepp, I. (2011). Potential for environmental improvements in laundering. International Journal of Consumer Studies, (35), pp. 254–264.

LG (ed.) (2015). LG TWINWash™ - Frequently Asked Questions. Available at http://www.lg.com/us/twinwash/pdf/LG-TwinWash-FAQ.pdf, last accessed on 22 Dec 2015.

Livesey, B. (2014). Whirlpool to Buy Control of Italy's Indesit for $1B. Available at http://www.bloomberg.com/news/articles/2014-07-11/whirlpool-to-buy-stakes-totalling-67-in-italy-s-indesit, last accessed on 15 May 2015.

Loveday, H.; Wilson, J.; Hoffmann, P. & Pratt, R. (2007). Public perception and the social and microbiological significance of uniforms in the prevention and control of healthcare-associated infections: an evidence review. British Journal of Infection Control, (8(4)), pp. 10–21.

Magalani, F.; Huisman, J. & Wang, F. (2012). Household WEEE generated in Italy: Analysis on volumes & consumer disposal behaviour for waste electrical and electronic equipment. Available at http://www.weee-forum.org/system/files/2012_ecodom_weee_arising_in_italy_en.pdf, last accessed on 09 Apr 2015.

Manhart, A. (2014). Visual observations in EEE trading hubs in Ghana and Nigeria between 2006 and 2014.

Michel, A.; Attali, S. & Bush, E. (2015). Energy efficiency of White Goods in Europe: monitoring the market with sales data: Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014.

Miele ([n.d.]a). Miele Service Zertifikat. Available at http://www.miele.de/media/domestic_de/media/files/download/MSZ2015.pdf, last accessed on 22 Jan 2016.

Miele ([n.d.]b). Miele@home. Available at http://www.miele-project-business.com/international/en/project_business/products/miele-at-home.aspx, last accessed on 14 Apr 2015.

Miele ([n.d.]c). Produktauswahl Waschmaschinen und Waschtrockner. Available at http://www.miele.de/haushalt/produktauswahl-waschmaschinen-und-waschtrockner-1565.htm#5, last accessed on 06 May 2015.

Montalvo C., Perk D., Rietveld E., A longer lifetime for products: Benefits for consumers and companies, (2016) Study for the IMCO Committee, IP/A/IMCO 2015-11, available at: http:www.europarl.eu/studies

Nordic Ecolabelling (ed.) (2011). Nordic Ecolabelling of Laundry detergents and stain removers: Version 7.7, 15 December 2011 - 31 December 2017. Appendix 6: Nordic Ecolabel Performance Test (fitness for use). Available at http://www.nordic-ecolabel.org/Templates/Pages/CriteriaPages/CriteriaGetFile.aspx?fileID=519, last accessed on 06 May 2015.

Nordic Ecolabelling (ed.) (2014). Nordic Ecolabelling of White Goods: Version 5.0. 20 June 2013 - 30 June 2017. Available at http://www.svanen.se/Templates/Criteria/CriteriaGetFile.aspx?productGroupNumber=3&language=e, last accessed on 25 Mar 2015.

Nordstrom, J.; Reynolds, K. & Gerba, C. (2012). Comparison of bacteria on new, disposable, laundered, and unlaundered hospital scrubs. American Journal of Infection Control, 40(6), pp. 539–543.

Novem (ed.) (2001). Revision of energy labelling & targets washing machines (clothes): Study for the DG TREN of the Commission of the European Communities.

OCU (2015). Miele, a la cabeza: Los mejores electrodomésticos. OCU-Compra Maestra, 401(03/2015), pp. 28–31.

Omar Degoli (2015). Le molte vite della lavatrice: Circular Economy Blog. Available at http://circulareconomyblog.com/2015/05/20/le-molte-vite-della-lavatrice, last accessed on 20 Dec 2015.

Owen, P. (2012). Powering the Nation; Household electricity-using habits revealed. A report by the Energy Saving Trust, the Department of Energy and Climate Change (DECC), and the Department for Environment. Food and Rural Affairs (Defra),

Patel, S.; Murray-Leonard, J. & Wilson, A. (2006). Laundering of hospital staff uniforms at home. The Journal of Hospital Infection, (62(1)), pp. 89–93.

