European Commission

JRC TECHNICAL REPORT

Untapping multiple benefits: hidden values in environmental and building policies

Shnapp, S.

Paci, D.

Bertoldi, P.

2020

Joint Research Centre

EUR 30280 EN

Contact information
Name: Daniele Paci
Email: Daniele.paci@ec.europa.eu
Address: European Commission, Joint Research Centre, Via E. Fermi, 2749. 21027 Ispra. VA, Italy

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

JRC120683

EUR 30280 EN

PDF	ISBN 978-92-76-19983-0	ISSN 1831-9424	doi:10.2760/314081

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Shnapp, S., Paci, D., Bertoldi, P. *Untapping multiple benefits: hidden values in environmental and building policies.* EUR 30280 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-19983-0, doi:10.2760/314081, JRC120683.

Contents

Acknowledgements

A huge thanks first and foremost to the interviewees, without whom this report would not be in the shape is it:

Adrian Joyce – EuroACE & Renovate Europe

Andreas Hermelink - Energy | Navigant

Andrew Deacon – Future Climate

Catrin Maby - Research and Consultancy – Energy in Buildings

Chris Hughes - SEAI

Conor Hanniffy - SEAI

Dan Staniaszek – Sustainability Consulting Ltd

David Kensington - Working Research

Emilie Carmichael – Energy Saving Trust

Gavin Killip - Environmental Change Institute | University of Oxford

Ian Hamilton - UCL Energy Institute

Johannes Thema - Wuppertal Institute for Climate Environment and Energy

Judit Kockat – BPIE

Kristina Klimovich – GNE Finance

Martin Pehnt –IFEU

Matthias Reuter- Fraunhofer Institute for Systems and Innovation Research (ISI)

Orla Coyle - SEAI

Rod Janssen – Energy in Demand

Rui Fragoso - ADENE

Sea Rotman - IEA

Stefan Thomas – Wuppertal Institute

Thomas Boermans – E.ON

Tina Fawcett - Environmental Change Institute | University of Oxford

Yamina Saheb - EVO

The author's ever supportive mentors deserve multitudes of credit and acknowledgement for their ruthless editing, time and patience spent on making the report what it is: Rod Janssen and Dan Staniaszek.

The team from Wuppertal Institute was instrumental in the development of the final section on ways to calculate multiple benefits and specific and great thanks go to Stefan Thomas and Johannes Thema. This report relies heavily on the COMBI project and the authors would like to thank the team involved for developing such a comprehensive study.

Abstract

The untapped / hidden benefits of environmental policies are huge, this piece of research showcases and places a monetary value on the added benefits to our health, society and the economy that environmental investments and policy linked to energy efficiency can bring. Findings show that green policies can improve both our health and the economy and can go hand-in-hand. This study provides guidance to policy and decision-makers in developing a methodology for the inclusion of multiple benefits in a cost/benefit assessment of energy efficiency policy. It is envisaged that providing a macroeconomic understanding of the wider benefits of energy efficiency in buildings will encourage policy-makers and investors to develop and quantify the benefits of more effective energy efficiency policies and programmes and drive higher levels of renovation, thus supporting the EU's Renovation Wave. This Report provides the European Commission (EC), the national administrations in charge of implementing EU energy efficiency policies (such as the EPBD) in Member States (MS) and other decision makers seeking to include multiple benefits in their policies, building programmes and financial programmes with:

- Information on identified benefits;
- A methodology for an enhanced consideration of wider benefits, in particular in the calculation of cost-optimal minimum energy performance requirements under the EPBD; and
- A toolkit to calculate and quantify / measure the monetary value of these impacts, from a policy and investor standpoint.

1 Introduction

1.1 Scope of the study

By means of scientific research, this report highlights and puts a monetary figure on just how much environmental policy can help to improve our society. The untapped / hidden benefits of environmental policies are huge, and this report showcases and places a monetary value on all of the added benefits to our health, society and the economy that environmental investments and policy linked to energy efficiency can bring. Essentially, showing how the colossal benefits to, *inter alia,* our health, both physical and mental, our wellbeing, employment, the economy, productivity, biodiversity, air pollution, etc, are not currently included in policy. Concluding that green policies can improve both our health and the economy and can go hand-in-hand.

This study sets out to provide guidance to policy and decision-makers in developing a methodology for the inclusion of multiple benefits in cost/benefit assessment of a building's renovation. It is envisaged that providing a macroeconomic understanding of the wider benefits of energy efficiency in buildings will encourage policy-makers and investors to develop and quantify the benefits of more effective energy efficiency policies and programmes and drive higher levels of efficient building design and renovation.

Not only are wider benefits often hard to quantify, they are also prone to higher levels of uncertainty than more direct impacts of energy efficiency measures. A clearer understanding of such benefits in European policies, and specifically in relation to this study, in the cost-optimality calculations under Directive 2010/31/EU on the energy performance of buildings (from now on referred to simply as "the EPBD"), could be beneficial. This report sets out to create an awareness of the monetary impacts these wider benefits have on society. It presents specific indicators and methodologies for potential use in European policies linked to energy efficiency, the economy, health and the environment. The insights presented can also be of interest to EU Member States' administrations in implementing EU policies and designing national policies.

This Report provides the European Commission, the national administrations in charge of implementing EU energy efficiency policies (in particular EPBD) in Member States (MS) and other decision makers seeking to include multiple benefits in their policies, building programmes and financial programmes with:

- Information on identified benefits;
- A methodology for an enhanced consideration of wider benefits, in particular in the calculation of cost-optimal minimum energy performance requirements under the EPBD; and
- A toolkit to calculate and quantify / measure the monetary value of these impacts, from a policy and investor standpoint.

1.2 Policy context

Environmental and climate policy is one of the key areas of intervention for the EU, with a long-term vision of a carbon neutral Europe by 2050, where ambitious energy efficiency and renewable targets are in place for 2020 (20% energy efficiency and 20% renewables) and 2030 (40% cuts in greenhouse gas emissions from 1990 levels, at least 32% share for renewable energy and at least 32.5% improvement in energy efficiency) (EC, 2019b).

Between 1970 and 2004 global greenhouse gas emissions increased by 70%. The Lancet Commission's 2015 Global Health Report concluded that, "*tackling climate change could be the greatest global health opportunity of the 21st century"* and the 2018 report describes investments in zero-carbon energy and energy efficiency as a key health indicator. Fossil fuel is now widely viewed as the new tobacco – Professor Costello, lead author of the 2009 Lancet Report states: "*The big message […] is that climate change is a health issue affecting billions of people, not just an environmental issue about polar bears and deforestation.*" This global issue requires huge effort and investment on the part of global, national and regional politicians, industries and stakeholders.

Sustainable Energy for All (SE4All) is the United Nations Secretary General's overarching global initiative, launched in 2011. It focuses on three interlinked 2030 objectives:

1. Ensuring universal access to modern energy services;
2. Doubling the global rate of improvement in energy efficiency; and
3. Doubling the share of renewable energy in the global energy mix.

The International Energy Agency (IEA) broadly agrees with point 2 and claims energy efficiency is the "first fuel" for economic development and it is also viewed as a "first fuel" / "low hanging fruit" in the clean energy transition.

The Communication of the European Commission on the European Green Deal (EC, 2019d) sets out a new growth strategy aiming at a climate-neutral economy by 2050 and refers to an increased ambition on greenhouse gas emission reduction for the EU by 2030 ("*at least 50% and towards 55% compared with 1990 levels in a responsible way*"). The Communication also reminds of the need to prioritise energy efficiency and underlines renovation of buildings as a key challenge: "*To address the twin challenge of energy efficiency and affordability, the EU and the Member States should engage in a 'renovation wave' in public and private buildings. Whilst increasing renovation rates is a challenge, renovation lowers energy bills, and can reduce energy poverty. It can also boost the construction sector and is an opportunity to support SMEs and local jobs.*" There is, hence, strong and clear international acknowledgement and support for energy efficiency to provide the route for saving energy and reducing GHG emissions, whilst also improving society's health and wellbeing and improving the economy.

At EU level, the building stock consumes 40% of final energy consumption and 75% of these buildings are energy *inefficient* (i.e. not at an energy performance level needed to meet our 2050 decarbonisation goals) and are being renovated at a slow rate of 1 and 1.5% per annum, whereas the pathway towards the EU's 2050 target requires a market transformation and for this rate to triple (EC, 2019c). Energy efficiency is a key priority for the EC who have set an EU-wide reduction target of 32.5% by 2030. It is estimated that an investment of 177 billion Euros per year is needed to meet the 2030 targets, **70%** of this estimated sum **(133 billion Euros)** should be allocated to **specifically enhance the energy performance of buildings** and the annual renovation rate needs to be increased to 3-5% (EC, 2016b).

The EPBD requires Member States to develop long-term renovation strategies to decarbonise the building stock by 2050 and mandates nearly zero-energy buildings (NZEB) as the standard for all new buildings (public buildings from 2019 and for other buildings from 2021). These strategies should include roadmaps with measurable progress indicators and indicative milestones. Although there are many initiatives that support the uptake of NZEB renovations, there is not yet a mandate for nearly zero-energy renovations, unless such renovations are major. The importance of the building sector in enhancing the efficiency of the European building stock is paramount and the EPBD's cost-optimal methodology can be used as a key tool for ensuring the building stock's minimum performance requirements are at an efficient level. In the EPBD:

- Article 4.1 states that MS shall take the necessary measures to ensure minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels.
- Article 5 requires that MS calculate cost-optimal levels of minimum energy performance requirements for buildings and building elements using a comparative methodology framework.

Under the EPBD, in the context of their long-term renovation strategies (LTRS), MS are required to report on the wider benefits associated with the energy savings to be achieved by their strategy (although there is not yet a requirement for these benefits to be monetised). MS must also report these wider benefits in their National Energy and Climate Plans (NECPs). In Commission Recommendation 2019/786 on building renovation, the Commission sets out guidance on recently revised provisions of the EPBD, including the new Article 2a on LTRS. The guidance includes an elaboration of indicators and milestones, which may include quantitative and qualitative data related to potential wider benefits.

1.3 Barriers

There is a tremendous need (to an extent of 133 billion Euros per year) for investment in building renovation to increase the renovation rate and reach climate and energy goals. There are also technical, functional, demand side and economic constraints hindering the uptake of deep renovations (Hamilton 2017, EC, 2019). From the demand side, residents are often reluctant to undertake a deep renovation for several reasons, for example:

- Overall complexity of works
- Lack of expertise
- Lack of information on the wider benefits
- Lack of knowledge of whom to contact
- Lack of knowing about efficient renovation measures
- Lack of trust in construction companies
- Lack of finance

From an investor's perspective, there are also several barriers hindering the advancement of energy efficient investments, such as (Klimovich, 2019):

- Risky investment from lack of information / experience
- Not enough robust data
- Decentralized projects that are not aggregated –the difficulty of investing large sums in small projects
- Lack of standardization
- Benefits are not properly monetised

Energy efficiency programmes and policies are commonly designed based solely on energy savings, which leads to an underestimation of their full impact (IEA 2016). The Intergovernmental Panel for Climate Change (IPCC) holds the same view and stresses the importance of the building sector in meeting climate targets, suggesting that investments in the building sector can act as a driver for achieving many other policy goals and a leverage for societal and economic benefits (EPA, 2018; IEA, 2014; IPCC, 2019, IEA, 2012b; Goodacre, 2001). If Ministries from a wider range of sectors were to be included in energy and building related policy development, the prospects of raising awareness about the role of high energy performative buildings for human health, environment, social policy, agriculture, economy and energy security would be improved. In turn, this could lead to a convergence of interests and encourage inter-departmental and cross-sectoral cooperation, which is essential in order to establish a holistic perspective on societal development (COMBI, 2016).

Including the multiple benefits of enhancing energy efficiency into the evaluation and development stages of the mandated policies and programmes can help to unlock the potential of their vast economic and societal impacts. In this regard, were MS to consider multiple benefits in the calculations of their cost-optimal minimum energy performance requirements, these minimum requirements would be more stringent due to the cost-effectiveness of multiple benefits. Similarly, it would be easier to justify ambitious minimum energy performance requirements if associated multiple benefits are considered (EPA, 2018; IEA, 2014). Lastly, there could be additional economic benefits: a study commissioned by the EC examined the positive societal effects of the EPBD under different implementation scenarios and showed that the EPBD could improve the GDP in Member States by up to 0.6% (EC, 2016).

However, under current practices, cost-optimal energy performance requirements calculations for existing buildings tend to omit important indicators (such as multiple benefits). The inclusion of these indicators could drive new and existing building standards to nearly zero in an economic fashion (Gopalan, 2018).

1.4 Overview of multiple benefits

There are many ways to assess multiple benefits associated with enhancing energy efficiency. A literature review of multiple benefits from improved energy efficiency in buildings identifies several terms to describe these, for example: non-energy benefits (NEB), multiple impacts, energy efficiency impacts, co-benefits, positive impacts, wider benefits, etc. Often these terms have slightly different definitions, which can be confusing, however, the IEA and the IPCC have attempted to define the term "co-benefits":

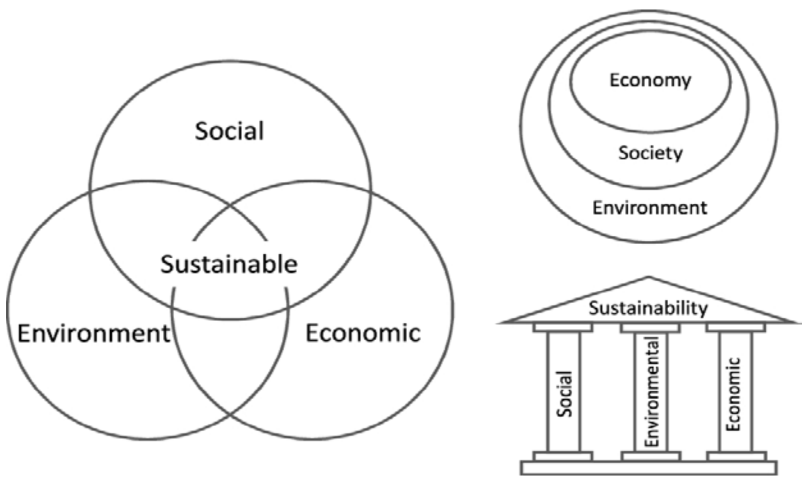
- IEA IBC Annex 56: "*The term co-benefits includes all effects of energy related renovation measures besides reduction of energy, CO_2 emissions and costs*" (Cappelletti, et al., 2015).
- IPCC: "*Co-benefits are the positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices*." (IPCC, 2014)

It is clear, however, that energy efficiency is widely viewed as an effective tool for achieving multiple economic, societal and environmental benefits, as confirmed by several reports issued by the UN, IEA, OECD, IPCC and many others, highlighting the importance of including the additional benefits in policy development. As stated by the IEA (IEA, 2016a), "*all of the core imperatives of energy policy – reducing energy bills, decarbonisation, air pollution, energy security, and energy access – are made more attainable if led by strong energy efficiency policy.*" These benefits can be reached at both macro (societal perspective) and micro (private perspective) economic levels (Staniaszek, 2013; IEA, 2014; Kolstad et al, 2014) and some studies even suggest that the wider benefits of energy efficiency can exceed the direct benefits connected to the investment. (Kats, 2006; Ürge-Vorsatz et al. 2009)

Typically, the multiple benefits are grouped into different typologies: private perspectives (experienced at the building level) and macroeconomic or social perspectives. The value of the co-benefit depends on which classification they fall under. Based on suggested classifications of co-benefits from several studies, in line with the ubiquitous three pillars of sustainability (UN, 2019, Purvis, 2019 and as early as Barbier, 1987), the following three categories are proposed for the building sector, shown in Figure 1.1:

- Environmental
- Economic
- Societal

Figure 1.1. The Three Pillars of Sustainability



Source: Purvis et al, 2019

Two important documents found in the literature review come from the Commission:

- The Commission Recommendation[1] on building renovations that provides a possible framework for defining indicators of multiple benefits.
- The Energy Efficiency Financial Institutions Group's (EEFIG)[2] "Toolkit"[3], designed to assist financial institutions to scale up their deployment of capital into energy efficiency, and within this toolkit, the "Value and Risk Appraisal" section in which multiple benefits to be taken into account when investing in energy efficiency are described.

When appropriate, the multiple benefits described in both of these documents have been taken into account when developing the benefits in this report. Further details of these studies and the multiple benefits can be found in Annex A.

1.4.1 Micro multiple benefits

On a micro (private) level, the impacts represent the benefits from an energy efficiency investment linked to the actual use and value of the building, for example the increased comfort and health of the inhabitants, increase in asset value of the building and the reduced expenditure on energy. The table below gives examples of private perspective impacts (Ürge-Vorsatz and Novikova, 2014, IEA 2016).

Table 1.1. List of micro (private) multiple benefits

Building quality	Building Physics
Building quality	Ease of use and control by user
Building quality	Aesthetics and architectural integration
Building quality	Useful building areas
Building quality	Safety (intrusion and accidents)
Economic	Reduced exposure to energy price fluctuations
User wellbeing	Thermal comfort
User wellbeing	Natural lighting and contact with the outside
User wellbeing	Indoor air quality
User wellbeing	Internal and external noise
User wellbeing	Pride, prestige, reputation
User wellbeing	Ease of installation and reduced annoyance

Source: Authors' elaboration

(1) Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation (notified under document C (2019) 3352) (Text with EEA relevance.) C/2019/3352.
(2) Established by the European Commission Directorate-General for Energy (DG Energy) and United Nations Environment Program Finance Initiative (UNEP FI).
(3) EEFIG UNDERWRITING TOOLKIT: Value and risk appraisal for energy efficiency financing June 2017:
https://www.unepfi.org/wordpress/wp-content/uploads/2017/06/EEFIG_Underwriting_Toolkit_June_2017.pdf

1.4.2 Macro multiple benefits

On a macro level, the impacts represent the benefits from investment to society as a whole, for example: a decrease in energy and carbon emissions; an increase in GDP and employment and improved public health. Quantification and monetisation of these wider benefits can help policy makers and investors understand the importance of the associated impacts and hence increases the appeal of energy efficiency measures, in order to mobilize investments to achieve the EU's 2050 goals.

Table 1.1. List of macro (societal) multiple benefits

Environmental	Reduction of air pollution
Environmental	GHG impacts
Environmental	Energy savings
Environmental	Resource Management - circularity/life-cycle
Economic	Lower energy prices
Economic	Innovation and Competitiveness
Economic	Employment effects
Economic	GDP
Economic	Reduced public budget
Economic	Energy security
Social	Health & wellbeing: reduced mortality
Social	Health & wellbeing: morbidity
Social	Fuel Poverty Impacts
Social	Improved productivity

Source: Authors' elaboration

Based on recommendations from interviewees and the objectives of this project, the study looks into the macroeconomic rewards of energy efficiency and methods of including these gains in the cost-optimal calculation. Table1.2 shows the macroeconomic benefits chosen for this study and were selected based on an in-depth review of the literature and discussions with experts.

1.5 Life-cycle approach and cost-optimality

The methodology for calculating cost-optimal energy performance requirements under the EPBD is based on the economic "*global cost calculation model*", normally referred to as the "*lifecycle cost analysis*" (LCCA). This methodology was developed in the 1960's in order to assess an activity, service or product's impact on the environment, from cradle to grave, taking into account damage to human health and the environment. In the mid-90s, researchers began to define more consistent measuring methods of these impacts and in 2004 a UNEP and SETAC joint organisation set up a working group to integrate social criteria into the life cycle assessment (Sala et al, 2015).

According to BPIE, since the cost-optimality analysis in the EPBD is mainly based on conventional economic aspects it does not sufficiently take into account wider societal or economic benefits (BPIE 2016). This can reduce the cost-effectiveness of energy efficiency measures, which can contribute to limiting investments in energy efficiency and to higher minimum energy performance requirements for both new and existing buildings than in the case where such benefits are taken into account (COMBI, 2016). According to some references and to the feedback from interviews held with energy efficiency experts, this approach could, potentially, lead to less ambitious requirements (than optimal ones) in some of the most advanced MS (Ferreira & Almeida, 2015, Ürge-Vorsatz et al., 2009)

Adequate policies and building standards are recognised as essential to stimulate the energy efficiency renovation market. The inclusion of wider benefits could convince MS of the value of accelerating the transformation towards a decarbonised society and has the potential to push the minimum energy performance requirements towards nearly zero-energy and beyond. Thus supporting the achievement of the EU's energy efficiency target for 2030 of 32.5% while accelerating the transformation of buildings into healthy, comfortable and efficient buildings.

1.6 Building types

As this report targets finding indicators for and the monetisation of the macro multiple benefits of energy efficiency, it does not provide a methodology per building typology. However, in terms of looking at multiple benefits from an investor's point of view, the differentiation between building types is central and hence a strategy to determine the MBs of the different types will be important going into the future when multiple benefits become a standardised part of the strategy development of a policy or investment of a nation, company or investment. The benefits and drivers per each building type differ. The following section discusses each building type - Residential, Public and Commercial - and the barriers and opportunities associated with each.

Commercial buildings (primarily used for businesses) are mainly offices, restaurants, hotels, shops and hospitals. The normal set-up for commercial buildings is a business renting and occupying the space, giving rent to a third party who owns the building, thus resulting in split owner-occupier incentive. As such, investment horizons are often based on short investment time frames, based on the business occupying the space. Commercial buildings are often large, energy-intensive and owned in portfolios.

Public buildings are primarily owned or occupied by national or regional governing bodies and are often government offices or agencies and can also be publicly owned residential buildings, such as social housing, schools and universities. These buildings are generally owned and occupied by the same entity and hence the owner can enjoy the energy savings, productivity and value improvements from enhanced energy efficiency and the benefits of increased employment, reduced emissions and improvements in public accounts.

Residential buildings are either owned or rented and can be broken down into subcategories: multi-family dwellings, semi-detached and single-family homes. Depending on whether the building is owner-occupied or occupied will result in different investment opportunities and constraints, the biggest of which is often owner-tenant split incentives. Most of the EU residential building stock is inefficient and hence offers attractive energy efficiency investment returns. However, as most buildings are standalone or owned by one party, an efficiency renovation strategy that engages buildings at scale and is able to aggregate the building works has not yet been fully developed. R&D into how to aggregate renovation works will be key to unlocking this typology's potential.

1.7 Multiple Benefits and Sustainable Development Goals

The UN's Sustainable Development Goals (SDG) are at the heart of both policy and investments, as they are both concerned with planning and investing for the long-term well-being of their beneficiaries. The SDGs are vitally important to the health of the global economy and are aimed at creating a viable model for the future in which all economic growth is achieved without compromising the environment or placing unfair burdens on society (UNEP, 2019b). Energy efficiency is regarded as being pivotal in achieving the SDGs, and is seen as being one of three key objectives of the UN's Sustainable Energy for All (SE4all), to be achieved by 2030:

- Ensuring universal access to modern energy services,
- Doubling the global rate of improvement in energy efficiency and,
- Doubling the share of renewable energy in the global energy mix.

The SE4ALL Framework for Action recognises that many benefits would be able to be reached with the successful implementation of the three objectives, stating:

"Achieving each of the three objectives would realise multiple, substantial benefits to countries, companies

and society. Energy is the world's largest industry, and the transition to sustainable energy systems provides perhaps one of the largest global economic opportunities of the 21st century – particularly important at a time of financial hardship in many nations." (ICSU, 2019)." Figure 1.2 shows the 17 SDGs.

Figure 1.2. **The 17 UN's Sustainable Development Goals (SDG)**

Source: UN, 2020

The multiple benefits highlighted for this study are directly linked to many of the UN's SDGs, the SDGs are listed per multiple benefit in table 1.3 below.
All of the MB are linked to one or more of the SDGs and taken together the identified benefits reach 10 out of the 17 SDGs. The remaining 7 SDGs that are not directly linked to the MB highlighted above are:

- GOAL 5: Gender Equality
- GOAL 6: Clean Water and Sanitation
- GOAL 2: Zero Hunger
- GOAL 14: Life Below Water
- GOAL 15: Life on Land
- GOAL 16: Peace and Justice Strong Institutions
- GOAL 17: Partnerships to achieve the Goal

Table 1.2. Multiple benefits and their related SDGs

Category	Co-benefit	SDGs
Environment	**Energy Savings**	GOAL 12: Responsible Consumption & Production GOAL 13: Climate Action GOAL 11: Sustainable Cities & Communities
Environment	**GHG Impacts**	GOAL 13: Climate Action
Environment	**Reduction of air pollution**	GOAL 7: Affordable and Clean Energy
Environment	**Resource Management**	GOAL 12: Responsible Consumption & Production GOAL 11: Sustainable Cities & Communities
Economic	**Employment effects**	GOAL 8: Decent Work & Economic Growth
Economic	**GDP**	GOAL 8: Decent Work & Economic Growth
Economic	**Public Budget**	GOAL 8: Decent Work & Economic Growth
Economic	**Energy security**	GOAL 7: Affordable and Clean Energy GOAL 11: Sustainable Cities & Communities GOAL 12: Responsible Consumption & Production
Economic	**Innovation and Competitiveness**	GOAL 9: Industry, Innovation and Infrastructure GOAL 11: Sustainable Cities and Communities
Social	**Health & wellbeing: reduced mortality**	GOAL 3: Good Health & Well-being
Social	**Health & wellbeing: morbidity**	GOAL 3: Good Health & Well-being
Social	**Poverty Alleviation**	GOAL 1: No Poverty GOAL 7: Affordable & Clean Energy GOAL 10: Reduced Inequality
Social	**Improved Productivity**	GOAL 4: Quality Education GOAL 8: Decent Work & Economic Growth

Source: Authors' elaboration

However, links can be made between the remaining 7 and some of the economic, social and environmental benefits. For example: it is widely agreed that a more efficient building stock would reduce local, national and global emissions (IEA, 2019). Globally, reduced emissions will help life on land, reduce droughts, water scarcity and hunger in many places, and will also support gender equality (by means of technological empowerment and gained time and resources). For example, A UNDP project found that energy poverty affects women and girls by virtue of the impact it makes on their time, or lack of it, for rest or leisure, resulting in 'time poverty'. In many places across the globe, women spend immoderate amounts of time gathering fuel, food and water for basic human needs, resulting in severe 'time poverty' and preventing them from participating in other beneficial ventures (for example, education). It was found that by improving the efficiency of and mechanising devices, women's empowerment and changes in gender relations could be catalysed, for example, by reducing time spent on household tasks, improving their health and increasing access to information services such as the internet (UNDP, 2013).

2 Approach

2.1 Methodology

This paper looks into the multiple benefits generated by enhancing energy efficiency in buildings; provides examples of how these have been and can be monetised and proposes a methodology for the inclusion of multiple benefits within the EPBD's cost-optimality framework. Although the aim of this research is to explain how multiple benefits can be integrated into the EPBD's cost-optimality calculation, the methodologies described can also be relevant at national level (e.g. energy, health and economy policies developed by the MS). The principal objectives of this study are to propose:

1. A methodology for the inclusion of multiple benefits in the EPBD's cost-optimality framework; and
2. A toolkit to help MS monetise the multiple benefits of energy efficiency in the building sector and include these wider impacts when developing minimum performance requirements.

The methodology of the study follows a three-tiered approach. Interviews were held with 22 stakeholders working in the field of multiple benefits; energy policy, energy efficiency policy, EPBD implementation and health institutions and energy poverty alleviation researchers. During and after the interview period a literature review was undertaken that provided the core information for the study, and lastly a peer review process allowed experts in the field time to comment on and analyse the results of the study.

The interviews took place between December 2018 and February 2019, which together with the peer review process ensured this report:

a. Acquired comprehensive insight from experts covering the wider benefits of energy efficiency, ensuring that the quantifiable and monetised multiple benefits of improving energy efficiency in buildings were encompassed in this report;

b. Received in-depth input from statisticians working in the field of multiple benefits to ensure a robust methodology for monetising and including wider impacts into the cost-optimality calculations; and

c. Provided the researchers with a full body of literature that fed into and formed the foundation of this report.

The Literature review took place between November 2018 and March 2019 and covered the following key sources:

- Research Gate
- Google Scholar
- Science Direct
- Horizon 2020 projects
- Scopus
- Web of Science

The research also incorporated additional grey literature by searching websites for key words and organisations. Additionally, the interviews fed into the literature review and the interviewees provided many of the reports. Over 100 papers were reviewed for this report and their bibliographic details can be found in the References.

2.2 Report Outline

This guide aims to address and fill some of the informational voids for analysts and decision makers working to develop, as well as implement, energy efficiency policies, and is divided into three sections:

1. Quantification and monetisation of multiple benefits – providing information on each multiple benefit with regards to their indicators and some examples of monetised values for each impact.

2. Methodology to include multiple benefits into the cost-optimal calculations – providing Member States with a new global cost calculation that includes the wider benefits of energy efficiency.

3. Methodology for monetising multiple benefits – describing how Member States can find the monetary value of the multiple benefits to be included in the global cost calculations of the cost-optimality framework.

The chosen impacts of energy efficiency were selected based on an in-depth literature review undertaken by the researchers. The impacts listed in these studies were cross-referenced against the recent comprehensive studies undertaken by COMBI and ODYSSEE-MURE to give a full list of societal impacts to be included in the quantification and monetisation section. Both studies included quantifying the multiple benefits of energy efficiency. Although the list of multiple benefits is not exhaustive, it includes those impacts that are widely acknowledged as having significant benefits, largely based on the extensive studies undertaken by the IEA, IEPP, the EC, the OECD, UNEP, Fraunhofer Institute, Copenhagen Economics, COMBI and Odyssee-Mure. The list and description of multiple benefits can be consulted in Table 2.1 in the "Multiple Benefits: Quantification, Indicators and Values" section below.

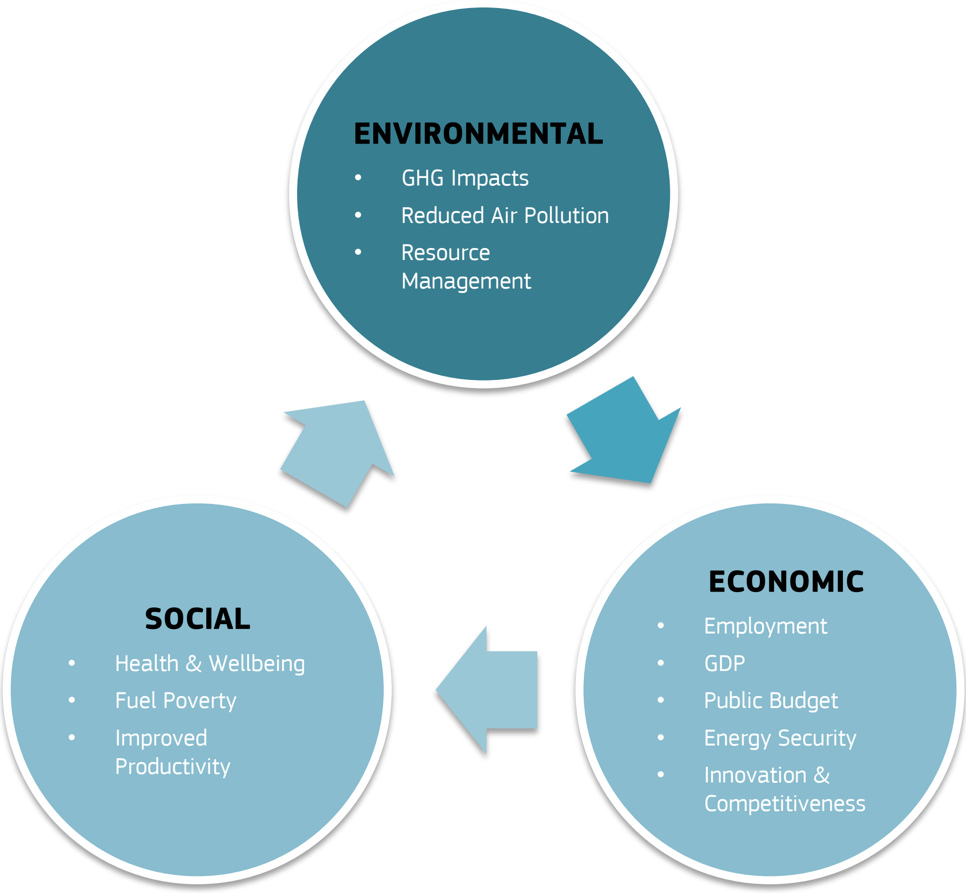
Part 2 provides a methodology for the inclusion of wider benefits in the global cost calculation of the cost-optimality framework under the EPBD. This was developed initially based on the 22 interviews with experts working in this field and additional consultation of relevant literature.

This research represents a first step in establishing a mechanism for monetising the impacts of energy-efficient buildings in order to include these in the cost-optimal calculations. Several different techniques for monetising the multiple benefits were identified and are further described in the literature review section. Although each impact leads to monetised benefits, the report does not provide a calculation method for all impacts. The reasons for that are: a. if all impacts were calculated and subtracted from the total costs, there would be overlaps between them and therefore some could be double-counted; b. some of the multiple benefits were proved to be minimal and have therefore not been included in the calculation procedure (as described in the methodology); and c. to be monetised, some of the impacts would require a detailed and resource-heavy modelling process, which works against the objective of ensuring that all major benefits are included in a workable monetising process. The most detailed and comprehensive research on multiple benefits has been undertaken in the COMBI project. The results of this project have largely been used to provide input into this research.

3 Part One – Multiple Benefits: Indicators / Quantification / Values

This chapter presents the results and examples from an array of studies, as described in the methodology above, most of which have been undertaken using a baseline / reference scenario and suggested energy efficiency scenario that allows them to calculate and monetise the multiple benefits of energy efficiency. In the modelling of these scenarios, the assumptions vary in each case (depending on the level of energy efficiency investment, level of political ambition, the building types targeted and the depth of efficiency measure). The researchers suggest that further research needs to be done to define each of the scenarios against the monetised impacts. Figure 3.1 below shows the multiple benefits diagram of the benefits included in this study.

Figure 3.3. Multiple Benefits Diagram of the benefits included in this study



Source: Authors' elaboration

This section describes the multiple benefits linked to a macroeconomic approach of monetising and quantifying multiple benefits. These benefits are divided into three subsections; environmental, economic and societal impacts:

- **Environmental impacts**: these are the effects energy efficiency has on the environment: *the reduction of air pollution, energy savings, GHG emission reductions and resource management*. These all link to environmental benefits with respect to reducing air pollution emissions (NOx, SO_2, small particulate matters) and CO_2. Not only will the reduction of these bring better health to society (as per social impacts), they will also help local and regional governments meet their environmental targets.

- **Economic impacts:** Energy efficiency improves economic development by: *lowering energy prices, inducing innovation and competitiveness, reducing the public budget, providing energy security and impacting favourably on GDP and employment.*
- **Social impacts**: Energy efficiency measures have huge consequences for the *health and wellbeing of a society, poverty alleviation and productivity*. Health impacts are especially relevant in relation to reduction of morbidity and mortality and poverty alleviation. By improving public health, productivity increases and this leads to a reduction of hospital and GP visits and sick days.

Table 3.1 gives an overview of each impact, categorised into the three main groups with a description of the indicators for calculating and monetising each benefit. The results provided in Table 1.3 are elaborated in the subsequent sections. The explanations and scenario descriptions for each monetised value listed in the table are found in the preceding sections.

Table 3.3. Overview of multiple benefits, indicators and their descriptions

Category	Co-benefit	Indicators (units)	Description of benefit	Monetary Range in the EU	Reference
Environment	Energy Savings	Annual energy savings (TWh)	Energy is saved due to efficient buildings using less energy	energy savings between € 37 billion (2030) and €175 billion (2020) per year	COMBI, 2018 & Copenhagen Economics, 2012
Environment	GHG Impacts	Annual CO_2 and other emissions savings linked to energy savings (Mt CO_2eq)	GHG is reduced due to efficient buildings using less energy	Increase between € 3.5 – 17 billion in 2020 per year	Copenhagen Economics, 2012
Environment	Reduction of air pollution	Emission factors per avoided pollutant: NOX SO2 CO2 PM2.5 (kt)	Air pollution is limited due to reduced fuel combustion.	Increase in € 9 - 12 billion in 2020 per year	IEA, 2016
Environment	Resource Management	Savings on fossil fuels and metal ores (Mt)	Building renovations lead to reduction, reuse and recycling of waste compared to the replacement of existing buildings by new ones, additionally less exploitation of natural resources related to fuel consumption.	€ 20 billion per year in 2030	COMBI, 2018
Economic	Employment effects	I/O - input-output, economic activity-construction *(1000 person years)*	Employment increase generating GDP/ income/ profit generated as a consequence of new business opportunities in energy efficiency measures and related energy savings.	17 to 19 jobs are created per million € invested in energy efficiency	IEPP 2013, BPIE, 2011
Economic	GDP	Impact of energy savings on GDP *(billion €)*	GDP increased through electricity system, emissions, and health improvements yielding overall economic benefits, including savings in energy and fuel costs for consumers, businesses, health care and the government.	Increase in GDP between 0.2 and 2.3%	Cambridge Econometrics, 2014 & Joyce et al, 2012
Economic	Public Budget	Energy savings: public expenditure on energy saving equipment, the value of energy savings to the public sector, state income from employment based on energy savings *(billion €)*	Savings in the public budget through improved public health, reduction on energy expenditure, income from increased employment.	Increase between € 30 - 40 billion in EU in 2020 per year	IEA, 2016

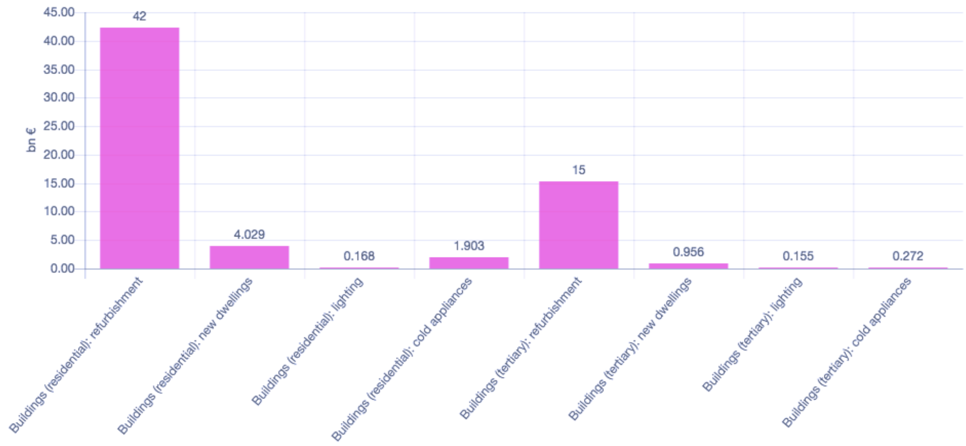
Category	Co-benefit	Indicators (units)	Description of benefit	Monetary Range in the EU	Reference
Economic	Energy security	Avoided electric power output & investment costs *(TWh)*. Share of fossil fuel/energy imports in GDP *(% share from outside EU28 in primary energy)*	Reduced dependence on imported energy. Increasing supplier diversity allows for consumer choice and increases competition amongst suppliers, which reduces the price of energy.	Increase between €4.3 billion and € 20.58 billion in EU.	mBuild, 2017 & COMBI, 2018
Economic	Innovation & Competitiveness	Quantitative output: growth potential of the innovation markets for energy efficiency in buildings. Qualitative output: competitive advantage of European industries compared to non-EU players.	Higher economic growth through innovation and competition amongst companies and a larger turnover of energy efficiency goods.	Potential to decrease of 16% of EU's total annual energy demand by 2020. Total benefits range between € 30 – 60 billion savings per year.	EEO, 2014, EC, 2016, Boromisa et al, 2016
Social	Health & wellbeing: reduced mortality	All in no. of deaths per year: Excess winter mortality Mortality ozone Mortality PM2.5	Reduced mortality due to less indoor and outdoor air pollution.	Increase in total health benefits between € 926 million and € 88 billion per year	EC, 2016 & IEA, 2016
Social	Health & wellbeing: morbidity	Indoor air pollution (1000 YOLL) Winter morbidity (asthma) (DALY) Morbidity PM2.5 (YOLL)	Reduced morbidity due to better IEQ and reduced indoor and outdoor pollution.	Increase in total health benefits between € 5 and € 88 billion per year[4]	Renovate Europe, 2013 & IEA, 2016
Social	Poverty Alleviation	Utility costs / household. Diseases arising from thermal discomfort.	Reduced expenditures on fuel and electricity; fewer affected persons by low energy service level, less exposure to energy price fluctuations.	Cut of utility costs by € 465 to €1,195 per household per year	EC, 2019 & EC, 2005).
Social	Improved Productivity	Active days gained (*indoor exposure)* *Workforce performance (minimum workdays)*	Learning and productivity benefits due to better concentration, savings/higher productivity due to avoided "sick building syndrome".	Increase between € 15 and € 42 billion per year	Lovins, 2005 & Fraunhofer, 2017

Source: Authors' elaboration

Several studies have monetised and quantified the multiple benefits of energy efficiency. Their findings are based on a variety of methodological approaches: basic calculations; input/output models and detailed modelling. The main studies used for this analysis are by COMBI, the EC, the IEA, Odyssee-Mure and Copenhagen Economics, all of whom used models to calculate the multiple benefits.