Persson, T. (2007). Dishwasher and washing machine heated by a hot water circulation loop. Applied Thermal Engineering, 27(1), pp. 120–128. doi:10.1016/j.applthermaleng.2006.05.005.

Plepys, A. & Mont, O. ([n.d.]). Towards sustainable consumption practices: community based services for households.

Porter, A. ([n.d.]). Which? Tumble dryer glossary. Available at http://www.which.co.uk/reviews/tumble-dryers/article/tumble-dryer-glossary, last accessed on 20 Aug 2015.

Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher T. & Stamminger, R. (2015). Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz“: ZWISCHENBERICHT: Analyse der Entwicklung der Lebens-, Nutzungs- und Verweildauer von ausgewählten Produktgruppen. Available at http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_10_2015_einfluss_der_nutzungsdauer_von_produkten_auf_ihre_umwelt_obsoleszenz_17.3.2015.pdf, last accessed on 06 Apr 2015.

Prakash, S.; Stamminger, R.; Dehoust, G.; Gsell, M. & Schleicher T. (2016). Influence of the service life of products in terms of their environmental impact: Establishing an information base and developing strategies against "obsolescence": Final report.

Quack, D. (2010). Prices and life cycle costs of comparable energy efficient products in Europe. Available at http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/euro-topten_plus_price_and_life_cycle_costs_in_europe.pdf, last accessed on 21 May 2015.

Que choisir (2013). Lave-linge Frontaux, pp. 36–38.

RainWaterHarvesting ([n.d.]). Rainwater Harvesting: Supplying WCs and Washing Machines. Available at http://www.rainwaterharvesting.co.uk/downloads/wcs-and-washing-machines.pdf.

Ral gGmbH (ed.) (2013a). Household Washing machines RAL-UZ 137: Basic Criteria for Award of the Environmental Label. Available at https://www.blauer-engel.de/sites/default/files/raluz-downloads/vergabegrundlagen_en/e-UZ-137-2013.zip, last accessed on 24 Feb 2015.

Ral gGmbH (ed.) (2013b). Household Washing machines RAL-UZ 137: Basic Criteria for Award of the Environmental Label. Available at https://www.blauer-engel.de/sites/default/files/raluz-downloads/vergabegrundlagen_en/e-UZ-137-2013.zip, last accessed on 24 Feb 2015.

Ricardo-AEA (ed.) (2014a). The Durability of Products: Task 1 Report: Standard assessment for the circular economy under the Eco-Innovation Action Plan. Task 1 – Selection of Products. Available at www.productdurability.eu/assets/Product-Durability-Task-1-Report.pdf, last accessed on 18 Mar 2015.

Ricardo-AEA (ed.) (2014b). The Durability of Products: Task 2 Briefing: Standard assessment for the circular economy under the Eco-Innovation Action Plan. Task 2 – Review of Existing Methodologies. Available at http://www.productdurability.eu/assets/Product-Durability-Task-2-Briefing-tc.pdf, last accessed on 18 Mar 2015.

Riley, K.; Laird, K. & Williams, J. (2015). Washing uniforms at home: adherence to hospital policy. Nursing Standard, (29(25)), pp. 37–43.

RReuse (ed.) (2013). Investigation into the repairability of Domestic Washing Machines, Dishwashers and Fridges. Available at http://www.rreuse.org/wp-content/uploads/RREUSE_Case_Studies_on_reparability_-_Final.pdf, last accessed on 08 Apr 2015.

Rüdenauer, I. & Gensch, C.-O. (2004). Energy demand of tumble driers with respect to differences in technology and ambient conditions: Final Report.

Rüdenauer, I.; Gensch, C.-O. & Liu, R. (2008a). Vergleich der Umweltauswirkungen und Kosten verschiedener Wäschetrocknungssysteme: Studie im Auftrag der B/S/H Hausgeräte GmbH.

Rüdenauer, I.; Gensch, C.-O. & Liu, R. (2008b). Vergleich der Umweltauswirkungen und Kosten verschiedener Wäschetrocknungssysteme 2: Studie im Auftrag der B/S/H Hausgeräte GmbH, last accessed on 09 Apr 2015.

Saker, D.; Vahdati, M.; Coker, P. & Millward, S. (2015). Assessing the benefits of domestic hot fill washing appliances. Energy and Buildings, 93 (2015), pp. 282–294.

SAMSUNG UK (2012). Samsung Ecobubble Range | Washing Machines. Available at http://www.samsung.com/uk/ecobubble/, last accessed on 01 Apr 2015.

Sanner, J. (2011). i-Dos, an intelligent dosing system. 45th International Detergency Conference, Düsseldorf.

Scheid, F.; Lambert, E.; Maitra, W.; Niestrath, M.; Fäh, D.; Portmann, C.; Gorny, S. & Stamminger, R. (2016). Textile Quality Depletion due to Household Machine Wash – Ways to Measure and Impacts of Wash Duration and Temperature on Textiles. Tenside Surf. Det., 53(5).

Schmitz, A. & Stamminger, R. (2012). Usage of Washer-Dryers in Europe. SÖFW-Journal, 138(5).

Schmitz, A. & Stamminger, R. (2014). Usage behaviour and related energy consumption of European consumers for washing and drying. Energy Efficiency, 7(3).

SENS/Swico/SLRS (ed.) (2014). Technical Report 2014. Available at http://www.swicorecycling.ch/downloads/dokumente/technical-report-swico-sens-slrs-2014.pdf/1841, last accessed on 21 Apr 2015.

Sharp (ed.) (2012). Sustainability Report 2012. Available at http://www.sharp.co.jp/corporate/eco/report/backnumber/pdf/esr2012e.pdf, last accessed on 19 Mar 2015.

Siemens ([n.d.]). iSensoric: Die sensorgesteuerte Technologie für perfekte Wäschepflege. Available at http://www.siemens-home.de/store/resources/campaigns/a02/iSensoric/de/#section-welcome, last accessed on 21 May 2015.

Sinner, H. (1960). Über das Waschen mit Haushaltwaschmachinen: in welchem Umfang erleichtern Haushaltwaschmaschinen und -geräte das Wäschehaben im Haushalt? Haus & Heim Verlag, (8).

Smulders, E.; Rybinski, W.; Sung, E.; Rähse, W.; Steber, J.; Wiebel, F. & Nordskog, A. (2002). Laundry detergents: Wiley-VCH, Weinheim.

Sobey, E. J. C. (2007). A field guide to household technology. Chicago, Ill.: Chicago Review Press.

Spray project (2015a). Layman's report Spray, last accessed on 07 May 2015.

Spray project (2015b). Project website. Available at http://www.spray-project.eu/, last accessed on 07 May 2015.

Stamminger, R. (2010). Reinigen. In L. W. GOMM U. (Ed.), Lebensmittelverarbeitung im Haushalt. aid Infodienst . Bonn.

Stamminger, R. (2011). Modelling resource consumption for laundry and dish treatment in individual households for various consumer segments. Energy Efficiency, (4), pp. 559–569.

Stamminger, R.; Alborzi, F. & Schmitz, A. (2015). Washer-dryer consumer behaviour and possible consequences for standardisation and energy labelling/ecodesign for washer-dryers.

Stekl, P. (2006). Washing Machine Three-Phase AC Induction Motor Drive. Available at http://cache.freescale.com/files/microcontrollers/doc/app_note/AN3234.pdf, last accessed on 23 Apr 2015.

Stiftung Warentest (2012a). Waschmittel: Pulver ist besser. test, (2/2012).

Stiftung Warentest (2013). Tricks für Sparmaschinen. test, (11/2013), pp. 66–71.

Stiftung Warentest (2014). Vollwaschmittel: Die Besten für Weißes. test, (11/2014).

Stiftung Warentest (2009). test Dampfbügeleisen und Bügelstationen. test, (1/2009).

Stiftung Warentest (2012b). LG hat die Schrauben locker. test, (10/2012), pp. 60–63.

Stiftung Warentest (2015). Je voller, desto toller. test, (11).

Süddeutsche Zeitung (2010). Die Waschmaschine der Zukunft – Plastik statt Wasser. Available at http://www.sueddeutsche.de/wissen/die-waschmaschine-der-zukunft-plastik-statt-wasser-1.175870, last accessed on 16 Apr 2015.