The total amount of euros per year that can be attributed to multiple benefits of energy efficiency actions in Europe **range from a conservative € 65 billion to € 291 billion** (COMBI, 2016, Copenhagen Economics, 2012, IEA, 2016). These figures and hence the ambition of each scenario depend on the level of investment, depth of efficiency scenario, baseline and future scenario year used by each study. The IEA's monetisation of multiple benefits study suggests a permanent annual benefit to society of € 104 - 175 billion in 2020 in the EU (IEA, 2017). The Copenhagen Economics study finds that energy efficient renovations can stimulate benefits accruing to € 153 - 291 billion in Europe (Copenhagen Economics, 2012). The COMBI graphs show the € 65 billion split per energy efficiency in monetary impacts in € per billion and action in Figure 3.2 below.

Figure 3.4. COMBI's total monetised multiple benefits (bn €)
split between energy efficiency building typologies and measures[4]



Source: COMBI, 2020

The impacts assessed to calculate the total monetised benefits in COMBI are: Asthma (DALY), avoided electricity generation, direct GHG emissions, energy savings, excess winter mortality, indoor air pollution, mortality - ozone, mortality - PM2.5, reduced congestion, workforce performance, YOLL PM2.5.

The EU countries included in the COMBI study are: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherland, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

The building energy efficiency actions modelled by COMBI include: Refurbishment (including materials, technical building systems, space heating and cooling), new dwellings, lighting, cold appliances (primarily fridges, freezers and fridge-freezers)[5].

The following sections provide a deeper analysis of each of the multiple benefits described above. Each impact will be described, mechanisms for quantifying will be explained and a range of monetary values will be provided where possible.

3.1 Environmental Impacts

3.1.1 Energy Savings

The role of energy savings is a direct and primary objective of energy efficiency and feeds into European, national and regional energy and climate policy objectives. The goal of reducing energy consumption is an output for energy policies, not only because it allows ministries to meet targets, but also because the energy savings realised at all levels have an impact on the wider society (IEA, 2012).

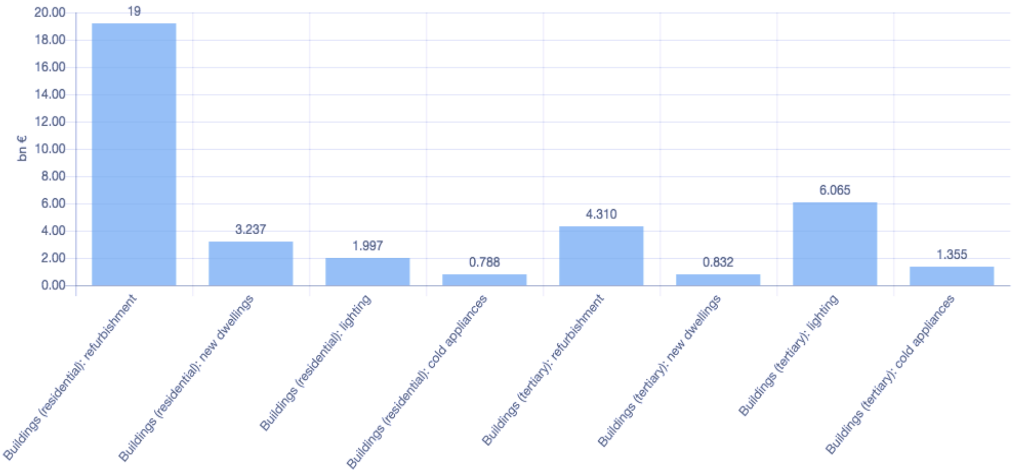
The indicator for energy savings is annual energy savings in TWh and energy savings for all fuels are calculated in TWh per year. Some studies monetise the energy saving impacts of energy efficiency measures as follows:

([4]) See Annex B for COMBI's scenario assumptions.
([5]) Cold appliances defined by BRE in 2017: Fridges with iceboxes; Fridges without iceboxes (also referred to as larder fridges); Fridge-freezers; Upright freezers; Chest freezers. (BRE, 2017)

- In the UK: in 2012, it was estimated that the yearly energy cost saving impacts of € 21.33 billion would be reached by the UK Green Deal[6]. In 2013 € 1.66 billion savings were achieved by implementing the Building Regulations Part L [7] and in 2014, € 582 million was saved from private rented sector (PRS) Minimum EE Standards (Payne et al, 2015).
- In the EU, based on available estimates of the potential for energy savings from the renovation of buildings, Copenhagen Economics monetised the permanent *annual* benefit to society to be € 104 - 175 billion in 2020, depending on the level of investments made from 2012 to 2020 (Copenhagen Economics, 2012).
- A New Zealand weatherization programme was found to amount to € 44 / household (hh) / year in 2007 that accounts for around 18.7% of the total annual energy expenditures saved (Stoecklein and Scumatz 2007).
- A Swedish study found that EE measures have the potential to generate energy savings of 46% in single-family houses and 41% in multi-family dwellings in 2030 compared to 2015, resulting in an aggregated value of 7.6 - 9.3 billion SEK in 2030 (Copenhagen Economics, 2016)

The most relevant reference in the scope of this study is the one from the COMBI team, which reported energy savings to be worth € 37 billion per year in 2030 relative to their baseline, as seen per building type in the graph below (Figure 3.3). These are quantified from a set of energy efficiency improvement indicators modelled as a stock model from the building sector.

Figure 3.5. Energy savings of all fuels (bn €), displaying additional annual savings in 2030 relative to current policies baseline



Source: COMBI, 2020

Taken from the literature review, the range of monetary values for energy savings was found to be **an increase of between € 37 billion (in 2030, COMBI, 2018) and € 175 billion** (in 2020, Copenhagen Economics, 2012)[8] **per year.**

([6]) UK Green Deal: https://www.gov.uk/green-deal-energy-saving-measures
([7]) Part L of the Building Regulations. Part L of the Building Regulations (England and Wales) contains requirements relating to the conservation of fuel and power: https://www.isurv.com/info/35/part_l_of_the_building_regulations
([8]) See Annex B for scenario assumptions for both COMBI and Copenhagen Economics.

3.1.2 GHG Impacts

Energy efficiency measures reduce the demand for fossil fuels. Most, if not all, climate change mitigation strategies see energy efficiency as being key to reducing GHG emissions and hence reducing global warming.

The indicators for GHG impacts are annual CO_2 and other emissions savings linked to energy savings *in Mt CO2eq*. Several methods for calculating the impact of GHG emissions exist. Odyssee-Mure calculates CO_2 savings by multiplying the total energy savings of the building sector by the average emission factor of the building sector in tCO2/toe. COMBI measures GHG emissions by directly linking them to the final energy demand based on the direct combustion of fossil fuels.

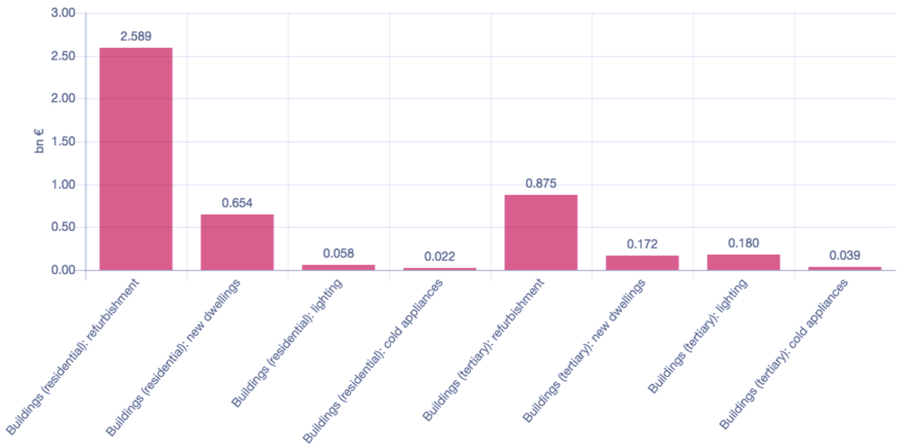
The OECD and IPCC estimate that, globally, more than 2,500 mtCO_2 emissions reductions could be achieved annually through end-use energy efficiency improvements in the building sector (IPCC, 2007). The OECD states that energy efficiency measures are expected to contribute to 44% of the carbon abatement needed to reach the international climate change targets by 2035 (OECD, 2012). Other studies have calculated the GHG emission reduction effects and associated monetary value generated by energy efficiency measures, including:

- In the UK, a study led by the former DECC suggests that, by implementing energy efficiency policies in the building sector, a 28% GHG emission reduction could be reached by 2030 (DECC, 2007).
- The EU Commission finds that moving from a 20% to a 30% GHG reduction target, the value of reduced air pollution (from CO2, NOx, SO2, and small particle matters (PM2.5)) ranges from € 3.5 – 17 billion (Copenhagen Economics, 2012).
- The study commissioned by the EC looking at the implementation effects of the EPBD (EC, 2016) suggests a reduction of CO_2 emissions in the EU28 ranging from -0.5% to -7.8% and GHG emissions from -0.4% in to -6.0% depending on the level of EPBD implementation and progressive updates up to 2030.
- The ÖkoKauf Program, providing investment to improve energy efficiency in the case of administrative buildings, has resulted in € 1.5 milion of cost savings and 1,723 tonnes of CO_2 emission reduction per year in Austria (Austria Energy Efficient Cities Initiative, 2011)
- GHG emissions from energy efficiency renovation measures in the EU building sector could amount to 0.13 billion SEK for Sweden in 2030, when exchanging the 2012 rate this is roughly € 12 million (Copenhagen Economics, 2016).

The COMBI team reported GHG emission savings[9] to be roughly € 4.6 billion per year in 2030 relative to their baseline, as seen per building type in the graph below (Figure 3.4). These are quantified from a set of energy efficiency improvement indicators modelled as a stock model from the building sector.

(9) Understood as the savings of direct GHG emissions (CO2eq) from fuel combustion

Figure 3.6. GHG emission savings (bn €) of all fuels (additional annual savings in 2030 relative to current policies baseline)



Source*: COMBI, 2020*

Taken from the literature review, the range of monetary values for GHG emissions savings was found to be **an increase of between € 3.5 – 17 billion in Europe in 2020.[10]**

3.1.3 Reduction of Air Pollution

The European Environmental Agency defines air pollution as *"the presence of contaminant or pollutant substances in the air at a concentration that interferes with human health or welfare, or produces other harmful environmental effects"* (European Environmental Agency, 2015a). The World Health Organization (WHO) states that up to 90% of Europeans were exposed to unsafe concentrations of PM10, PM2.5 and O3, suggesting a need for even stricter air quality standards than are currently in effect in the EU.

The indicators of reduction of air pollution are emission factors per avoided pollutant: NOX, SO2, CO2, PM2.5 assessed in kt. Although COMBI do not monetise air pollution due to its direct links with health benefits and hence the potential of overlapping or double counting of the total multiple benefits, it has been quantified and COMBI conclude that significant health benefits accrue as a result of end-use energy savings. In all of EU, COMBI calculate this to be 0.003 VOC, 0.004 SO2, 0.001 PM2.5, 0.002 PM10, 0.006 VOx Kt of reduction / billion € GDP (2015). Odyssee-Mure assesses air quality by taking data on annual energy savings by end-use and calculates the local pollutants linked to end use and fuel specific emission factors.

Other studies have monetised the estimated health related savings from reduced levels of local air pollutants:

- Copenhagen Economics and the IEA suggest this is € 9-12 billion in 2020 from the reduced outlay on subsidies and reduced air pollution from energy production (CE, 2012 & IEA, 2016).
- A study on an energy efficiency programme in the US found the NPV of air emission reduction (CO2, SOx, NOx, CO, CH4, PM) over lifetime of the measures is (all in thousand €/hh: a) from natural gas burning 30.2 - 37.7; b) from electricity consumption 118-185; c) air emissions of heavy metals is 0.75-12.8 (Schweitzer and Tonn 2002; Kats 2005; Kats 2006)

Taken from the literature review, the range of monetary values for GHG emissions savings was found to be **an increase of between € 9 - 12 billion in Europe in 2020**[11]**.**

([10]) Both the €3.5 and 17 billion assumptions were taken from the study undertaken by Copenhagen Economics in 2012 based on the EU Commission's findings that by going from a 20 per cent GHG reduction target to a 30 per cent target the value of reduced air pollution ranges from €3.5 – 17 billion.

3.1.4 Resources Management

Natural resources underpin the running of the economy, our environment and quality of life. Energy efficiency significantly reduces the impact on material resource use. Integrating an energy efficiency strategy with a decarbonisation and resource=efficiency strategy would further reduce resource use. Significantly, the impact of renovating, as opposed to building a new building, leads to reduction and reuse of resources and recycling of waste.

The indicators of resource management are savings on fossil fuels and metal ores in Mt. COMBI quantifies resources impacts by looking at the savings of our "material footprint" with a cradle-to-grave product life cycle assessment model for metal ores and fossil fuels.

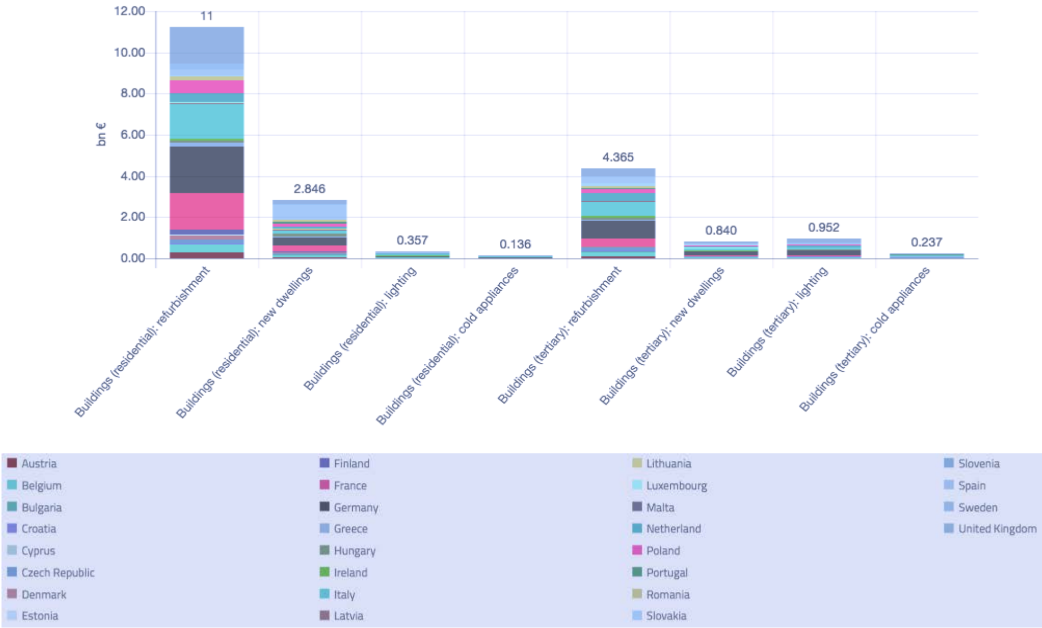
Some studies have quantified the effects of energy efficient buildings on resource management, some outcomes are:

- Building new efficient houses and renovating existing houses to an efficient depth reduces construction and demolition wastes up to 99% (Kats, 2005 and SBTF, 2001)
- An Irish study examining energy efficiency in buildings has calculated the impact of energy efficiency on resources will be around € 71 billion by 2030, based on reduced levels of local air pollutants (SEAI, 2011).

The COMBI team reported energy savings to be € 20 billion per year in 2030 relative to their business as usual scenario (current building stock's efficiency level with current policy being implemented), as seen per building type in the graph below (Figure 3.5), the biggest savings in resources come from renovating buildings.

([11]) These assumptions come from the high EE scenario in the Copenhagen Economics' 2012 report - assuming full penetration of best available EE technologies for renovating Europe's buildings. The scenarios used by Copenhagen Economics to come to these values can be found in Annex B.

Figure 3.7. Resource Management savings of fossil fuels and metal ores (additional annual savings in 2030 relative to current policies baseline)



Source*: COMBI, 2020*

Taken from the literature review, the value of the energy savings resulting from an enhanced resource management was found to be **€ 20 billion per year in 2030[12].**

3.2 Economic Impacts

3.2.1 Employment

Energy efficiency initiatives provide a number of employment benefits to nations, communities and individuals. Currently, the construction industry in Europe contributes nearly 10% to EU GDP and accounts for 18 million jobs (Toia, 2018). Depending on the outreach and level of investment, economic activity linked to energy efficiency activities could provide work for 760,000 – 1,480,000 people (IEA, 2016). Most of these jobs would incur in the sectors directly linked to energy efficiency, such as engineering, construction and production. However, investing in energy efficiency would also create some indirect employment opportunities through consumer surplus spending (OECD, 2012).

The indicator of employment is employment in relevant energy sectors in 100 person years. Incremental investment costs for energy efficiency measures are used as inputs to model effects on employment in job years, these are analysed using an input / output (IO) database. The COMBI IO-model takes multipliers from the OECD's 2010 macroeconomic model. The Odyssee-Mure team took two main drivers into account: investment in EE measures (triggering a demand impulse for energy products) and related energy savings (reducing the demand for energy products in the long-run). In order to trace the demand changes, Odyssee-Mure used an IO analysis that calculates how gross value added is affected by demand changes.

([12]) See Annex B for scenario assumptions for COMBI – COMBI look at the material footprint in terms of net savings in Mt of materials and differences in the production systems (production phase) for lighting systems in Mt of resources (partial use phase compensation). Calculated in avoided & unused extraction resources per bn € of 2015 GDP.

The study commissioned by the EC on the multiple benefits of implementing the EPBD (EC, 2016) quantifies the number of EU 28 jobs in the energy efficiency goods and services sold sectors, in 2010, these amounted to 0.9 million. However, according to the same study, by fully implementing the EPBD, this number could rise to 2.4 million which equates to an employment increase of roughly 0.25% (EC, 2016). The 2017 study commissioned by the EC on the multiple benefits of implementing the EED found that by implementing measures to meet 2030 energy targets, the most ambitious scenario sees employment increasing by more than 2% (EC, 2017). Numerous studies exist that monetise employment benefits to society, often this is presented in number of jobs per million € invested:

- In the UK, the energy efficiency sector has been estimated by government to be worth more than € 25.6 billion, supporting 136,000 jobs (EST, 2015).
- A 2011 analysis of spending $ 44.4 million (€ 39.19 million) in a single future year on efficiency in Vermont results in a net increase of close to 1,900 job-years (EPA, 2018)
- By implementing the EU EE targets, unemployment could be reduced by up to 3 million people by 2030 (EC, 2017).
- To 2020, there are about 19 net jobs generated per € 1 million investment in energy efficiency in the buildings sector (Janssen & Staniaszek, 2012).
- The general consensus in the industry and amongst modellers is that on average, 17 to 19 jobs are created per million € invested in energy efficiency, both inside and outside the EU (IEPP 2013, BPIE, 2011)
- Direct employment created per £ 1 million (€ 1.165 million) invested is in the range of 10-58 (person-years during programme). Indirect employment created over 15 years per £ 1 m invested is found to be above 60 person-years in the UK (Association for the Conservation of Energy, 2000)
- In the US, the 2005 Building Technologies programme could create 446,000 jobs by 2030 and increase wage income by $ 7.8 billion (€ 6.89 billion) per year (Scott et al, 2008)
- In Germany, 900,000 jobs have been created in retrofitting dwellings and public buildings between 2006 and 2011 (Power and Zalauf, 2011)
- In Germany, 127,000 additional jobs could be created in 2030 by implementing further energy efficiency measures, i.e. € 301 billion of additional investment by 2030 (Lutz et al, 2012).
- In Canada, energy efficiency improvements increased employment by 2.5% from 2002 to 2012 (Navius Research, 2014).

The general sector-wide accepted monetary value for employment is 17 to 19 jobs are created per million € invested in energy efficiency.[13]

3.2.2 GDP

Harvesting energy efficiency opportunities stimulates economic activity, and hence improves the overall GDP of a country. The GDP of a nation can increase through health benefits, emission reductions and electricity systems boosting the economy, by lowering energy costs for consumers, businesses and governments and increasing productivity and job creation.

The indicators of GDP are the impacts of energy savings on GDP in *billion €*. Calculating the impact on the increase of GDP in an area involves using incremental investment costs for energy efficiency measures as inputs for modelling the effect of GDP (COMBI, 2019). Odyssee-Mure calculate the effects of energy efficiency measures on GDP using the employment effects in an IO analysis, therefore these effects are considered to be the same as the employment effects.