Tano, E. & Melhus, A. (2014). Level of decontamination after washing textiles at 60°C or 70°C followed by tumble drying. Infection Ecology & Epidemiology, (4).

Tecchio, P.; Ardente, F. & Mathieux, F. (2016). Analysis of durability, reusability and reparability: Application to dishwashers and washing machines. Draft JRC Technical Report. Available at http://eplca.jrc.ec.europa.eu/uploads/JRC_report-Durability_Reusability_Reparability_V05-draft.pdf, last accessed on 28 Nov 2016.

Terpstra, P. (2001). Assessment of the cleaning efficiency of domestic washing machines with artificially soiled test cloth: Springer.

TIG (ed.) (2015a). Policy recommendations for Dishwashers. Available at http://www.topten.eu/uploads/File/Recommendations_Dishwashers_March_15.pdf, last accessed on 07 Apr 2015.

TIG (ed.) (2015b). Washing Machines & Combined Washer-driers: Policy Recommendations. Available at http://www.topten.eu/uploads/File/Topten_recommendations_Washing_machines.pdf, last accessed on 07 Apr 2015.

Topten.eu (2013). Standby and off-mode: Recommendations for policy design. Available at http://www.topten.eu/uploads/File/STANDBY%20Topten%20EU%20policy%20recommendations%20Feb%2013.pdf.

U.S. Government (ed.) ([n.d.]). Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-automatic Clothes Washers: 10 CFR Section 430.23(j), Appendix J2 to Subpart B of Part 430. Available at http://www.ecfr.gov/cgi-bin/text-idx?SID=65e61c223c984cd959f41a19c17a8f4d&mc=true&node=ap10.3.430_127.j2&rgn=div9, last accessed on 01 Dec 2015.

UNEP (ed.) (2013). Metal Recycling: Opportunities, Limits, Infrastructure. A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Available at http://www.unep.org/resourcepanel/Portals/24102/PDFs/Metal_Recycling_Full_Report.pdf, last accessed on 12 Apr 2015.

US EPA (ed.) ([n.d.]a). ENERGY STAR® Program Requirements - Product Specification for Clothes Washers: Eligibility Criteria Version 7.0. Available at http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf, last accessed on 24 Feb 2015.

US EPA ([n.d.]b). Learn More About EnergyGuide. Available at http://www.energystar.gov/index.cfm?c=appliances.pr_energy_guide, last accessed on 25 Mar 2015.

US EPA (2015). ENERGY STAR® Program Requirements - Product Specification for Clothes Washers: Eligibility Criteria Version 7.0. Available at http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf, last accessed on 24 Feb 2015.

Vanthournout, K.; Ectors, D.; Bogaert, S.; Viegand, J.; Stamminger, R.; Geppert, J.; Rivière, P. & Götz, T. (2015). Ecodesign Preparatory study on Smart Appliances: Discussion note on Interoperability and Standardisation, last accessed on 17 Apr 2015.

Vanthournout, K.; Ectors, D.; Claessens, S.; Viegand, J.; Stamminger, R.; Geppert, J.; Riviere, P.; Götz, T. & Bogaert, S. (2015). Preparatory study on Smart Appliances: Task 1 Scope. Study accomplished under the authority of the European Commission DG Energy under Framework Contract ENER.C3.2012-418-lot1-2014/TEM/R/. Available at http://www.eco-smartappliances.eu/Documents/Smart%20appliances_Task%201%20report_draft_150615.pdf, last accessed on 22 Nov 2016.

VHK (ed.) (2014 / Status 2013). Ecodesign Impact Accounting: Part 1 – Status Nov. 2013. Available at https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf, last accessed on 07 Apr 2015.

VHK (ed.) (2014). Exploratory analysis of Resource efficiency requirements in Ecodesign: Review of practical and legal implications: Final report, last accessed on 24 Jan 2016.

VHK et al. (ed.) (2014). "Omnibus" Review Study on Cold Appliances, Washing Machines, Dishwashers, Washer-Driers, Lighting, Set-top Boxes and Pumps. Available at http://susproc.jrc.ec.europa.eu/Washing_machines_and_washer_dryers/docs/omnibus_studyf_2014-03.pdf.