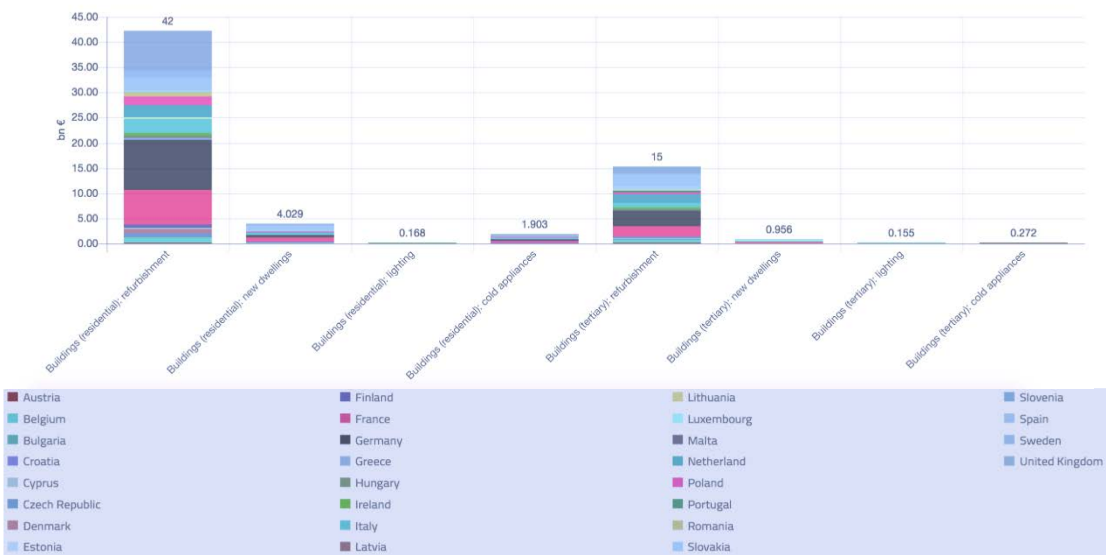
The 2017 study commissioned by the EC found that, by implementing measures to meet 2030 energy targets, the most ambitious scenario sees a GDP increase of more than 4% (EC, 2017). The overall benefits to GDP calculated by the IEA can see EU Member States achieving benefits of between € 153 - 291 billion, depending on measures undertaken and the level of investments. They associate these

([13]) The average number of jobs created per million euros invested in EE in the EU and worldwide is between 17 and 19 jobs (IEPP, 2013 and BPIE, 2011).

benefits with "*more activity and more employment, and (they) come from increased revenue from income taxation, corporate taxation, and VAT, and from reduced outlay on unemployment benefits*" (IEA, 2016). Various other studies have calculated the monetary impacts of energy efficiency on GDP, some of which are described below:

- By fully implementing the EPBD the study calculates a rise in GDP of 0.6%.
- Using English Household survey data, this study found energy efficiency programmes could deliver £ 3.20 (€ 3.73) through increased Gross Domestic Product (GDP) for every pound invested by the government, and the equivalent of a 0.6% GDP increase by 2030 compared to a baseline scenario (Verco & Cambridge Econometrics, 2014)
- Cambridge Econometrics estimates that investing in energy efficiency measures in energy poor households in the UK could increase GDP by 0.2%.
- Lutz estimates that investing in energy efficiency measures in Germany households could increase GDP € 22.8 billion by 2030 and Prognos estimates that it could rise by 0.25% compared to a baseline values (Prognos, 2013, Lutz et al., 2012)
- In Canada, every $ 1 (€ 0.88) spent on energy efficiency could increase GDP by $ 5 – 8 (€ 4.41 – 7.06) (Acadia Center, 2014)
- On an EU scale, Joyce et al 2012, suggest that renovating buildings could lead to GDP increases in the range of 1.2 - 2.3%.

Figure 3.8. Selected monetary impacts of GDP in billion €



Source*: COMBI, 2020*

The COMBI analysis calculates the monetary benefits of energy efficient buildings with respect to an increase of GDP as € 65 billion in 2030, based on their energy efficient scenario), as shown by the graph above (Figure 3.6) where breakdown into building categories and countries is also reported.

Taken from the literature review, the general range in value for GDP was found to be **increase in GDP of between 0.2 and 2.3%.**[14]

([14]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values of % od GDP were used: 0.2 and 2.3% - these vary depending on the type and depth of measures implemented, as well as the difference in renovation rate.

3.2.3 Public Budgets

Member States' public sector budget balances would feel the positive effects from energy efficiency improvements in different ways: improved public health, lower energy bills, higher employment, reduction of energy expenditure, income from employment, revenues from labour taxes and an increase in social welfare.

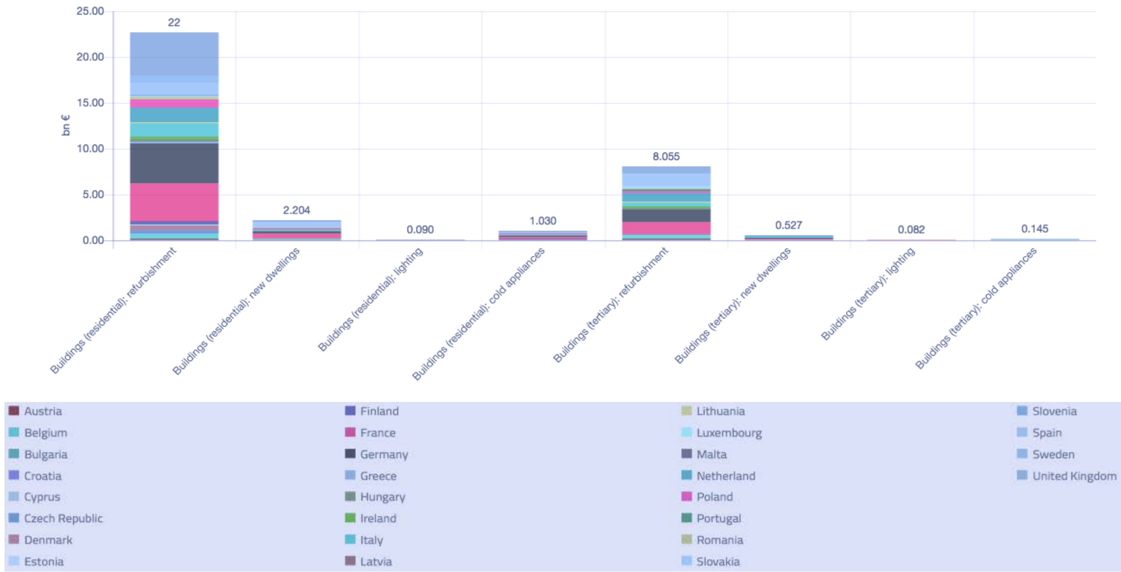
Indicators include public expenditure on energy saving equipment, the value of energy savings to the public sector and state income from employment based on energy savings. COMBI used a "semi-budgetary elasticity", by applying the same method they used for GDP and employment to calculate public budgets. Their IO model is based on the GTAP World Input-Output Database that calculates an immediate stimulus entailing an aggregated demand of the country's economy. Odyssee-Mure takes state income from employment based on energy savings as their indicator for calculating the impact on the public budget.

By fully implementing the EPBD, the 2016 study commissioned by the EC (EC, 2016) calculate savings in the public budget to be up to € 28 billion. This is due to changes in public budgets reflecting price reductions, calculated as being up to 0.11% of GDP. Many studies have calculated the impact on public budgets in different geographic areas around the world, including:

- An analysis of the Austrian energy efficiency programme, ÖkoKauf, has led to €1.5 million cost savings per year (Energy Efficient Cities Initiative, 2011).
- In the Czech Republic, a study found that every CZK 1 million (€ 39,038) invested in enhanced energy efficiency in buildings has a direct fiscal effect of CZK 0.967 million (€ 37,740) (Zámečník and Lhoták, 2012).
- Frontier Economics, 2015, finds that investing in energy efficiency in Britain would reflect in £ 8.7 billion (€ 10.13 billion) of net benefits, the analysis is based on the costs and benefits of a major programme of energy efficiency measures in domestic and non-domestic properties to 2022 (the majority of the costs and benefits relate to domestic properties). The base year for present values varies between 2010 and 2013.
- Annual permanent net revenue gains to public finances could reach € 30 – 40 billion in 2020 in the EU (Renovate Europe, 2013).
- The IEA found the annual permanent net revenue gains to public finances from renovating the building stock could reach € 30 – 40 billion in 2020 (IEA, 2016).

The COMBI analysis calculates the public budget impact of energy efficient buildings as € 34 billion in 2030, based on their energy efficient scenario), the figure below divides this into their building categories.

Figure 3.9. Public budget effect in 2030 (maximum estimation)



Source: COMBI, 2020

Taken from the literature review, the range of monetary values for public budget was found to be **an increase of between € 30 to € 40 billion in Europe in 2020.**[15]

3.2.4 Energy Security

The IEA defines energy security as "*the uninterrupted availability of energy sources at an affordable price*". Security of supply is one of the EU's economic development risks, currently fossil fuels worth € 570 billion are imported each year. However, moderating this demand could reduce the EU's import dependency, which is currently 54% (EEIF, 2019). There are many factors to take into account when thinking about how energy efficiency can impact energy security, mainly supplier diversity and import dependency. For example, every kWh not used does not need to be provided or imported; ensuring less shocks in energy supply and reduced peak loads in energy demand. Depending on the energy mix, some EU MS are highly dependent on imported energy or have only a few energy suppliers; this leaves them vulnerable to supply distributions.

The indicators that should be considered when monetising energy security are: avoided electric power output (TWh), investment costs *(avoided power capacity multiplied by specific capital costs per technology)* and share of fossil fuel/energy imports in GDP *(% share from outside EU28 in primary energy supply).* The COMBI project used five energy security and system indicators, although only included the first in their cost-benefit analysis:

1. Avoided electricity generation (physical, TWh) from and investments (monetary, €) in combustibles-based power plants and CHP
2. Increase in percentage points of de-rated capacity margin. Positive values indicate improvement of reserve power capacity taking into account capacity availability (%)
3. Reduction in energy intensity (ktoe / 1000 € GDP)
4. Percentage change in COMBI energy security HH index (including independency, political stability and diversity. Positive values indicate an increase in energy security
5. Fossil fuel imports. Physical: change in % of fossil fuel import share from outside EU28; Monetary: reduction from fossil fuel import costs from outside EU28.

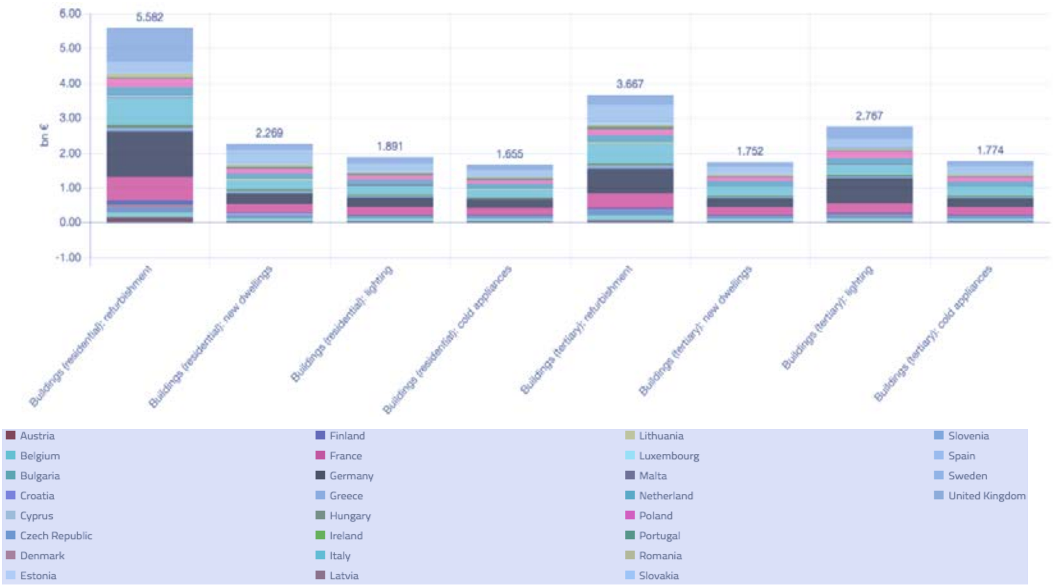
([15]) Based on the studies undertaken that take the whole of the EU into account – as per Renovate Europe, 2013 and the IEA, 2016.

The study on macroeconomic and other benefits of energy efficiency (EC, 2016) measures energy security as the economic value of energy imports, expressed as a share of GDP. The reduction of dependency of energy imports as a share of GDP based on the full adoption of the EPBD varied between MS (LU) from 0 to 0.019 (MT). The IEA calculated the benefits of emergency energy efficiency measures that support energy security, measured by the electricity demand reduction, to be between 0.5% (France) and 40% (Juneau, Alaska), depending on the country analysed.

- Energy imports in Europe could be reduced by € 4.3 billion by employing energy efficiency strategies for deep renovation to reduce primary energy demand by 6% in 2020 (mBuild, 2017).
- A study found that efficiency-driven reductions in demand can result in long-term energy price reductions from 100-200% (Ürge-Vorsatz and Novikova, 2014)
- In the US, it was found that a 1% reduction in natural gas demand resulted in a 0.75-2.5% reduction in the long-term wellhead prices.
- NPV of enhanced national energy security over the lifetime of weatherisation measures is up to 2,488 € / hh (Schweitzer and Tonn 2002).

The COMBI analysis calculates the monetary benefits of energy efficient buildings linked to energy security in fossil fuels and metal ores as € 20.6 billion in 2030, based on avoided electricity generation and fossil fuel imports, the figure below divides this into their building categories.

Figure 3.10. Energy security in terms of avoided electricity generation and fossil fuel imports in 2030 in €



Source: COMBI, 2020

Taken from the literature review, the monetary value range for energy security was found to be **an increase of between €4.3 billion and € 20.6 billion in Europe.**[16]

([16]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values of cost savings from energy security were used: €4.3 billion (mBuild, 2017) and € 20.6 billion (COMBI, 2019) - these vary depending on the type and depth of measures implemented, as well as the difference in renovation rate.

3.2.5 Innovation and Competitiveness

Investing in energy efficiency creates new opportunities, market niches and innovation opportunities to drive economic growth. The market for low-carbon products (in terms of products that are utilised in the context of energy efficiency) and services within the EU represents revenues of over € 150 billion per year in the EU and is growing rapidly (EEIF, 2019). This impact is seen as important factor in transitioning the economy towards a competitive, secure and sustainable energy system. Market trends in energy efficiency can trigger new opportunities for EU-wide value creation.

The indicators of innovation and competitiveness are the growth potential of the innovation markets and competitive advantage of EU industries. Odyssee-Mure suggest identifying and researching data on the share of stock and sales of relevant energy technologies and linking them to suitable patent classes as per the International Patent Classification (IPC) system. In order to calculate the impact of energy efficiency on innovation and competitiveness in (EC, 2016), the contractors use both quantitative (growth potential of the innovation markets for energy efficiency in buildings) and qualitative output analysis (advantage of European industries compared to non-EU players).

In the case of a fully implemented EPBD in all MS, the study calculated a doubling of the renovation market by 2030. Some benefits to society are described below:

- EE investments will produce a positive knock-on effect for the insulation market (doubling would produce benefits of up to € 15 billion) and the flat glass industry (an increase of 40% with benefits up to € 15.1 billion) (EC, 2016).
- The OECD study supports this view and found multiple benefits in the industrial sector could see a 40-50% increase in the value of energy savings per measure and up to 2.5 times the value of energy savings (OECD, 2012).
- It is suggested that by meeting the EU's 2020 goals of 20% renewable energy target and 20% energy efficiency improvement via innovation and competitiveness could save € 60 billion on Europe's bill for oil and gas (Boromisa et al, 2016).
- The EEO calculate that by 2020, in Europe alone, investment in more efficient equipment and could reduce annual energy consumption by approximately 250 megatonnes of oil equivalent (Mtoe), representing about 16% of Europe's total demand (EEO, 2014).

Taken from the literature review, the value for innovation and competitiveness was found to be **a decrease in energy demand of 16%, bringing benefits of € 30 – 60 billion.**[17]

3.3 Social Impacts

3.3.1 Health and Wellbeing

Europeans spend more than 90% of their time inside buildings (Fraunhofer, 2017). It has been reported that between one in three and one in six Europeans live in an "unhealthy" building (damp, lack of daylight, inadequate heating, etc.) depending upon which MS is being discussed (Fraunhofer, 2017). The health impacts of living in an energy inefficient home (e.g. an unhealthy building) can be divided into a higher risk of mortality and increased morbidity rates. The WHO determines that in 2016, 556,000 premature deaths in Europe were attributable to the effects of household and ambient air pollution and due to indoor pollution, European citizens lose 50 million years of healthy life from environmental risks every year (WHO, 2019). Energy inefficient buildings impose forbidding health consequences on the population; people are 40% more likely to get asthma living in a damp and mouldy house; it is estimated that 2.2 million disability-adjusted life years (DALYs) are lost in Europe due to exposure to indoor air pollutants; and 110 million Europeans are exposed to hazardous pollutants due to poor ventilation (BPIE, 2018). Additionally, poorly inefficient buildings affect the mental wellbeing of inhabitants and can generate stress, anxiety and depression from, *inter alia*, chronic thermal discomfort, high bills and lack of affordable warmth, fear of

([17]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values for innovation and competitiveness were used to give the range.

falling into debt, a sense of lacking control, feeling dirty and having the smell of mould and damp linger (Payne et al, 2015).

The indicators for this are divided into two categories: reduced mortality and reduced morbidity. When calculating reduced mortality the indicators MS should take into account (and also those used by COMBI) are all calculated using *number of deaths/year:*

- Avoided excess winter mortality due to improved indoor conditions and lower health risks
- Avoided mortality due to lower ozone air pollution levels
- Avoided mortality due to lower PM2.5 air pollution concentration

When calculating reduced morbidity the indicators MS should take into account are (again those used by COMBI):

- Indoor air pollution - PM2.5 in avoided Years of Life Lost (1000 YOLL),
- Winter morbidity (asthma) from cold and dampness (1000 DALYs)
- Healthy life years gained by avoiding indoor exposure to air pollutants in refurbished buildings (disability-adjusted life years, 1000 DALY)

Although calculated health benefits are uncertain, the IEA state this to be in the range of € 42 - 88 billion in 2020 and for this to double by 2030 – up to € 176 billion[18] (Renovate Europe, 2013 & IEA, 2014). A study commissioned by the EC mentions a similar figure for total morbidity & mortality costs and healthcare costs at € 139 billion for EU28 (EC, 2016). A plethora of studies from a wide geographic scope have attempted to put a monetary value on energy efficiency, some of these are described below:

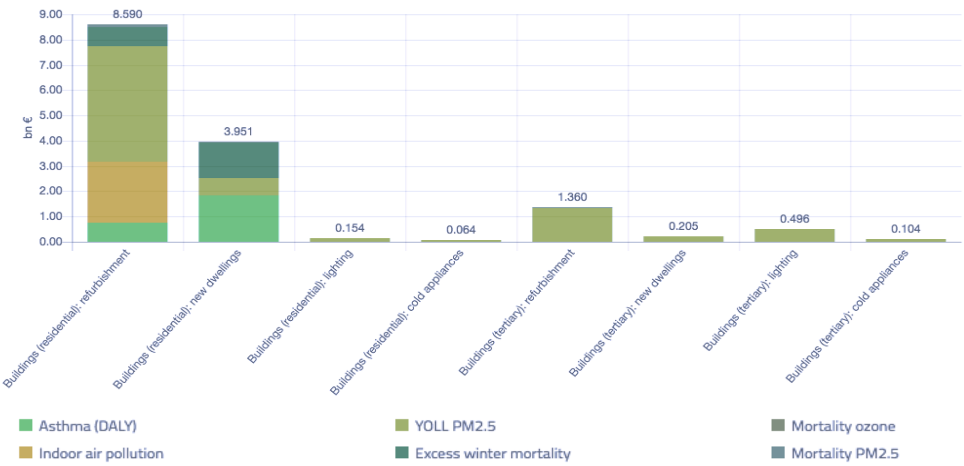
- In Ireland, a total mortality benefit of a hypothetical thermal-improving program is estimated as € 1.5 billion undiscounted (Clinch & Healy, 2000).
- In England, the annual cost to the NHS of treating winter-related disease due to cold private housing is over £ 850 m (€ 989 m) (Stafford, 2014).
- The Warm Up New Zealand scheme calculated health savings of $ 64.44 in total hospitalisation costs per year for a household that received some combination of ceiling or floor insulation; a $ 67.44 (€ 40.48) yearly saving in circulatory illness related hospitalisation costs, a $ 98.88 (€ 59.35) reduction in respiratory illness related hospitalisation costs and for asthma-related hospitalisation costs (a subset of respiratory illness) a higher saving at $ 107.52 (€ 95.69) (Grimes et al, 2011).
- On average, there are around 25,000 excess winter deaths (EWDs) each year in England, 21.5% of all EWDs can be attributed to the coldest quarter of housing (Marmot Review Team, 2011).
- By fully implementing the EPBD health cost savings are up to € 925.9 million per year between 2020-2030 (EC, 2016).
- Renovating the building stock would lead to an annual health benefit worth € 5-8 billion to the European population from 2020 (Renovate Europe, 2013).
- Total annual cost for European societies is calculated at € 82 billion attributable to asthma and chronic obstructive pulmonary disease (Fraunhofer, 2017).
- The ratio of benefits to cost is as high as 4:1, health benefits representing up to 75% of overall benefits (IEA, 2014).
- EU wide annual health cost savings of € 180 million (EC, 2016)
- The mean cost saving per renovated building can be estimated at € 5.60/m2 (EC, 2016).
- In the US, over the lifetime of an energy efficiency programme focussed on improving ventilation, as high as € 1,652 / hh can be saved (Mendell et al. 2002).