Viegand, J.; Mulder, G.; Breucker, S. de; Stamminger, R.; Geppert, J.; Riviere, P.; Perret-Gentil, M.; Götz, M. & Bogaert, S. (2015). Preparatory study on Smart Appliances: Task 4 Technologies - Technical Analyses of Existing Products. Available at http://www.eco-smartappliances.eu/Documents/Prep%20Study%20Smart%20appliances_Task%204_draft_151110.pdf, last accessed on 17 Dec 2015.

Viegand Maagøe (2015, October). Review study on standby regulation: Request for services No. ENER/C3/2012-418-lot 2/08/2014-558. Available at http://www.ecostandbyreview.eu/downloads/ Presentation%20stakeholders%20meeting%20211015%20-%20Review%20Standby%20Regulation%20VM%20041115.pdf, last accessed on 22 Nov 2016.

VITO et al. (ed.) (2015). Ecodesign Preparatory study on Smart Appliances: Discussion note on Interoperability and Standardisation. In preparation of the Stakeholder meeting of 10 March 2015. Available at http://www.eco-smartappliances.eu/Documents/Ecodesign%20Smart%20appliances_Discussion%20note_workshop_150310.pdf, last accessed on 11 Apr 2015.

VZ RLP & Öko-Institut (2012). Energieverbrauch von Spülmaschinen. Available at www.oeko.de/uploads/oeko/forschung_beratung/themen/nachhaltiger_konsum/infoblatt_spuelmaschine.pdf, last accessed on 21 May 2015.

V-ZUG (2013). Wärmepumpentechnologie Waschmaschine - V-ZUG AG - Schweiz. Available at http://www.vzug.com/ch/de/int_novelties_2013_washing_machine, last accessed on 06 May 2015.

V-ZUG operating instructions (2014a). 11004/11006 Adora SLQ, last accessed on 06 May 2015.

V-ZUG operating instructions (2014b). 11004/11006 Adora SLQ WP, last accessed on 06 May 2015.

Wagner, G. (2011). Waschmittel-Chemie, Umwelt, Nachhaltigkeit: John Wiley & Sons.

Which? (2013a). So you think you're washing at 60ºC? (09/2013), pp. 62–64.

Which? (2013b). So you think you're washing at 60°C?, pp. 62–65.

WRAP ([n.d.]a). Closed-loop recycling - opening the door to cost savings: Case study. Available at http://www.wrap.org.uk/sites/files/wrap/Closed%20loop%20recycling%20-%20opening%20the%20door%20to%20cost%20savings%20EEE%20Indesit.pdf, last accessed on 17 Mar 2015.

WRAP ([n.d.]b). Product design review - Washer Dryer. Available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20Design%20Review%20Case%20Study%20Washer%20Dryer.pdf, last accessed on 17 Mar 2015.

WRAP ([n.d.]c). Product design review - Washing Machine. Available at http://www.wrap.org.uk/sites/files/wrap/Washing%20Machine%20%20Product%20Review%20Case%20Study.pdf, last accessed on 17 Mar 2015.

WRAP ([n.d.]d). Product design review of two washing machines. Available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20Design%20Review%20Case%20Study%20Two%20Washing%20Machines.pdf, last accessed on 17 Mar 2015.

WRAP ([n.d.]e). Re-use protocols for electrical products. Available at www.wrap.org.uk/content/re-use-protocols-electrical-products, last accessed on 27 Feb 2015.

WRAP (ed.) (2011a). Benefits of Reuse: Case Study: Electrical Items. Available at http://www.wrap.org.uk/sites/files/wrap/Electricals%20reuse_final.pdf, last accessed on 18 Mar 2015.

WRAP (ed.) (2011b). Specifying durability and repair in washing machines: A case study of two washing machines by Siemens and Bosch to illustrate and encourage durability and repair. Available at http://www.wrap.org.uk/sites/files/wrap/Washing%20machine%20case%20study%20AG.pdf.

WRAP (ed.) (2013a). Design for Longevity: Guidance on increasing the active life of clothing. Final report.

WRAP (ed.) (2013b). Electrical and electronic product design: product lifetime. Available at http://www.wrap.org.uk/sites/files/wrap/WRAP%20longer%20product%20lifetimes.pdf, last accessed on 18 Mar 2015.

WRAP (ed.) (2013c). PAS 141 Protocol: Product Guide: Washing machines, tumble dryers and washer/dryers. Available at http://www.wrap.org.uk/sites/files/wrap/PAS%20141%20Product%20Guide%20-%20Washing%20machines%20tumblers.pdf, last accessed on 21 Apr 2015.

WRAP (2013d). Washing machines: Identifying failure drivers and opportunities for life extension. Electrical Product Pathfinder Group. Available at http://www.wrap.org.uk/system/files/priv_download/Product%20Summary%20Washing%20Machines%2018%2012%202013.pdf, last accessed on 17 Mar 2015.

A.I.S.E. ([n.d.]). Product Environmental Footprint (PEF). Available at http://www.aise.eu/our-activities/sustainable-cleaning-78/contributing-to-the-eu-agenda/product-environmental-footprint-pef.aspx, last accessed on 25 Apr 2015.

A.I.S.E / Insites 2014 (14 Oct 2015). Estimation of cost of detergents per washing cycle of washing machines (Email).

Alborzi, F.; Schmitz, A. & Stamminger, R. (2015). Washing behaviour of European consumers 2015.

Allacker, K.; Mathieux, F.; Manfredi, S.; Pelletier, N.; Camillis, C. de; Ardente, F. & Pant, R. (2014). Allocation solutions for secondary material production and end of life recovery: Proposals for product policy initiatives. Resources, Conservation and Recycling, 88, pp. 1–12. doi:10.1016/j.resconrec.2014.03.016.

BMWi , 2017 Kathrin Graulich, Prof. Dr. Rainer Stamminger, Dr. Jasmin Geppert, Lara Belke, Verbraucherbefragung – Nutzung der Programme bei neuen Politik-optionen für das Ökodesign und das Energielabel von Waschmaschinen. Projekt BfEE 12/2016 im Auftrag des Bundesamtes für Wirtschaft und Ausfuhrkontrolle (BAFA) und dem Bundesministerium für Wirtschaft und Energie (BMWi). Available at: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/bff-verbraucherbefragung-nutzung-programme-bei-neuen-politikoptionen-fuer-oekodesign-und-energielabel-von-waschmaschinen.pdf?__blob=publicationFile&v=22

CECED (2014). Database with data about performance of washing machines and washer-dryers in 2013

CECED (2015). Database with data about performance of washing machines and washer-dryers in 2014

CECED (2016). Database with data about performance of washing machines and washer-dryers in 2015

CLASP (2013) Estimating potential additional energy savings from upcoming revisions to existing regulations under the ecodesign and energy labelling directives: a contribution to the evidence base. Available at http://clasp.ngo/en/Resources/Resources/PublicationLibrary/2013/CLASP-and-eceee-Point-To-Additional-Savings-from-Ecodesign-and-Energy-Labelling.aspx, last accessed on 20 Dec 2015

Cordella, M.; Stramigioli, C.; Santarelli, F. (2013) A Set of Coherent Indicators for the Assessment of the Energy Profitability of Energy Systems. Journal of Sustainable Bioenergy Systems, 3, 40-47. http://dx.doi.org/10.4236/jsbs.2013.31005

COWI and VHK (ed.) (2011). Methodology for Ecodesign of Energy-related Products MEErP 2011: Methodology Report. Part 1: Methods. Available at http://ec.europa.eu/ enterprise/policies/sustainable-business/ecodesign/methodology/files/ meerp_methodology_part1_en.pdf, last accessed on 07 Apr 2015.

COWI and VHK (2014). EcoReport 2014: Version 3.06; VHK for European Commission 2011; modified by IZM for European Commission 2014.

Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV. Available at http://bookshop.europa.eu/en/study-on-socioeconomic-impacts-of-increased-reparability-of-increased-reparability-pbKH0216507/, last accessed on 16 December 2016

Goodright V.; Wilkes E. (2015) Energy Consumption in the UK (2015), Chapter 3: Domestic energy consumption in the UK between 1970 and 2014. Prepared for the Department of Energy & Climate Change, available at: http://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/ecuk_chapter_3_-_domestic_factsheet.pdf, last accessed on 20 Dec 2016

Euromonitor / A.I.S.E (14 Oct 2015). Estimation of cost of detergents per washing cycle of washing machines - 'apparent' price per load (Email).