([18]) Total health benefits.

- Energy saving program resulted in the total health benefit of € 489 million/year. Due to a decrease of chronic respiratory diseases and premature mortality in Hungary (Aunan et al, 2000).
- Measures installed through energy efficiency schemes in the UK in the period January – December 2003 resulted in the customers being on average US $ 21.2 (€ 18.72) better off / household / year (DEFRA, 2005)
- A Swedish study found that by implementing EE measures would see benefits of 1.9 - 2.1 billion SEK (€ 0.18 – 0.2 billion) for outdoor pollution and 0.4-1.1 billion SEK (€ 0.038 – 0.10 billion) for indoor pollution in 2030 (Copenhagen Economics, 2016)

The COMBI analysis calculates the monetary benefits of energy efficient buildings linked to mortality as € 2.3 billion and for morbidity as € 12 billion as in 2030, based on avoided electricity generation and fossil fuel imports, figure 3.9 below divides all health impacts into their corresponding building categories.

Figure 3.11. Total benefits of energy efficiency in terms of avoided health & wellbeing costs in 2030 in billion €



Source: COMBI, 2020

Taken from the literature review, the general range of monetary value for health benefits was found to be **increase of between € 5 and € 88 billion per year.**[19]

3.3.2 Poverty Alleviation

The European Commission explains the commonly used phrase to describe energy poverty as the *"inability to keep homes adequately warm"* (EC, 2019) explaining that *"adequate warmth, cooling, lighting and the energy to power appliances are essential services needed to guarantee a decent standard of living and citizens' health"* (EC, 2020). The unofficial term to describe this amongst MS is taken from the 1991 UK definition, *"a household is said to be fuel poor if it needs to spend more than 10% of its income on fuel to maintain an adequate level of warmth".* Poor housing linked to ever-rising energy prices and stationary salaries results in energy or fuel poverty.

According to the EU's 2015 study on Income and Living Conditions, 15.2% of the European Union's population live in housing characterised by leaking roofs, damp walls, floors or foundations and rot in window frames or floors, 9.2% of people were unable to keep their homes adequately warm (EU, 2015). Where fuel poverty exists, often parts of the house / building are unusable. This can affect students' ability to study in residential and educational buildings with concomitant impacts on educational attainment. The culture within the home is also affected when many people have to share a small space, having visitors can be difficult and this has an impact on social relationships.

([19]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values for health and wellbeing were used to give the range.

The indicators of energy efficiency on energy poverty should include a calculation of the monetary value of diseases primarily arising as a result of thermal discomfort in indoor living conditions. The COMBI team used three indicators to determine the impacts on fuel poverty:

- Excess winter mortality due to indoor cold
- Excess winter morbidity due to indoor cold
- Asthma morbidity due to indoor dampness

Analysis shows that by targeting low-income households, the EPBD, through ambitious programmes, could lift more than 8 million households out of energy poverty (EC, 2017). By improving efficiency in low-income households, this would reduce energy expenditure and therefore reduce income inequalities. In terms of the monetary benefits of energy efficiency improvements on fuel poverty, of the studies analysed for this report, most of the benefits are expressed as € per household per year, as are described below:

- A European Commission study, 2015, shows that cost-effective improvements in energy efficiency could cut utility costs by $ 270-1,360 per household (hh)/year (€ 243 – 1,195 per hh / year) (EC, 2005).
- A US study showed that the net present value of lower bad debt write-off over the lifetime of weatherisation measures is up to € 2,610 / household.
- In the UK, an energy efficiency scheme was applied to 6 million households in 2003 that resulted in the average benefit of € 12.7 per hh/year (DEFRA, 2005).
- The Warm Up New Zealand programme calculated the comfort benefit to households to be US $ 140 per hh/year (€ 84 per hh/year) accounting for 43% of the total annual energy savings (Stoecklein and Scumatz, 2007).
- An Irish energy efficiency programme calculated the total comfort benefits for households amount to € 473 million discounted at 5% over 20 years (Clinch and Healy, 2000).
- Excess morbidity associated with domestic energy inefficiency and fuel poverty amounts to an excess exchequer expenditure of at least € 58 million in Ireland per annum (Clinch and Healy, 1999).
- Sovacool (2015) indicates that £ 1 (€ 1.16) invested in UK Warm Front programme produced as much as £ 1 to £ 36.30 (€ 1.16 – 42.24) in benefits over a 20-year period.
- In the UK in the period January – December 2003 measures installed through energy efficiency schemes resulted in the customers being on average US $21.2 better off/year (€ 18.72) (DEFRA, 2005).
- From 2015 new energy efficiency measures will help Europeans save € 45 per every EU household (EC, 2019)
- EU consumers only using energy efficient products in their homes could be saving € 465 annually per hh by 2020 (EC, 2019)

Taken from the literature review, the general range of monetary value for poverty alleviation is often expressed in € per household and was found to be **increase € 465 and € 1,195 per household per year.** [20]

3.3.3 Improved Productivity

Productive employees are essential for creating competitive businesses. Mounting evidence, as reviewed in this report, shows that energy efficiency improvements improve indoor environmental quality and working conditions (air quality, temperature, lighting, thermal comfort) and hence improve comfort and productivity. "Sick building syndrome" is often used to describe working in an "unhealthy building" that directly affects

([20]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values for Poverty Alleviation were used to give the range from the EC in 2005 and 2019.

the inhabitants' health. These symptoms include; *inter alia;* headaches; blocked or runny nose; dry, itchy skin; dry, sore eyes; rashes; tiredness; and difficulty concentrating (BPIE, 2016).

The indicators for labour productivity can be calculated using: Active days gained *(indoor exposure)* and workforce performance (*mn workdays).* The COMBI team express their labour productivity in terms of these three indicators:

1. ***"****The amount of* ***active time*** *available for productive work. This can be affected, for instance, by being sick - more precisely absenteeism and presenteeism, which reduces the amount of active time available.*

2. ***Workforce performance*** *within a certain time frame. Indoor air quality and thermal comfort of tertiary buildings can improve the mental wellbeing of the entire workforce and this can result in more productive time for work.*

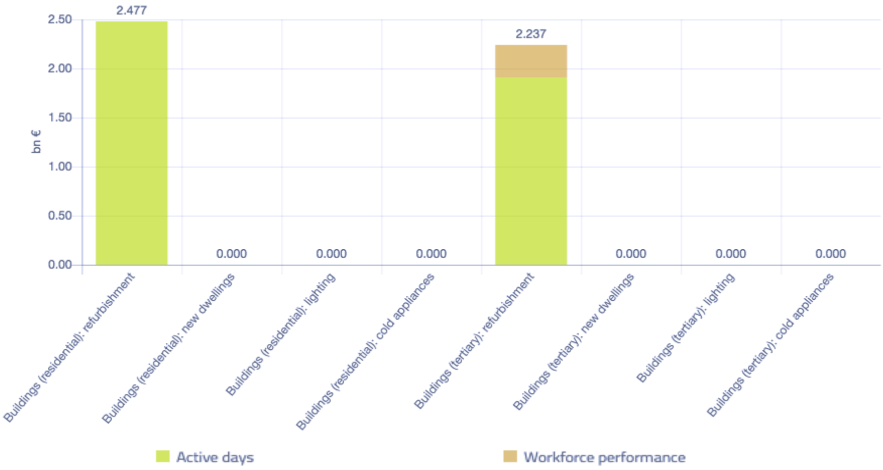
3. ***Earning ability/value added*** *per unit of time worked. For instance, more efficient buildings will improve education productivity and earning ability per unit time worked."*

The study commissioned by the EC calculates the productivity gains by using the total area of non-residential buildings renovated each year by the ratios drawn from their literature review (cost savings between € 0.60 and € 1.00 per m^2 renovated) (EC, 2016). In doing this, they calculate the absolute gains of productivity in EU28 to range between € 53.4 million to € 88.9 million per year in 2020-2030, based on the implementation of the EPBD (EC, 2016). The benefits to employment sectors that are largely office-based (accounting for 81 million EU citizens) are calculated by weighting the average value for employers of an energy efficiency improvement that equates to € 51.5 billion per year. Other analyses of the effect on productivity of energy efficiency are described below:

- In the US, improved ventilation was calculated to result in net savings of € 302 / employee/year, on a national scale this represents a productivity gain of € 17 billion/year (Mendell et al, 2002).
- Net savings of up to US $ 400/employee/year (€ 353) may be obtained through the ventilation increase due to increased productivity (Milton et al 2000).
- Every 1% improvement in performance in offices theoretically produce € 42 billion per year in the EU (based on 36% of the European workforce is deployed in offices, i.e. 81 million) (Fraunhofer, 2017).
- More comfortable temperature and lighting results in productivity increase by 0.5%-5%; considering only US office workers, such a change translates into an annual productivity increase of roughly € 15–121 billion (Lovins, 2005).
- In the EU, every 1°C reduction in overheating increases students' learning performance by 2.3% (BPIE, 2018).
- In the EU, every 100 lux in improved lighting in schools is associated with a 2.9% increase in educational performance (BPIE, 2018)
- In the EU, every 1°C reduction in overheating increases a worker's performance by 3.6% (BPIE, 2018)
- In the EU, better daylight is associated on average with a 10% increase in performance (BPIE, 2018).

The COMBI analysis calculates the monetary benefits of energy efficient buildings linked to labour productivity as € 4.7 billion in 2030, based on avoided electricity generation and fossil fuel imports. Figure 3.10 below divides this into their building categories, below.

Figure 3.10. Total benefits of energy efficiency in terms of labour productivity in active days and workforce performance in 2030 in billion €



Source: COMBI, 2020

Taken from the literature review, the general range of monetary value for productivity was found to be **an increase of between € 15 and € 42 billion in Europe per year.**[21]

([21]) Based on the studies undertaken that take the whole of the EU into account the lowest and highest values for productivity were used to give the range.

4 Part Two – Multiple Benefits: Cost-optimality Calculations

4.1 Cost-Optimality & the EPBD

The EPBD requires Member States to set minimum energy performance requirements for buildings or building units with a view to achieving cost-optimal levels (2018/844/EU). In the EPBD, the cost-optimal level refers to "*the level of energy performance which leads to the lowest cost during the estimated lifecycle of the building*[22]." The EC developed a methodology framework within this Guideline and additional guidelines to support Member States in finding the minimum energy performance for different building types under this methodology.

As aforementioned, the life-cycle economic approach was developed to provide indicators, for policy makers and project developers, of economic performance to enable a project to assess its impact on society. However, this approach can lead to an insufficient consideration of wider benefits of energy efficiency and hence it is recommended that the approach is evolved to ensure that an adequate consideration of such benefits is included. Not only would this allow Member States to reach a better understanding of the true economic, environmental and social value of energy efficiency, but it would also help reduce the gap between current minimum energy performance requirements and NZEB requirements set under Article 9 of the EPBD.

As stated in Annex III to the EPBD, the global cost calculation should be calculated using both the societal and private perspectives: *"for the main costs and for energy costs and the applied discount rate for both macroeconomic and financial calculation."* (EC, 2012)

Currently, fewer than half of Member States take into account the macroeconomic and societal perspective despite the fact that this perspective is the most relevant for the calculation of global costs (Ecofys, 2013). The guidelines on cost-optimal calculations mention that: *"The global cost concept is also not fully in line with a complete life cycle assessment (LCA) that would take into account all environmental impacts throughout the lifecycle including so-called 'grey' energy. Member States are however free to extend the methodology towards full life cycle costing."* (EC, 2012).

4.2 Global Costs Calculations & Multiple Benefits

The societal formula for the global cost concept as taken from the CEN Standard "EN 15459:2007 Superseded by EN 15459-1:2017" and the guidelines accompanying the Commission Delegated Regulation (EU) No 244/2012 (EC, 2012c) is:

$$C_{G(\tau)} = C_I + \sum_j [\sum_{i=1}^{\tau} (C_{a,i(j)} \times R_d(i) + C_{C,i(j)}) - V_{f,\tau(j)}]$$

Where;

CG(τ) is the global cost referred to starting year τ0;

CI is the sum of initial investment costs;

Ca,i (j) is the annual cost for component j at the year i;

Rd (i) is the discount term, for year i;

Cc,i(j) means carbon cost for measure or set of measures j during year i.

Vf,τ(j) is the final value of component j at the end of the calculation period.

(22) Commission Recommendation (EU) 2016/1318

The discount term can be calculated using the equation below:

$$R_d(p) = \left(\frac{1}{1+\frac{r}{100}}\right)^p$$

Where;

p means the number of years from the starting period; and

r means the real discount rate

As can be seen, in terms of wider benefits, none are yet included in this calculation, except the cost of GHG emissions. In order to assess how wider benefits could be included in the global cost calculation, interviews were held with a series of experts and based on their suggestions and a targeted literature review (Ürge-Vorsat et al, 2014. Becchio et al, 2015, Touceda, 2016, Gopalan 2018, Fregonara et al, 2015, Buso and Tiziana, 2017. and Heiselberg, 2016) it was concluded that the global cost calculation could follow the equation below. The new elements are highlighted in red, whereby each wider impact has a global cost to be included within the equation.

$$C_{G(\tau)} = C_I - C_{EN} - C_{EC} - C_{SO} + \sum_j [\sum^{\tau}_{i=1} (C_{a,i(j)} \times R_d(i) + C_{C,i(j)}) - V_{f,\tau(j)}]$$

Where;

C_G (τ) is the life-cycle cost including environmental, economic and social indicators [€];

C_I is the sum of initial investment costs;

C_{EN} is the savings related to the *environmental impacts;*

C_{EC} is the savings related to *economic impacts:* the change in GDP and the cost savings due to improved energy security;

C_{SO} is the savings related to *social impacts;*

Ca,i (j) is the annual cost for component j at the year i;

Rd (i) is the discount term for year i;

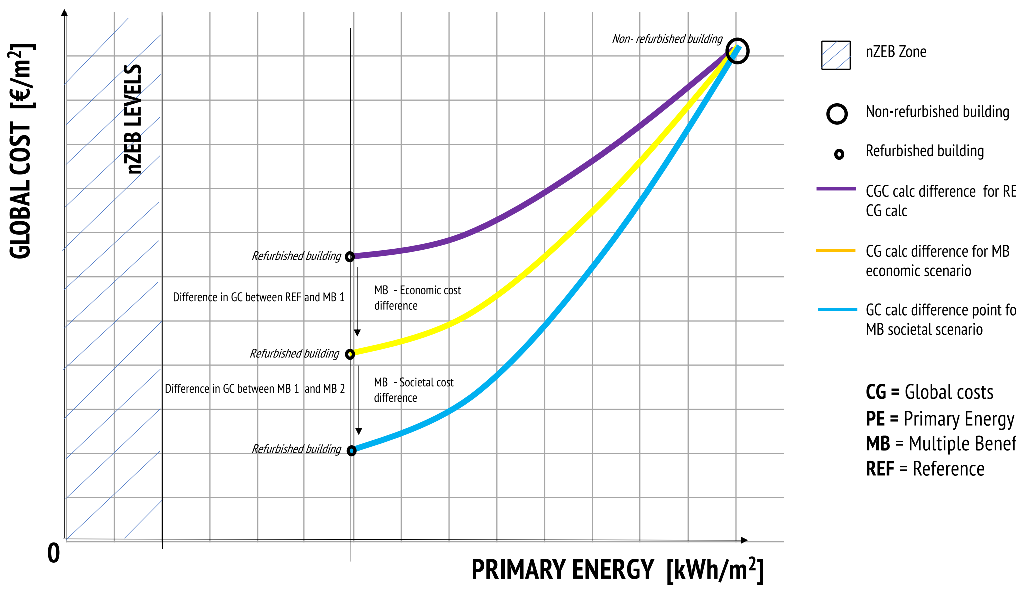
Cc,i (j) means carbon cost for measure or set of measures j during year i. (not included in the financial perspective methodology)

Vf,τ (j) is the final value of component j at the end of the calculation period.

Calculating the total cost of each multiple benefit will depend on the level of efficiency of the measures: the deeper the measure, the more monetary potential the co-benefits unlock. The figures below demonstrate a. how one point on the cost-optimality curve might change when including the global costs of individual multiple benefits (Figure 4.1), b. an example of one type of curve that could come out if the global-cost cost-optimality graph (Figure 4.2). In order to include multiple benefits into the global cost calculations the indicators that can be used for each co-benefit category have been described in the section above, and the calculation methodologies for finding the values described below.

Figure 4.1 below has been designed to give readers an idea of how one point on the curve might change when taking multiple benefit indicators into account. This graph shows a non-renovated building as the reference point then three separate points of this building renovated: a standard reference global cost calculation point, a global cost calculation point including one MB indicator and a global cost calculation point including 2 MB indicators. As can be seen, the global cost decreases when more multiple benefit indicators are taken into account.

Figure 4.1. Example of one point on a cost-optimal curve showing both the reference C_G and 2 multiple benefit C_G scenarios



Source: Authors' elaboration

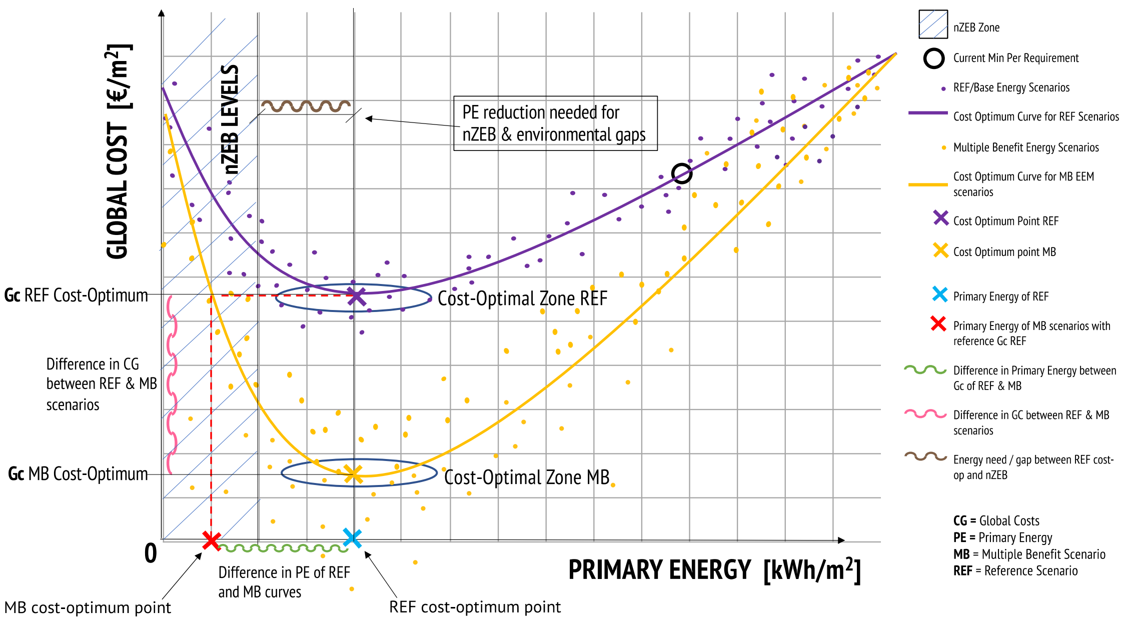
It is to be noted that regarding any specific point on the reference line, over a life span of 30 years, there is a likelihood that the sum of multiple benefits has such a positive impact that their global costs result is negative. This would mean that for such a point the positive impacts on, *inter alia,* GDP, health, productivity, etc are greater than, and outweigh, the initial installation and investment costs. It is also to be noted that, due to their nature, each multiple benefit will have a different impact on the global cost, and this will vary from MS to MS. If we take an example of a dot on the curve that does not include multiple benefits, as the cost-optimality methodology is well defined in the EPBD and clear Guidelines provided, the investment costs are all well known, PE savings related to measures are also well known and easy to assess. Therefore, the point on the graph will not differentiate greatly between the Member States. However, when introducing multiple benefits into the equation, it is likely that this point on the graph will be different for each Member State.

To illustrate this, it is possible to imagine one point on the curve without multiple benefits that results in a similar CG vs PE point in both France and Portugal as both the investments for the technical solutions and the energy savings are similar. Then, when applying multiple benefits to this point, say for example looking at the comfort benefits of a renovated residential building (1 day less sick day, 1 less day in hospital, 1 less social support session, resulting in *1-day extra day of work*) it is likely that there will be a big difference regarding where these points land on the graph. Looking exclusively at the average daily salary in the two countries shows just how variant these two points are - Portugal being ~47€/day and France being ~101€/day. Taking this one day of work saved per year and multiplying it by the 30-years of the building's lifetime (as suggested in the Guidelines) would equate to a difference of €1,620, without taking medicine, medical or social support costs into account.