European Commission (1996). Commission Directive 96/60/EC of 19 September 1996 implementing Council Directive 92/75/EEC with regard to energy labelling of household combined washer-driers (OJ L 266, pp. 1–27). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31996L0060&from=EN, last accessed on 19 May 2015.

European Commission (2010a). Commission Delegated Regulation (EU) No 1061/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household washing machines (OJ L 314, 2010, pp. 47–63). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1061&from=en, last accessed on 24 Feb 2015.

European Commission (2010b). Commission Regulation (EU) No 1015/2010 of 10 November 2010 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household washing machines (OJ L 293, 2010, pp. 21–30). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010R1015&from=en, last accessed on 24 Feb 2015.

European Commission (2010c). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy 2020 - A strategy for competitive, sustainable and secure energy. Available at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0639:FIN:EN:PDF, last accessed on 19 May 2015.

European Commission (2011). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions: Energy Efficiency Plan 2011. Available at http://eur-lex.europa.eu/resource.html?uri=cellar:441bc7d6-d4c6-49f9-a108-f8707552c4c0.0002.03/DOC_1&format=PDF, last accessed on 19 May 2015.

European Commission (ed.) (2012). Accompanying document to the Draft Commission Regulation implementing directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for household dishwashers.

European Commission (ed.) (2016). EU Reference Scenario 2016: Energy, transport and GHG emissions - Trends to 2050: Main results. Available at https://ec.europa.eu/energy/sites/ener/files/documents/20160712_Summary_Ref_scenario_MAIN_RESULTS%20%282%29-web.pdf, last accessed on 07 Dec 2016.

European Council (1992). COUNCIL DIRECTIVE 92 / 75 / EEC of 22 September 1992 on the indication by labelling and standard product information of the consumption of energy and other resources by household appliances (OJ L pp. 16–19). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0075&from=EN, last accessed on 15 Oct 2015.

European Environment Agency (2003). Water prices: Indicator fact sheet. Available at http://www.eea.europa.eu/data-and-maps/indicators/water-prices/water-prices/at_download/file, last accessed on 01 Oct 2015.

European Environment Agency (2005). The European environment - State and outlook 2005: Part A: Integrated Assessment. Available at http://www.eea.europa.eu/publications/state_of_environment_report_2005_1/SOER2005_Part_A.pdf/view, last accessed on 16 Oct 2015.

Eurostat (2011). Household composition statistics. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Household_composition_statistics, last accessed on 16 Sep 2016.

Eurostat (2015). Electricity and natural gas price statistics. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_natural_gas_price_statistics, last accessed on 01 Oct 2015.

Eurostat (2016a). Number of private households by household composition, number of children and age of youngest child (1 000). Available at http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_hhnhtych&lang=en, last accessed on 20 Dec 2016.

Eurostat (2016b). Population on 1 January. Available at http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00001&plugin=1, last accessed on 20 Dec 2016.

Eurostat (2016c). Population projections. Available at http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00002&plugin=1, last accessed on 20 Dec 2016.

Eurostat (2016d). Electricity and heat statistics. Available at http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics#Consumption_of_electricity_and_derived_heat, last accessed on 21 Dec 2016.

Eurostat (2016e). Harmonised index of consumer prices (HICP) - annual data. Available at http://ec.europa.eu/eurostat/web/hicp/data/database?p_p_id=NavTreeportletprod_WAR_NavTreeportletprod_INSTANCE_BO6Fgp25CkI9&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-2&p_p_col_count=3, last accessed on 22 Dec 2016.

Gensch, C.O., Bepp, M (2015) Betrachtungen zu Produktlebensdauer und Ersatzstrategien von Miele-Haushaltsgeräten. Oeko Institut, Available June 2017 on https://www.miele.com/media/miele_com/media/files/infomaterial/Studie_Oeko-Institut_Lebensdauer_2015.pdf.