When MS develop their cost-optimality graph, they will be able to plot a. the reference scenario (REF) of global costs versus the primary energy against b. the multiple benefits scenario (MB) of global costs versus primary energy. An example of what the multiple benefits graph might look like is given below, however, the shape of the curve will depend on many factors and depend on the multiple benefit indicators included within the global cost calculations for each point. It is to be noted that the graph below is an illustration of an example of one outcome of what the graph might look like and is not a tested scenario. What is certain, is that the cost-optimal curve of the MB scenario will not be the same shape as the reference scenario and the illustration below is one example of such a multiple benefit curve.

Figure 4.2 has been designed to allow stakeholders to understand the type of graph that can be developed when taking MBs into consideration. It shows two curves: one refers to the reference scenario obtained using the regular global cost formula, the other one is the result of the global cost formula that includes the multiple benefits. To understand the difference between these two curves, an example of both have been mapped out beside each other in Figure 3.2 below.

Figure 4.2. Example of cost-optimal curve illustrating an example of a reference and a multiple benefits curve



Source: Authors' elaboration

In the case of the figure above, both cost-optimality curves produce the same minimum energy performance in kWh/m2. However, the cost-optimum point of the multiple benefits curve has a lower global cost than the reference curve. Therefore, it is possible to use the global costs point from the reference curve as the minimum investment / global costs point. By using this minimum cost from the reference curve as the cost that developers or MS would use to determine the minimum performance values, it is then possible to use this point to find the place this intersects with the MB curve to determine a lower minimum performance point or range. In the case that the cost-optimal reference point does not meet the MB curve, this means the benefits of reaching a nZEB outweigh the investments. By taking the multiple benefits into account, the global cost of each energy scenario will be considerably lower, making the high performing energy scenarios more advantageous. This also means that the cost of an nZEB becomes economically viable.

The next section on monetising and calculation of multiple benefits clarifies what the additional elements included in the equation cover and how these can be estimated.

5 Part Three – Multiple Benefits: Monetising and Calculating

There are different ways a Member State can determine the monetised value for the multiple benefits of energy efficiency in buildings. The interviews and literature suggest many MS have already started doing so. Mechanisms for calculating MB are available and range from very basic calculation methodologies to complex modelling methods. In order to support the assessment of the impacts related to the wider benefits of energy efficiency, it can also be useful to refer to the monetised values developed by COMBI and the EC 2016 study or the values shown using the rule of thumb methodology[23]. To monetise MBs, the following approaches (from the most reliable to most basic) are listed:

1. **Review available literature on monetisation of MB in individual MS** (requires a corpus of knowledge to be available in the considered MS)
2. **Calculation of MB in individual MS** (in the case where available knowledge is not sufficient, MS to undertake their own calculations to determine the monetised value of MB)
3. **Use generic pre-determined monetised values** (MS use the figures and findings from other research as the monetised value to be used in their global cost calculations)
4. **Rule of Thumb** (MS use already developed and defined monetary values for benefits and calculate them into a value that is relevant and suitable in their country)

When better understanding the MB, it becomes clear that there are overlaps between some of the impacts - as an example: air pollution and health and wellbeing have obvious crossovers. When monetising the non-energy impacts of energy efficiency, the COMBI team guaranteed there was no double counting of the benefits and hence their approach can be seen as a conservative way to monetise multiple benefits. Based on the chosen impacts to be included in their analysis, the researchers have developed a table highlighting the multiple benefits that should be included within each MS global cost calculations, Table 5.1 below.

Table 5.1. Impacts to include in Global Cost Calculations and Overlaps

Category	Co-benefit	Included in Calculations?
Environmental	Climate: Reduction of air pollution	No, overlaps with productivity & health & wellbeing
Environmental	**GHG Impacts**	**Yes**
Environmental	**Energy Savings**	**Yes**
Environmental	Resource Management	No, overlap with investment costs in GC calculation & energy savings
Economic	Lower energy prices	No, overlaps with GDP
Economic	Innovation and Competitiveness	No, overlaps with GDP
Economic	Employment effects	No, overlaps with GDP
Economic	**GDP**	**Yes**
Economic	Reduced Public Budget	No, overlaps with GDP
Economic	**Energy security**	**Yes**
Social	**Health & wellbeing: mortality**	**Yes**
Social	**Health & wellbeing: morbidity**	**Yes**
Social	Poverty Alleviation Impacts	No, overlaps with health & wellbeing & GDP
Social	**Improved Productivity**	**Yes**

Source: Authors' elaboration based on COMBI 2020

(23) The "rule of thumb" method would see a MS/municipality using already developed monetised values for multiple benefits to calculate their own wider benefits. This is a very rough and imprecise manner of finding a monetised MB value and should only be used as a last resort and it will not be developed further in this report.

List of multiple benefits to be calculated by MS:

- GHG emissions
- Energy savings
- GDP
- Energy security
- Reduced mortality
- Reduced morbidity
- Improved productivity

This means that within the global cost calculation:

C_{EN} is the total cost savings of GHG emissions and energy savings.

C_{EC} is the total cost savings of GDP and energy security.

C_{SO} is the total cost savings of health impacts (reduced mortality, reduced morbidity) and improved productivity.

Although this research suggests the use of above defined impacts when including each social, environmental and economic benefit into the global costs, this is provided as a guideline for Member States. Member States can make their own selection of multiple benefits, providing they do not double count an indicator or benefit.

5.1 Desk study – finding existing multiple benefits

Before anything else, MS should undertake a desk-based study to find out if a. quantified multiple benefits, b. monetised multiple benefits or c. a defined methodology for calculating multiple benefits have been developed in their country by a government or a scientific/academic institution. The literature review shows that a number of the MS have already developed a methodology and have calculated some of the multiple benefits of energy efficiency.

5.2 Calculation – defining multiple benefits

When calculating multiple benefits, ideally MS will use scenarios, baselines and targets that ensure they meet their own national and the wider EU energy efficiency, energy and zero carbon targets up to 2050. Therefore, the national calculations for multiple benefits are to be based on the MS becoming zero carbon or negative carbon by 2050 and the assumptions should be in line with their NECPs, LTRS or equivalent legislation.

The sections below give Member States some examples of calculation mechanisms used by research groups in calculating the monetary value of the multiple benefits. The table below provides different sources for interested parties to find different methodologies for the calculation of multiple benefits. The sections that follow provide a detailed summary of how to calculate each multiple benefit.

Table 5.2. Toolbox on sources to find multiple benefit calculation methodologies

Source	Study	Website
COMBI	Multiple Benefits Calculations	https://combi-project.eu
EC	The Macroeconomic and Other Benefits of Energy Efficiency	https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf
EPA	Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy. A Guide for State and Local Governments	https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state
IEA	Co-benefits of energy related building renovation - Demonstration of their impact on the assessment of energy related building renovation (Annex 56) Energy in Buildings and Communities Programme	http://www.iea-annex56.org/Groups/GroupItemID6/Co-benefits%20of%20energy%20related%20building%20renovation%20(Annex%2056).pdf
Gopalan	Renovating Houses in the Netherlands to Nearly Zero Energy Standard- Important Drivers of Economic Feasibility	https://repository.tudelft.nl/islandora/object/uuid%3A7f9a8061-dc79-46ca-bec9-d78e328fd6c5
Touceda	Implementation of Socioeconomic Criteria in a Life Cycle Sustainability Assessment Framework Applied to Housing Retrofitting	https://dipot.ulb.ac.be/dspace/bitstream/2013/238640/3/Touceda-SocioeconomicCriteria-retrofitting.pdf

Source: Authors' elaboration

It is to be noted that the following mechanisms can also be used when calculating multiple benefits for other policy measures, for example; in the context of long-term renovation strategies, as required by Article 2a in the EPBD, and in NECPs, as required by Article 4(b)(3) and Annex I of the Governance Regulation.

5.2.1 Energy Savings

Member States can calculate the monetary benefits of energy savings by following one of the three mechanisms described below. Generally, MS will find the total energy savings of their chosen energy efficiency scenario compared to the baseline building stock in as little or as much detail as resources will allow. MS can then find the monetary value of this by either multiplying the energy savings by the price of energy (without taxes and tariffs) or by using a more detailed modelling approach.

A) Study on macroeconomic and other benefits of energy efficiency

Using data from a separate study, estimates of the energy savings potentials were calculated in terms of:

- EU28 final energy demand for heating (and breakdown by fuels), hot water, cooling, auxiliary and lighting, 2013-2030 in TWh per year.
- Investment costs (three types: Building envelope, HVAC-Systems, financing costs), 2020-2030 in billion €.

From this, energy savings were first allocated using floor area information, then allocated to the main energy carriers in the model[24] (coal, oil, gas, electricity, heat) and used (after conversion) in the model.

B) COMBI Model

Energy savings (TWh) of all fuels are quantified based on their set of building improvements modelled in detailed stock models for the building sector for additional annual savings in 2030 relative to current policy baselines.

C) Copenhagen Economics

Energy savings are calculated from the TWh of saved energy (in each scenario) and the price of energy without taxes and grid tariffs.

([24]) E3ME, a proprietary macro-econometric model of the study contractor, see https://www.e3me.com/

5.2.2 GHG emissions

Member States can calculate their monetary benefits of GHG emissions using one of the following three mechanisms. An approach MS could use to find the monetary benefit of GHG emission savings is to find the total final energy demand of the building sector for the different energy efficiency scenarios and use this to calculate the reduced combustion of fossil fuels. GHG emissions can be found using the European guidelines for monitoring carbon emissions from 2007 (European Commission, 2019). To find a monetary value for the reduced combustion of CO_2 per year, MS can find the value of CO_2 per year (and estimated future values) and calculate the GHG emission impacts for their MS. The approaches used by the EU, COMBI and Copenhagen Economics can be seen below.

A) Study on macroeconomic and other benefits of energy efficiency

In order to calculate GHG and CO_2 emissions, the study used the E3ME model. The PRIMES model provided the saved energy consumption that was then disaggregated by carrier using a further set of econometric equations. The emission results were derived using fixed coefficients that are calibrated using the last year of available data (main data source is the EDGAR database)

B) COMBI Model

GHG emissions (Mt CO_2eq) - savings from the reduced combustion of fossil fuels are quantified using the indicator "direct combustion of fossil fuels" and by directly linking them to the final energy demand of the building sector. The GHG emissions are based on the European guidelines for monitoring carbon emissions from 2007 (European Commission, 2007) and refer to a global warming potential of 100 years.

C) Copenhagen Economics

The values for reduced CO_2 emissions were quantified using the Thomson Reuters reference scenario forecast of emissions allowance price for EU ETS 2030. They presume these prices are likely to increase significantly based on the European Commission's market cap on CO_2 emissions.

5.2.3 GDP

Most methods to find the monetary value of GDP, as a bare minimum uses increased employment or gross value added per employee (GVA) as a key indicator. Using the GVA (average salary) of the construction sector and other sectors linked to energy efficiency and the number of estimate job creations; it is possible to calculate the impact on GDP per year. Other methods have been highlighted below.

A) Study on macroeconomic and other benefits of energy efficiency

The study calculates impact on the economy by inputting the energy savings and associated investment into their E3ME model.

B) COMBI Model

Calculating the impact of the increase of GDP in an area involves using incremental investment costs for energy efficiency measures as inputs for modelling the effect of GDP (COMBI, 2019). The effects are estimated using an IO model based on the GTAP World Input-Output Database creating an aggregate demand effect on the economy (calculated by multiplying the immediate stimulus with the Keynesian multiplier). OECD multipliers from their global macroeconomic model from 2010 are applied to the IO model, which are 0.8% for the year of the shift in spending and the year after, decreasing to 0.1% in t+4.

For the increased investment costs on GDP and public finance in energy efficiency renovations, the COMBI indicator of how many jobs are created per € investment is used. The gross value added (GVA) per employee in sectors, using the GVA per employee in the construction sector.

C) Copenhagen Economics

The gross value added (GVA) per employee in sectors associated with energy efficiency investments in buildings was used to calculate the GDP. As an example, they took the GVA per employee in the construction sector – that is € 55,740. They also added the GVA from employees in the other sectors linked to energy efficiency, such as manufacture of glass and glass products, manufacture of ceramic insulators and insulation, plumbing, heat and air conditioning installations. The GVA per employee of all of these sectors ranges from € 46,110 to 52,220.

D) IEA

In order to calculate the effect of increased investments in energy renovations, the IEA look into how many jobs are created per investment. They use the GVA per employee in the energy sectors that are linked to energy efficiency investments in buildings. They find the GVA for the people involved and based on these statistics; a low, an average, and a high estimate for GVA per employee was created.

5.2.4 Energy security

A method that can be used by the MS is to find their energy balance sheets and avoided electric power output and investment costs in TWh. Using these the MS can find their net power output that can be used to estimate their energy system and security indicator, they may have one already. Using this indicator, MS can calculate the monetary value of energy security by multiplying the avoided power capacity of the energy efficiency scenario by specific capital costs per technology.

A) Study on macroeconomic and other benefits of energy efficiency

The study calculates impact on the economy by inputting the share of energy imports in GDP as the key indicator in their E3ME model.

B) COMBI Model

The energy system of each Member State is assessed by making a detailed energy balance sheet of each. Avoided electric power output and investment costs in TWh is based on COMBI's energy balance power sector model (a reworked version of the balances published by EUROSTAT) that determines the relevant generation output as a net power output in order to estimate the energy system and security indicator. From this the avoided investment costs are calculated by multiplying the avoided power capacity by specific capital costs per technology.

5.2.5 Health

There are many methodologies that can be used to calculate the health benefits of the MS energy efficiency improvement scenarios. These are described in detail below.

A) Copenhagen Economics

In order to calculate the health effects of energy efficiency, Copenhagen Economics look into the health impacts from PM2.5. They use the IVL study that quantifies the population exposure to small particles. Copenhagen Economics use the IVL estimates of the total costs of PM2.5 and the total emissions of PM2.5 in 2010. Using European Commission data, their sensitivity analysis finds a value for health benefits in Euros.

B) IEA

The IEA developed cost-benefit ratios by comparing the cost of implementing the programmes with the estimated health benefits the improvements gave rise to from the studies that state both investment costs and the value to health. Using these estimates and the cost of the specific energy efficient projects, a cost-benefit ratio for each individual health benefit was calculated. When studies gave different results, an interval from the lowest estimate to the highest estimate was constructed.

5.2.6 Health: Reduced Mortality

A) Study on macroeconomic and other benefits of energy efficiency

The study finds the cost savings by multiplying the total square meters renovated in each country by ratios for mortality that have been drawn up from a literature review. The total floor area of buildings renovated in each country is the input for this value.

B) COMBI Model

Mortality ozone and mortality PM2.5 (Nr. of deaths per year)

Avoided mortality estimated in COMBI can be regarded as part of the health effects but are kept separate to maintain the distinction between health and mortality. The GAINS model is used to quantify premature mortality due to ground-level ozone and PM2.5 exposure, the model produces estimations of ground-level ozone and PM2.5 concentrations (among other pollutants) and its effect on human health.

Excess winter mortality (Nr. of deaths per year)

COMBI used the standard calculation for calculating excess winter mortality (higher number of deaths in the winter months December–March over rest of the year) and then further developed it to include heating degree-days (HDD) by countries to capture better the climatic circumstances in each country.

$$\boldsymbol{EWD = \sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2} \qquad \text{Equation 1}$$

$$\boldsymbol{EWD_i = \frac{\sum_{i=12}^{3} deaths - \sum_{i=4}^{11} deaths/2}{\sum_{i=4}^{11} deaths/2} \times 100\%} \qquad \text{Equation 2}$$

Where: *EWD* – excess winter deaths,

EWDi – excess winter death index,

i – number of the month (1 – January, 12- December).

The number of excess winter mortality cases is calculated by adding up the number of deaths occurring during the months that are universally agreed to represent winter in Europe (December, January, February and March) (actual deaths) and subtracting the total number of deaths occurring during the rest of months (April to November) divided by two (relation of expected deaths in 4 winter months vs. the remaining 8 months of the year) (see equation 1). Excess winter deaths index is calculated dividing the total number of excess winter deaths (equation 1) by the total number of deaths occurring during the rest of months (April to November) divided by two (expected deaths) (see equation 2).

5.2.7 Health: Reduced Morbidity

A) Study on macroeconomic and other benefits of energy efficiency

The study finds the cost savings by multiplying the total square metres renovated by ratios for morbidity drawn from their literature review. The total floor area of buildings renovated in each country is the input for this value.

B) COMBI Model

Indoor air pollution 1000 DALYs

The indicator for the COMBI study measures "healthy life years gain" in disability-adjusted life years (DALY) reached from better indoor air quality thus resulting in a lower burden of disease after residential building refurbishment. Hanninen et al. (2013) provides the quantification methodology for estimating the impact of indoor air pollutants such as VOC, radon, PM 2.5, CO and dampness on asthma, allergies, cardiopulmonary diseases and cancer. DALYs are then estimated based on additional data (time spent in a building, number and depth of retrofits, total burden of disease from sick days estimation).

Winter morbidity (asthma) 1000 DALYs

In the case of COMBI, the asthma environmental burden of disease assesses health impacts of environmental factors, due to indoor dampness and mould. Global reports on the burden of disease deliver final results on the human health assessment in a societal perspective including morbidity and mortality rates in the indicator disability adjusted life years (DALYs). The total disease burden on the society from a certain health risk can be found using a relative risk value (percentage difference in observed morbidity between the exposed and unexposed populations) from epidemiology literature.

COMBI calculate the burden of risk associated with the environmental risks of housing as a result of energy efficiency improvement actions. This depends on:

a. The distributional aspects of the tentative energy efficiency policy;

b. The degree of housing stock profile changes in terms of quantity from the COMBI input data (demolished housing units versus new housing) and quality (levels of retrofits – shallow, medium and deep; and

c. Types of new buildings built – standard, net zero-energy buildings or passive houses; and

d. The assigned mitigation potential rate to different housing types (expert score indicating the extent, to which housing quality changes may contribute to a decrease in certain exposures and consequently health conditions).

The change in disease burden is then monetised using country-specific values of a life year (VOLY), with the EU average being at € 115,290 / year.

YOLL PM2.5 1000 YOLL

Years of life lost (YOLL) due to Particulate Matter (PM2.5) are estimated in COMBI using the GAINS model[25] is used to quantify YOLLs due to PM2.5 concentrations (among other pollutants) and its effect on human health.

C) Copenhagen Economics

To calculate the health benefits of energy efficiency, Copenhagen Economics quantify the avoided incidence of asthma.

- Initially, they estimate the share of mould and damp problems that can be met by renovating; data for this comes from the National Board of Housing, Buildings and Planning BETSI project.
- Finding the rollout rate of renovations in their scenario and the spread of mould and damp problems.
- They then give a percentage of how many cases can be addressed by their scenario, for example 30% until 2020 and that 72% can be addressed until 2030.
- They then calculate the current annual number of new asthma cases (from The National Health Association) and the estimate of mould and damp caused asthma cases (from the National Board of Housing, Building and Planning).
- Based on these estimates and the national average life expectancy they estimate the annual incidence of new asthma cases due to mouldy and damp indoor environment.
- Finally, they calculate the annual savings in asthma spending on avoided asthma cases, based on the cost estimations of asthma treatment per person and year.

The total cost of asthma consists of both direct cost of medical care and indirect cost to the society in form of reduced productivity. To find the total annual benefit they multiply the cost per individual by the estimated number of avoided asthma cases per year in 2020 and 2030 to illustrate the annual savings due to avoided asthma cases.

([25]) http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html

5.2.8 Improved Productivity

All three scenarios to calculate the monetary value of improved productivity are accurate methodologies for the calculation of improved productivity, described below.

A) Study on macroeconomic and other benefits of energy efficiency

The study finds the cost savings of improved labour productivity by multiplying the total square metres of non-residential buildings renovated each year by the productivity cost savings per m2 renovated. The cost savings per m2 were drawn from their literature review (cost savings between € 0.60 and € 1.00 per m2 renovated). The total floor area of non-residential buildings renovated in each country is the input for this value.

B) COMBI Model

Active Days

The COMBI model calculates labour productivity with an "active days" approach using two indicators: sick days and healthy life years loss. These are based on reduction of productivity due to asthma, cold and flu, cardiovascular disease, cancer, Chronic Obstructive Pulmonary Disease (COPD). A "sick day" is a combination of absenteeism (absent from work due to building related illness) and presenteeism (working with illness or working despite being ill) – both referring to the productivity loss from indoor exposure-related health problems (asthma, cardiovascular diseases, and mental well-being) affecting quantity and quality of work. These two indicators (absenteeism and presenteeism) estimate the morbidity of working population i.e. number of days of suffering from building related illness by working population. For sick days, disability adjusted life years (DALY) is used to estimate mortality and morbidity with a sick days indicator, thus providing the severity of the indoor exposure. The quantification follows effects based on the number of refurbished buildings and HVAC systems and thus is relevant only to the EEI actions of residential and tertiary building refurbishment.