Golsteijn, L.; Menkveld, R.; King, H.; Schneider, C..; Schowanek, D.; Nissen, S. (2015). A compilation of life cycle studies for six household detergent product categories in Europe: the basis for product-specific A.I.S.E. Charter Advanced Sustainability Profiles. Environmental Sciences Europe, 27:23. doi:10.1186/s12302-015-0055-4

Honisch, M., Stamminger, R., and Bockmuhl, D. Impact of wash cycle time, temperature and detergent formulation on the hygiene effectiveness of domestic laundering. Journal of applied microbiology.

ISIS (ed.) (2007b). Preparatory Studies for Eco-design Requirements of EuPs Lot 14: Domestic Dishwashers & Washing Machines: Task 5: Definition of Base case. Task Final

Report. Available at http://www.eup-network.de/fileadmin/user_upload/Task_5_Definition_of_Base_Case.pdf, last accessed on 19 Mar 2015.

Kruschwitz, A.; Karle, A.; Schmitz, A. & Stamminger, R. (2014). Consumer laundry practices in Germany. International Journal of Consumer Studies, 38(3), pp. 265–277.

Lasic, E.; Stamminger, R.; Nitsch, C. & Kessler, A. (2015). Construction of a Virtual Washing Machine. Tenside Surfactants Detergents, Vol. 52(No 3), pp. 193–200.

Michel, A.; Attali, S. & Bush, E. (2015). Energy efficiency of white goods in Europe: monitoring the market with sales data: Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014. Available at http://www.topten.eu/uploads/File/WhiteGoods_in_Europe_June15.pdf, last accessed on 16 Sep 2015.

Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher T. & Stamminger, R. (2015). Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz“: ZWISCHENBERICHT: Analyse der Entwicklung der Lebens-, Nutzungs- und Verweildauer von ausgewählten Produktgruppen. Available at http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_10_2015_einfluss_der_nutzungsdauer_von_produkten_auf_ihre_umwelt_obsoleszenz_17.3.2015.pdf, last accessed on 06 Apr 2015.

Prakash, S.; Dehoust, G.; Gsell, M.; Schleicher T. & Stamminger, R. (2016). Einfluss der Nutzungsdauer von Produkten auf ihre Umweltwirkung: Schaffung einer Informationsgrundlage und Entwicklung von Strategien gegen „Obsoleszenz“: Abschlussbericht (11/2016). Dessau-Rosslau. Available at http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_11_2016_einfluss_der_nutzungsdauer_von_produkten_obsoleszenz.pdf.

Quel choisir? 2015

Saker, D.; Vahdati, M.; Coker, P.J.; Millward, S. (2015) Assessing the benefits of domestic hot fill washing appliances. Energy and Buildings, 93, 282-294

Stamminger, R.; Alborzi, F. & Schmitz, A. (2015). Washer-dryer consumer behaviour and possible consequences for standardisation and energy labelling/ecodesign for washer-dryers.

Stamminger, R. & Schmitz, A. (2016). Washing Machines in Europe – Detailed Assessment of Consumption and Performance. Tenside Surf. Det., 53.

Stamminger, R. et al. (2015). Washing and drying behaviour of European consumer with a washer-dryer: Result of the consumer survey of 2015 contracted by DIN Consumer council. Available at: http://www.din.de/en/about-standards/benefits-for-consumers/din-consumer-council/news/how-do-consumers-use-a-washer-dryer--96634

Statista (2016). Percentage of households with washing machines in the United Kingdom (UK) from 1970 to 2014. Available at: https://www.statista.com/statistics/289017/washing-machine-ownership-in-the-uk/, last accessed on 20 Dec 2016

Stiftung Warentest, personal communication (2015)

Tecchio, P.; Ardente, F.; Mathieux, F. (2016) Analysis of durability, reusability and reparability- Application to washing machines and dishwashers. EUR 28042 EN, doi:10.2788/630157

VHK (ed.) (2014 / Status 2013). Ecodesign Impact Accounting: Part 1 – Status Nov. 2013. Available at https://ec.europa.eu/energy/sites/ener/files/documents/2014_06_ecodesign_impact_accounting_part1.pdf, last accessed on 07 Apr 2015..

KJ-1A-28809-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/029939

ISBN 978-92-79-74183-8