C) Copenhagen Economics

Copenhagen Economics calculate the value of improved productivity as a result of avoided sick building syndrome and follow three steps:

- Valuation of the reduction in the prevalence of sick buildings syndrome among the office workers at average increase in labour productivity of the cured workers using the traditional human capital (HC) method, valuing the lost or gained productivity in terms of gross earnings. Copenhagen Economics use GDP per hour worked (data from The National Institute of Economic Research). Figures for the current date and the growth rate are used. Based on the hourly productivity estimations, a productivity increase in per cent per hour worked gives them a monetary unit per hour (both currently and in the future).
- To estimate the number of office workers affected by sick building syndrome, they use data from a national health survey that estimates the share of people that suffer from at least one sick buildings syndrome related symptom at school or workplace, as a per cent of the population between 18 and 80.
- The share of sick building cases that are addressed by renovations is assumed to be proportional to the share of non-residential buildings renovated until that year.
- Based on number of people affected by sick buildings syndrome and the renovation rate they estimate the amount of sick building syndrome cases that can be addressed until 2020 and 2030.

5.3 Direct use of existing calculated multiple benefits

The EC and COMBI have already calculated some of the wider monetary benefits of energy efficiency in each country. If the MS do not have the resources to calculate this independently, the authors advise that the MS look at a range of the monetary benefits from each study and use a conservative monetary value as their input into the cost optimality calculations. The authors stress the importance of checking their energy efficiency scenarios against the scenarios developed by the EC and COMBI.

5.3.1 COMBI Monetised Values

The COMBI online tool and reports provide monetary values per:

- Member State,
- Impact, and
- Building Scenario,

These monetised impacts can be found in Annex B. In order to use the COMBI values per country in terms of kWh and €, one must first know and take into account the consumption scenario used by COMBI, in order to see whether the MS have developed a more or less energy efficient roadmap for their buildings.

COMBI scenario

Energy efficiency improvements for both residential and non-residential buildings in the COMBI scenario:

• Improvements of the building envelops (existing buildings);

• Passive House standards for heating and cooling demands (new buildings);

• Improvements of domestic hot water (DHW) systems;

• Improvements of (room and/or central) air-conditioning systems and fans;

• Improvements of lighting systems;

• Improvements of refrigerators / freezers (residential) and commercial refrigeration and freezing;

Residential: For residential existing buildings, the building envelope and heating systems respectively account for 45% and 24% of the total energy saving potential. Adding the 16% energy savings potential resulting from new dwellings gives a total of 85%. By including the 7.1% potential of improved domestic hot water systems and the 4.7% potential of more efficient lighting, almost 97% is covered. Household appliances are good for the remaining 3%, but COMBI opted for looking only at refrigerators/freezers, as they have the largest potential of residential appliances.

Non-residential: The potentials for the tertiary sectors are very similar, where improvements of the envelopes of existing buildings and more efficient heating and space cooling systems give rise to energy savings of 40% and 24% respectively. New buildings would contribute another 15%, giving a grand total of 79%.

Lighting: has a much larger share in the savings potential as compared to the residential sector, namely 12% (but including 3% savings from better street lighting). Ventilation systems (or “fans”) are more prominent in tertiary buildings and may contribute 4.5% of the total energy saving potential. Also typical for the commercial sectors are the large refrigeration and freezing systems, with a saving potential of 3%. This means that COMBI would cover more than 98% of energy savings potentials identified in existing EU scenarios.

COMBI monetised impacts

COMBI approaches each indicator with a different calculation mechanism. The following list provides a summary of the monetised impacts of the COMBI study, all are provided in billion € per country and impact:

- Active days
- Asthma
- Avoided electricity generation
- Direct GHG emissions
- Energy savings
- Excess winter mortalities

- Fossil fuels
- GDP
- Indoor air pollution
- Metal ores
- Mortality ozone
- Mortality PM2.5
- Public budget
- Workforce performance
- YOLL PM2.5

As aforementioned, only the impact linked to GHG emissions, energy savings, GDP, energy security, reduced mortality, reduced morbidity and improved productivity (highlighted in bold) should be used and included within the global cost calculations.

COMBI approach

There are two approaches to using COMBI values:

1. Either directly using the COMBI monetised figures for MBs (provided in Annex C) and include them into the global cost calculations, as described above. When using these figures, the MS must make sure their building efficiency scenario is just as, if not more, stringent. If the building scenario in their country is less stringent, it is important to reduce the overall monetised value for each.
2. Using COMBI's billion € per multiple benefit per country and total kWh per multiple benefit per country to give a cent/kWh for each MB for each indicator and building type.

Option One:

Point 1 provides the total monetary savings in 2030 per year per policy measure. As aforementioned: These data points should be used as a fall back option. If this is the chosen methodology of the MS, they would then either insert the € per country per benefit into the societal perspective global cost – by directly subtracting this from the calculation. Such as:

- C_{EN} is the total savings related to GHG emissions and energy savings = Direct GHG emissions + Energy savings
- C_{EC} is the total savings related to GDP and energy security = GDP + Avoided electricity generation
- C_{SO} is the total savings related to reduced mortality, reduced morbidity and improved productivity = Active days + Asthma + Excess winter mortalities + Indoor air pollution + Mortality ozone + Mortality PM2.5 + YOLL PM2.5

Option Two:

In the case of choosing option 2, the MS would include the cent/kWh as a new "term" as part of the minimum requirements calculations. The steps to be taken in this case are:

1. MS calculate the original global cost formula for both the baseline-building configuration and for the nZEB configuration they want to compare.
    a. This will provide MS with an "inefficient" starting point of the variety of packages the MS analyse in order to get a curve. This is MS-specific and could be the current building code requirement.
2. MS then calculate the difference in global cost Cg(T) and the difference in kWh/year between the two building configurations for each package/point on the curve against the baseline.

3. 3. MS then add a “term” for multiple benefits against the difference in global costs between each package/point on the curve and the baseline, which sums up the term over the years.
    a. *The term* = (COMBI average cost savings in EUR/kWh)*(difference in kWh/year between the two building configurations)*(inflation to year i)*(discount rate for year i).

By following this methodology, MS reduce the global cost Cg(T) for each package/point on the curve by the multiple benefits term. The COMBI average cost savings are added up to give a EUR/kWh.

5.3.2 EC Monetised Values

The European Commission's 2016 report 'The Macroeconomic and Other Benefits of Energy Efficiency' highlights a robust methodology for MS to calculate the indicators described in this report, including: energy security, health and well-being. The EC report provides monetary values per Member State, Impact and Building Scenario, the monetised impacts can be found in Annex C at the end of this report.

In order to use the EC values per country in terms of % difference and €, we must first know and take into account the consumption scenario they used, in order to know whether the MS have developed a more or less energy efficient roadmap for their buildings.

Scenarios

Four scenarios are assessed, based upon the policy options set out in the EPBD Impact Assessment. Summarised as:

- Option 0: No-change option (reference case)
- Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive (S1)
- Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions (S2)
- Option III: Enhanced implementation and increased harmonization, while introducing substantial changes (S3)

All other factors are assumed to remain constant across the scenarios, so that the model results are able to isolate the effects of these specific policy changes.

Monetised impacts

The EC used the E3ME Standard outputs model as a general model of the economy, based on the full structure of national accounts. The E3ME is capable of producing a broad range of economic indicators as well as a range of energy and environmental indicators. The following list provides a summary of the monetised impacts of the EC study:

- Energy imports as a share of GDP
- Change in health-related costs (€)
    - In terms of morbidity, mortality and productivity
- Energy consumption (% difference)
- Impact on CO2 and GHG emissions in 2030 (% difference)
- Impacts on material consumption (% difference)
- Total EU reductions in energy poverty in 2030 (in 1000 HH)
- Air pollution (% difference)

Approach

Apply directly the EC monetised figures for MBs (provided in Annex C) and include these into the global cost calculations, as described above. When using these figures, the MS must make sure their building efficiency scenario is just as, if not more, stringent. If the building scenario in their country is not as stringent, it is important to reduce the overall monetised value for each by the % of difference their scenario is from the baseline scenario.

Point one provides the total monetary savings per year per policy measure. If this is the chosen methodology of the MS, they would then either insert the € per country per benefit into the societal perspective global cost – by directly subtracting this from the calculation. Such as:

- C_{EN} is the total savings related GHG emissions and energy savings = Final energy consumption + Direct GHG emissions
- C_{EC} is the total savings related to GDP and energy security = GDP + Energy imports as a share of GDP
- C_{SO} is the total savings related to reduced mortality, reduced morbidity and improved productivity = morbidity, mortality & health care + productivity gains

Final energy consumption to be calculated by MS – taking the final energy consumption in 2030, % difference from reference case and multiplying this by the cost of energy in each Member State.

Impact on CO_2 and GHG emissions – taking the GHG and CO_2 emissions in 2030, % difference from reference case and multiplying this by the cost of carbon emissions in each Member State.

Energy imports as a share of GDP – to be calculated by MS- taking the energy imports as a share of GDP in 2030, percent difference from reference case and calculating the percent difference in their Member State's currency units.

6 Conclusions

6.1 Limitations / Further research

In order to come up with a comprehensive and robust method for including multiple benefits in the cost-optimality calculations, additional research and information has been identified. Firstly, more resources should be put into securing the integrity of the solutions this report has found, including a round table and peer review that would allow experts in the field time to discuss the techniques proposed for the inclusion and calculation of multiple benefits within the EPBD.

Although this report takes into account as many of the co-benefits in the macroeconomic perspective as have been deemed valuable, the list is not exhaustive and some co-benefits have not been included, such as: the distinction between indoor and outdoor air pollution, Construction and Demolition (C&D) waste reduction benefits, lower energy prices, rate subsidies avoided, lower energy prices, accessibility for persons with disabilities, removal of asbestos and other dangerous substances, improved fire safety, improved resistance to risks related to intense seismic activity, climate adaptation and resilience, to name some. Additionally, the report does not look into the private perspective benefits, such as; asset value, decreased bill payments, etc. The approach taken by the authors was limited due to constraints in resources, data and models.

Additional suggestions are proposed to overcome to the limitations of this project:

- Develop a set of co-benefits to be calculated per building type, not just as a whole.
- Develop a list of co-benefits to be used in the private perspective for the cost-optimality calculations.
- Develop a list of possible EU data sources each country could use as baseline data for their cost calculations for each multiple benefit.
- More detailed information on how to gather and calculate the total cost of each multiple benefit.
- A toolkit with a list of possible modelling software and companies who could undertake the modelling exercise of calculating multiple benefits for each country.
- A set of case studies monetising each multiple benefit.
- More research into what the Member States should use as discount rates and more research into the price of CO_2 in € per tonne.

As with many policy areas in the EU, data availability is a huge challenge and an area that needs work, both in terms of MS setting up adequate data collection procedures and in terms of accessing the already available data which may be dispersed across different public authorities/other entities. Therefore, a project looking into the collection and management of the data points necessary to calculate the multiple benefits in each MS would be useful.

An important point highlighted by the interviewees of this study, that would enable the MS to easily calculate their wider benefits, is for the EC to develop a toolkit (online templates), based on this research, for MS to calculate their own multiple benefits by requesting data points from each MS and calculating the MB using one of the proposed methodologies.

6.2 Outcomes & Conclusions

The findings of this study were established based on a series of interviews with relevant experts in the fields of energy, health and economy, followed by a desktop review of literature on the multiple benefits of energy efficiency. The report was reviewed by a selected number of experts from research institutions, industry and the Commission. This report provides policy makers and stakeholders an understanding of how to monetise (and quantify) multiple benefits linked to energy efficiency policies and programmes, alongside providing them with a toolkit to do so. The research suggests the multiple benefits on a macroeconomic level reach monetary gains at EU-level at the range of up to:

- Energy Savings: €175 billion (2020)
- GHG Impacts: €17 billion (2020)
- Reduction of Air Pollution: €12 billion (2020)
- Resource Management: €20 billion (2030)
- GDP Growth: 2.3%
- Employment Benefits: 19 jobs per million € invested
- Public Budget: €40 billion (2020)
- Energy Security: €20 billion
- Innovation & Competitive of €50 billion
- Health Benefits: €88 billion (2020)
- Poverty Alleviation: increased household income of €1,195 per year
- Improved Productivity: €42 billion (2020)

The studies examined indicate that the total monetary gains of the multiple benefits to be in the range of a conservative **€ 65 billion to € 291 billion** (COMBI, 2016, Copenhagen Economics, 2012, IEA, 2016). This scope demonstrates how momentous and important it is to include co-benefits when investing in and developing policies for energy efficiency.

With respect to the current cost-optimality framework in the EPBD and most other energy efficiency policy tools, the main driver is the reduction of energy demand. In order for policy decisions to be effectively transformed and translated into accurate tools for market transition, it is key for the wider benefits of energy efficiency to be included. The inclusion of multiple benefits is essential for unlocking the economic, environmental and social potentials of energy efficiency in the Member States.

To make effective and informed policy judgements, decision makers must have robust data sources together with quantification, monetisation and calculation mechanisms for the inclusion of these wider benefits. This report attempts to provide an initial examination of possible mechanisms Member States can use to ensure these wider benefits are not omitted in national regulation. The findings of the report:

- Show that the *benefits of energy efficiency improvements largely outweigh the high investment costs* that are seen as the biggest barrier to transforming the EU building stock to nearly zero-energy buildings.
- Synthesize global literature and existing knowledge on the quantification of non-energy impacts to *provide a range of monetary values for each multiple benefit.*
- Provide a *simple methodology and calculation mechanism for multiple benefits to be taken into account within the EPBD*. The approach provided can and should also be used in other policy tools.

The inherent relationship between environmental, economic and social impacts suggests that, first and foremost, an integrated EU approach should be developed within the EPBD that allows for the MS to calculate the MB of efficiency measures, set their minimum energy requirements in the building codes, develop robust LTRS but also these MB of energy efficiency should feed into and be incorporated into other sectors and policies such as health and economics.

Policy making in the area of energy efficiency is very much focused on energy savings, however, the authors hope that this report will be used as a first step towards a concerted action to ensure that multiple benefits of energy efficiency are widely acknowledged and considered in important policy decision-making. The results of this research suggest that multiple benefits should be included in policy development and taken into account in regard to project investment and highlights the need for further research in and funding for this subject.

Similarly, investors must influence the situation by accepting, acknowledging and promoting the multiple benefits of energy efficiency in order to develop and inspire energy efficiency markets. Investors are able to increase renovation rates by requiring the portfolios of projects they invest in to show social, economic and environmental benefits. By investing in energy efficiency, not only will governments and investors be saving money, creating markets and realising great economic benefits, they will also be targeting and meeting many of the UN's SDGs.

References

1. Acadia Center, 2014, Energy Efficiency: Engine of Economic Growth in Canada
2. Arrow et al, 2013. Determining Benefits and Costs for Future Generations. Accessed: http://ipclimatechange.trg-learning.com/wp-content/uploads/2015/04/science-2013-arrow-349-50.pdf
3. Baranda, 2014. Cost Optimality of Energy Systems in Zero Emission Buildings in Early Design Phase. NTNU. Norwegian University of Science and Technology Faculty of Engineering Science and Technology Department of Energy and Process Engineering
4. Barbier, 1987. The Concept of Sustainable Economic Development
5. Becchioa, Corgnatia, Orliettia, Spigliantinia, 2015. Proposal for a modified cost-optimal approach by introducing benefits evaluation a DENERG Polytechnic of Torino, Corso Duca degli Abruzzi 24, Torino 10129, Italy
6. BER, 2017. Study of Over-Consuming Household Cold Appliances. Accessed: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/585520/Cold_appliances_field_trial_report_FINAL_230117__2_.pdf
7. Boermans, Grözinge, J, von Manteuffel, Surmeli-Anac, John, (Ecofys) Leutgöb, and Bachner, 2015. Assessment of cost optimal calculations in the context of the EPBD (ENER/C3/2013-414) Final report. 19 November 2015, Project number: BUIDE13705.
8. Bone, 2010. Will Drivers for Home Energy-efficiency Harm Occupant Health?
9. Boromisa, Tišma and Ležaić, 2016. Green Jobs for Sustainable Development
10. BPIE, 2011. Europe's buildings under the microscope. A country-by-country review of the energy performance of buildings
11. BPIE, 2017. 97% of Buildings in the EU Need to be Upgraded, Factsheet, Accessed: http://bpie.eu/publication/97-of-buildings-in-the-eu-need-to-be-upgraded/
12. BPIE, 2018. Building 4 People: Quantifying the benefits of energy renovation investments in schools, offices and hospitals
13. Burke, Byrnes & Fankhauser, 2019. How to price carbon to reach net-zero emissions in the UK
14. Buso & Tiziana, 2017. Nearly Zero Energy multi-functional Buildings - Energy and Economic evaluations. PhD thesis
15. Buso, Becchio, Yilmaz, Corgnati, 2016. How to include co-benefits in valuation procedures? Paper IX Energy Efficiency and Financial Performance of a Reference Hotel - Proposing a Global Cost-Benefit Analysis. In P. K. Heiselberg, ed. CLIMA2016 - proceedings of the 12th REHVA World Congress Paper X
16. Buso, Dell'Anna, Becchio, Bottero, Corgnati, 2017. Of comfort and cost: Examining indoor comfort conditions and guests' valuations in Italian hotel rooms. Energy Research and Social Science, 32, pp. 94–111.
17. Cambridge Econometrics, 2015. Assessing the Employment and Social Impact of Energy Efficiency
18. CEN, 2007. EN 15459:2007. http://store.uni.com/catalogo/index.php/en-15459-2007.html?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com
19. Clinch & Healy, 1999. Housing standards and excess winter mortality in Ireland. Environmental Studies. Research Series Working Paper 99/02, Department of Environmental Studies, University College Dublin.
20. Clinch & Healy, 2000. Domestic energy efficiency in Ireland: correcting market failure.
21. COMBI, 2015. WP5 Social welfare: Literature review on social welfare impacts of energy efficiency improvement actions D5.1 report
22. Copenhagen Economics, 2012. Multiple benefits of investing in energy efficient renovation of buildings: Impact on Public Finances Commissioned by Renovate Europe. Accessed 2019: https://www.buildings2030.com/wp-content/uploads/2017/11/Multiple-benefits-of-EE-renovations-in-buildings-Full-report-and-appendix-1.pdf
23. Copenhagen Economics, 2016. Multiple benefits of energy renovations of the Swedish building stock.
24. CSTB, 2014. Étude exploratoire du coût socio-économique des polluants de l'air intérieur
25. Dasgupta, Maler, & Barrett, 2000. Intergenerational Equity, Social Discount Rates and Global Warming.
26. Department for Environment, Food and Rural Affairs (DEFRA), 2005. Fuel Poverty Monitoring: Energy Company Schemes 2003. Annex to UK fuel Poverty Strategy. 3rd Annual Progress Report 2005.
27. EC, 2011. Commission Staff Working Paper: Impact Assessment, Energy Roadmap 2050, Brussels, SEC (2011) 1565.

28. EC, 2012. Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. https://eur-lex.europa.eu/legal-content/EN/ALL%20/?uri=CELEX%3A52012XC0419%2802%29
29. EC, 2012b. IV (Notices) Notices from European Union Institutions, Bodies, Offices and Agencies European Commission Guidelines accompanying Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements (2012/C 115/01)
30. EC, 2012c. Regulations Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:081:0018:0036:EN:PDF
31. EC, 2016. The Macroeconomic and Other Benefits of Energy Efficiency. Contract no. ENER/C3/2013-484/03/FV2015-523 under the Multiple. Framework Service Contract ENER/C3/2013-484. https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf (Accessed 2019):
32. EC, 2016b. 860 final Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee, The Committee of the Regions and the European Investment Bank Clean Energy for All Europeans. Brussels, 30.11.2016 COM(2016)
33. EC, 2017. The macro-level and sectoral impacts of Energy Efficiency policies
34. EC, 2018. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018
35. EC, 2019. A monitoring system for carbon dioxide emissions
36. EC, 2019. Energy Poverty. https://ec.europa.eu/energy/en/eu-buildings-factsheets-topics-tree/energy-poverty
37. EC, 2019b. 2030 climate & energy framework. : https://ec.europa.eu/clima/policies/strategies/2030_en
38. EC, 2019c. LIFE PLATFORM MEETING ON CLIMATE ACTION AND THE BUILDING SECTOR
39. EC, 2019d. The European Green Deal. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, 11 December 2019. COM (2019) 640 final. https://ec.europa.eu/info/publications/communication-european-green-deal_en (accessed January 2020).
40. EC, 2020. What is Energy Poverty? Accessed: https://www.energypoverty.eu/about/what-energy-poverty
41. EEFIG, 2015. Energy Efficiency – the first fuel for the EU Economy How to drive new finance for energy efficiency investments. Accessed: unepfi.org/fileadmin/documents/EnergyEfficiency-Buildings_Industry_SMEs.pdf
42. EEFIG, 2015. Energy Efficiency – the first fuel for the EU Economy How to drive new finance for energy efficiency investments. Accessed: https://www.unepfi.org/fileadmin/documents/EnergyEfficiency-Buildings_Industry_SMEs.pdf
43. EEFIG, 2017. EEFIG Underwriting Toolkit Value and risk appraisal for energy efficiency financing June 2017. Accessed: https://www.unepfi.org/wordpress/wp-content/uploads/2017/06/EEFIG_Underwriting_Toolkit_June_2017.pdf
44. EEIF, 2019. The European Energy Efficiency Industries call for a fundamental change in Europe's approach towards energy supply and use. https://www.eeif.eu/the-european-energy-efficiency-industries-call-for-a-fundamental-change-in-europes-approach-towards-energy-supply-and-use/
45. EEO, 2014. The Energy Efficiency Opportunity Winning Strategies for a High-Growth Market. https://www.bcg.com/en-gb/publications/2014/sustainability-energy-efficiency-opportunity-winning-strategies-high-growth-market.aspx
46. Energy Efficient Cities Initiative, 2011. Good Practices in City Energy Efficiency: Vienna, Austria (European Union) – Municipal Eco-Purchasing
47. EPA, 2018. Quantifying the Multiple Benefits of Energy Efficiency and Renewable Energy. A Guide for State and Local Governments
48. EuroACE, 2017. How to Make the Most of It! Energy Efficiency Legislation in the 'Clean Energy for All Europeans' Package Position Paper of EuroACE
49. European Commission, 2019. "Buildings" Accessed: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings
50. Farber & Hemmersbaugh, 1993. The shadow of the future: Discount rates, later generations, and the environment. Vanderbilt Law Review 46: 267-304.

51. Fenwick, MacDonald, & Thomson, 2013. Economic analysis of the health impacts of housing improvement studies: a systematic review. Journal of Epidemiology and Community Health. ISSN 0143-005X. Accessed 2019: http://eprints.gla.ac.uk/82616/1/82616.pdf
52. Ferreira & Almeida, 2015. Benefits from energy related building renovation beyond costs, energy and emissions. 6th International Building Physics Conference, IBPC 2015.
53. Fisk, 2000. Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency
54. Fraunhofer, 2017. Healthy Homes Barometer. Buildings and Their Impact on the Health of Europeans.
55. Freeman & Groom, 2016. How certain are we about the certainty-equivalent long term social discount rate? Accessed: https://www.sciencedirect.com/science/article/abs/pii/S0095069616300845
56. Freeman, Groom & Spackman, 2018. Social Discount Rates for Cost-Benefit Analysis: A Report for HM Treasury.
57. Fregonara, Ferrando & Pattono, 2015. Economic–Environmental Sustainability in Building Projects: Introducing Risk and Uncertainty in LCCE and LCCA
58. Fregonara, Ferrando & Pattono, 2018. Economic–Environmental Sustainability in Building
59. Frontier Economics, 2015. Energy Efficiency: An Infrastructure Priority. Accessed: http://www.frontier-economics.com/uk/en/news-and-articles/articles/article-i4966-energy-efficiency-an-infrastructure-priority/
60. Gopalan, 2018, Renovating Houses in the Netherlands to Nearly Zero Energy Standard- Important Drivers of Economic Feasibility. Tu Delft. Msc Sustainable Energy Technology
61. Grimes et al, 2011. Warming Up New Zealand: Impacts of the New Zealand Insulation Fund on Metered Household Energy Use. http://www.healthyhousing.org.nz/research/past-research/evaluation-of-warm-up-new-zealand-heat-smart/
62. Gupta & Kapsali, 2015. Empirical assessment of indoor air quality and overheating in low-carbon social housing dwellings in England, UK. Adv. Build. Energy Res. 10, 46–68. doi:10.1080/17512549.2015.1014843
63. Hamilton, Brahmbhatt & Liu, 2017. Multiple benefits from climate change mitigation: assessing the evidence. Policy Report.
64. Harris, Hall, Meltzer, et al, 2010. Health, Mental Health and Housing Conditions in England. London, UK: National Centre for Social Research.
65. Healy, 2003. Fuel Poverty and Policy in Ireland and the European Union.
66. Heiselberg, 2016. CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 1. Aalborg: Aalborg University, Department of Civil Engineering.
67. Hermelink & de Jager, 2015. Evaluating our future. The crucial role of discount rates in European Commission energy system modeling. Ecofys. Eceee paper.
68. Hermelink & de Jager, 2015. Evaluating our future. The crucial role of discount rates in European Commission energy system modeling. Ecofys.
69. Hills, 2011. Fuel Poverty: The problem and its measurement CASE Report 69 ISSN 1465-3001. Accessed 2019: http://sticerd.lse.ac.uk/dps/case/cr/CASEreport69.pdf
70. ICSU, 2019. Toward Energy as a Sustainable Development Goal. Accessed: https://www.worldgbc.org/news-media/green-building-improving-lives-billions-helping-achieve-un-sustainable-development-goals
71. IEA, 2019. Tracking Buildings. Accessed: https://www.iea.org/reports/tracking-buildings
72. IEPP, 2013. Review of Costs and Benefits of Energy Savings. Task 1 Report 'Energy Savings 2030'
73. Intergovernmental Panel on Climate Change, 2007. Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
74. Intergovernmental Panel on Climate Change, 2014. Social, WG3 Art 5 Chapter 3: Economic, and Ethical Concepts and Methods. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
75. Intergovernmental Panel on Climate Change, 2019. Chapter 4. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter4_Low_Res.pdf
76. International Energy Agency, 2005. Saving Electricity in a Hurry. https://www.iea.org/publications/freepublications/publication/savingelec.pdf
77. International Energy Agency, 2014. Capturing the Multiple Benefits of Energy Efficiency. International Energy Agency, Paris. IPCC, 2014. Fifth Assessment Report.

78. International Energy Agency, 2017. Co-benefits of energy related building renovation - Demonstration of their impact on the assessment of energy related building renovation (Annex 56) Energy in Buildings and Communities Programme.
79. IPCC, 2007. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change
80. Janssen & Staniaszek, 2012. How Many Jobs? A Survey of the Employment Effects Of Investment in Energy Efficiency of Buildings
81. Kats, 2006. Greening America's Schools: Costs and Benefits. https://www.usgbc.org/ShowFile.aspx?DocumentID=2908
82. Klimovich, 2019. Interview undertaken December 2019.
83. Liddell & Guiney, 2014. Improving Domestic Energy Efficiency: Frameworks for Understanding the Impacts on Mental Health . University of Ulster. Accessed 2019: https://uir.ulster.ac.uk/31059/1/mental_health_framework_paper.pdf
84. Maby, Sunderland & Janssen, 2016. Efficiency First means Consumers First: the crucial role of energy advisory services in realizing the EU's energy ambitions.
85. Marmot Review Team, 2011. for Friends of the Earth. The Health Impacts of Cold Homes and Fuel Poverty. Accessed 2019: https://friendsoftheearth.uk/sites/default/files/downloads/cold_homes_health.pdf
86. Mayne, 2016. Assessing the intangibles: the socio-economic benefits of Energy Efficiency
87. Mendell et al. 2002. Improving the Health of Workers in Indoor Environments: Priority Research Needs for a National Occupational Research Agenda
88. Menzies, Pasztor, Nunes, Leduc, & Chan, 1997. Effect of a new ventilation system on health and well-being of office workers. Archives of Environmental Health, 52(5), 360-368.
89. Mikulić, Bakarić & Slijepčević, 2016. The socioeconomic impact of energy saving renovation measures in urban buildings, Economic Research-Ekonomska Istraživanja, 29:1, 1109-1125, DOI: 10.1080/1331677X.2016.1211952
90. Mills & Rosenfeld, 1996. Consumer Non-Energy Benefits as a Motivation for Making Energy-Efficiency Improvements. Energy—The International Journal, 21 (7/8):707-720. Also in Proceedings of the 1994 ACEEE Summer Study on Energy Efficiency in Buildings, pp. 4.201-4.213.
91. Mills, White, & Schaffhauser, 1995. Cutting Government Programs to Save Energy Overlooks Benefits. Los Angeles Times, Business Section, September 10, p. 2. Reprinted in Energy Efficiency News, 1(7):2-3 and Lighting Maintenance and Management.
92. Milton, Glencross & Walters, 2000. Risk of sick leave associated with outdoor ventilation level, humidification, and building related complaints. Indoor Air, 10(4), 212-21.
93. NHBC foundation, 2009, Indoor Air Quality in Highly Energy Efficient Homes – a Review
94. Odyssee-Mure, 2018. Multiple Benefits Of Energy Efficiency Tool. Accessed 2018: http://www.odyssee-mure.eu/data-tools/multiple-benefits-energy-efficiency.html
95. OECD & IEA, 2012. Spreading the Net: The Multiple Benefits of Energy Efficiency
96. Payne, Weatherall, Downy, 2015. Capturing the ―multiple benefits‖ of energy efficiency in practice: the UK example. ECEEE, London.
97. Preval et al, 2010. Evaluating energy, health and carbon co-benefits from
98. Preval, 2008. Improving Domestic Space Heating: A Cost Benefit Analysis Based on a Randomised Community Trial
99. Pridmore, Smith, Baker, Ahlgren & Williamson, 2017. Evidence Review of the Potential Wider Impacts of Climate Change Mitigation Options: Built Environment Sector
100. Prognos, 2013, Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren
101. Public Health England, 2014. Cold Weather Plan for England 2014 Protecting health and reducing harm from cold weather. Accessed 2019: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468722/CWP_2014withdrawn.pdf
102. Purvius, Mao & Robinson, 2019. Three pillars of sustainability: in search of conceptual origins. Accessed: https://link.springer.com/article/10.1007/s11625-018-0627-5
103. RAP, 2013. Recognizing the Full Value of Energy Efficiency (What's Under the Feel-Good Frosting of the World's Most Valuable Layer Cake of Benefits) Lead Authors Jim Lazar and Ken Colburn
104. Rasmussen, 2015. The additional benefits of energy efficiency investments— a systematic literature review and a framework for categorisation. Accessed 2019: https://liu.diva-portal.org/smash/get/diva2:1104638/FULLTEXT01.pdf

105. Renovate Europe, 2012. Multiple benefits of investing in energy efficient renovation of buildings Impact on Public Finances.
106. Russell, Baatz, Cluett, & Amann, 2015. Recognizing the Value of Energy Efficiency's Multiple Benefits. ACEEE
107. Ryan, Campbell , 2012. Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements. IEA Energy Papers. Organisation for Economic Cooperation and Development, Paris.
108. Sala, Vasta, Mancini, Dewulf, Rosenbaum, 2015. Social Life Cycle Assessment - State of the art and challenges for supporting product policies; EUR 27624 EN; doi:10.2788/253715
109. Sauter, Volkery, 2013. Review of costs and benefits of energy savings, A report by the Institute for European Environmental Policy (IEEP) for the Coalition of Energy Savings. Task 1 Report. Brussels. 2013
110. Schleicher & Köppl, 2013. Energieperspektiven für Österreich. Prognosen für 2020 und 2030, Projektberichte, in Arbeit, 2/2013.
111. Schweitzer & Tonn, 2002. Nonenergy benefits from the weatherization assistance program: A summary o findings from the recent literature. Oak Ridge National Laboratory.
112. SEAI, 2011. Economic Analysis of Residential and Small-Business Energy Efficiency
113. Shrubsole, Davies, Wilkinson, 2015. Health effects of home energy efficiency interventions in England: a modelling study. BMJ Open 5, e007298.
114. Stafford, 2014. The social cost of cold homes in an English city: developing a transferable policy tool. Accessed, 2019: https://academic.oup.com/jpubhealth/article/37/2/251/1593820
115. Thema, 2016. Widening the Perspective: An Approach to Evaluating the Multiple Benefits of the 2030 EU energy efficiency potential. 2016 International Energy Policies & Programmes Evaluation Conference, Amsterdam
116. Toia, 2018, Energy efficiency market will invigorate the EU economy, boost growth prospects and benefit European citizens. MEP. S&D Group, Vice-Chair of the ITRE Committee
117. Touceda, 2016. Implementation Of Socioeconomic Criteria In A Life Cycle Sustainablilty Assessment Framework Applied To Housing Retrofitting. The Brussels-Capital Region Case Study. Doctorat À L'ecole Polytechnique De Bruxelles En Art De Batir Et Urbanisme. Universite Libre De Bruxelles. 4mat Recycling & Environment
118. UCL institute of Health Equity, 2011. The Health Impacts of Cold Homes and Fuel Poverty
119. UCL institute of Health Equity, 2014, How to Improve Health and Well-being through Action on Affordable Warmth
120. UN, 2019. Sustainable Development. Accessed: https://www.un.org/ecosoc/en/sustainable-development
121. UNDP, 2013. Gender and Energy. Accessed: https://www.undp.org/content/dam/undp/library/gender/Gender%20and%20Environment/PB4-AP-Gender-and-Energy.pdf
122. UNEP, 2008. Green jobs: towards decent work in a sustainable, low-carbon world.
123. UNEP, 2015. The Multiple Benefits Of Measures To Improve Energy Efficiency
124. UNEP, 2019. Financial Initiatives: Energy Efficiency. Accessed: https://www.unepfi.org/climate-change/energy-efficiency/
125. UNEP, 2019b. Why the SDGs are relevant to institutional investors, why there is an expectation that investors will contribute, and the case for why investors should want to. Accessed: https://www.unpri.org/sdgs/the-sdg-investment-case/303.article
126. University of Florida, 2015. Energy Efficient Homes: Indoor Air Quality and Energy
127. Ürge-Vorsatz & Novikova, 2014. Counting good: Quantifying the co-benefits of improved efficiency in buildings
128. Ürge-Vorsatz, 2010. The Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary. The Center for Climate Change and Sustainable Energy Policy of Central European University, Budapest, on behalf of the European Climate Foundation
129. Ürge-Vorsatz, Herrero, Dubash, Lecocq, 2014. Measuring the Co-Benefits of Climate Change Mitigation. Annu. Rev. Environ. Resour. 39, 549– 582. doi:10.1146/annurev-environ-031312-125456
130. Ürge-Vorsatz, Novikova & Sharmina, 2014. Counting good: quantifying the co-benefits of improved efficiency in buildings
131. Watts, Amann, Arnell, et al, 2018. The 2018 report of the *Lancet* Countdown on health and climate change: shaping the health of nations for centuries to come.
132. Wei et al, 2010. Putting Renewables and Energy Efficiency To Work: How Many Jobs Can The Clean Energy Industry Generate in the U.S.?

133. Westminster Sustainability Forum, 2016. Warmer & Greener: A Guide to the Future of Domestic Energy Efficiency Policy.
134. WHO, 2019. United Nations agencies urge Europe's action on 1.4 million annual deaths from polluted environments. Accessed: http://www.euro.who.int/en/media-centre/sections/press-releases/2017/united-nations-agencies-urge-europes-action-on-1.4-million-annual-deaths-from-polluted-environments
135. Wiese, Cowart & Rosenow, 2018. Carbon leverage: Investing Europe's carbon revenues in energy efficiency. RAP.
136. Woolf et al, 2013. Energy Efficiency Cost-Effectiveness Screening in the Northeast and Mid-Atlantic States
137. World Health Organization, 2011. Environmental Burden of Disease Associated with Inadequate Housing
138. World Health Organization, 2014. Unlocking new opportunities - Jobs in green and healthy transport.
139. Wyon, 1994. The Economic Benefits of a Healthy Indoor Environment. Copenhagen, Denmark: National Institute of Occupational Health. http://www.rand.org/pubs/conf_proceedings/CF170.1-1/CF170.1.wyon.pdf
140. Zámečník & Lhoták, 2012. Should the Government Invest in Energy Efficiency of Buildings? Macroeconomic Impact Assessment.

List of abbreviation and definitions

bn - Billion
BPIE – Buildings Performance Institute Europe
CEN – European Committee for Standardization
CHP - Combined Heat and Power
CO2 – Carbon Dioxide
CO2eq - Carbon Dioxide Equivalent
COMBI - Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe
COPD - Chronic Obstructive Pulmonary Disease
DALY - Disability-Adjusted Life Year
EC - European Commission
EE – Energy Efficiency
EED – Energy Efficiency Directive
EEI – Energy Efficiency Indicators
EEO – Energy Efficiency Obligations
EPBD – Energy Performance of Buildings Directive
EST– Energy Savings Trust
EU – European Union
EU28 – European Union 28 countries
GDP – Gross Domestic Product
GHG – Greenhouse Gas
GP - General Practitioner
H2020 – Horizon 2020
HC - Human Capital
hh - Household
HVAC - Heating, Ventilation, and Air Conditioning
IEA – International Energy Agency
IO – Input / Output
IPC - International Patent Classification
IPCC - Intergovernmental Panel for Climate Change
kt - kiloton
Ktoe - Kilotonne of Oil Equivalent
LCCA - Lifecycle Cost Analysis
LTRS – long-term renovation strategy
mn – minimum
MB – multiple benefit
MS – Member States
Mt - Megatonne
NEB - Non-Energy Benefits
NECP – National Energy and Climate Plan
NOx- Nitrogen Oxide
NPV - Net Present Value
NZEB- Nearly Zero Energy Building
OCED - Organisation for Economic Co-operation and Development
PM - Particulate Matter
SE4All – Sustainable Energy for All
SETAC - Society of Environmental Toxicology and Chemistry
SO2 - Sulphur Dioxide
TWh - TeraWatt Hour(s)
UK – United Kingdom
UN – United Nations
UNEP - United Nations Environmental Programme
US – United States
VOLY - Values of a Life Year
YOLL - Years of Life Lost

List of figures

List of tables

Annexes

Annex A Multiple Benefits described by EC & EEFIG

Commission Recommendation (EU) 2019/786

The Commission developed some recommendations[26] on building renovations that provide a possible framework for defining indicators of multiple benefits. Within these recommendations the Commission provide an estimate of expected energy savings and wider benefits, such as those related to health, safety and air quality see these below:

- Reduction in energy costs per household (average)/decrease in energy poverty
- Actual energy savings achieved
- Average/aggregate indoor air quality indices (IAQIs) and thermal comfort index (TCI)
- Cost of avoided illnesses/reduction in health costs attributable to energy efficiency measures
- Reduction of whole life carbon
- Disability Adjusted Life Year (DALY)/Quality Adjusted Life Year (QALY) improvements attributable to the improvement of building stock and living conditions
- Labour productivity gains from better working environment and improved living conditions
- Reduction of emissions
- Employment in the building sector (No of jobs created per EUR million invested in the sector)
- GDP increase in the building sector
- % Energy imports for the Member State (energy security measures)
- Removal/prevention of accessibility barriers for persons with disabilities

Most of these indicators fit into the three categories (environmental, economic and social) described in a table found during the literature review and interviews. This list does not refer to all of the wider benefits identified in the EC's recommendation on building renovations; for example:

- Adaptability to climate change (although possible to include in the environmental benefits)
- Reduction of whole life carbon / circularity / life-cycle (although this fits into the resource management area as well as possibility to be accounted for in the global costs calculation under the carbon cost "Cc,i(j)" component)
- Accessibility for persons with disabilities (a new social category – equality and inclusion)

EEFIG Underwriting Toolkit

Most reports and studies in the literature review generally categorised multiple benefits into the above three themes. However, some reports categorised them into "energy benefits" and "non-energy benefits" such as the Energy Efficiency Financial Institutions Group (EEFIG). The EEFIG was established in 2013 by the European Commission Directorate-General for Energy (DG Energy) and United Nations Environment Program Finance Initiative (UNEP FI) to create a platform for public and private financial institutions, industry representatives and sector experts to identify the barriers to the long-term financing for energy efficiency. In 2017, the EEFIG designed a "Toolkit"[27] designed to assist financial institutions to scale up their deployment of capital into energy efficiency, and within this toolkit the "Value and Risk Appraisal" section they state: "Energy efficiency projects can produce many types of benefits beyond just energy cost savings, both energy benefits and non-energy benefits:

Energy benefits

- Energy cost savings
- Reduction in the effects of price volatility
- Value of demand response
- Reduced need to invest in energy supply infrastructure

(26) Commission Recommendation (EU) 2019/786 of 8 May 2019 on building renovation (notified under document C (2019) 3352) (Text with EEA relevance.) C/2019/3352

(27) EEFIG UNDERWRITING TOOLKIT Value and risk appraisal for energy efficiency financing June 2017: https://www.unepfi.org/wordpress/wp-content/uploads/2017/06/EEFIG_Underwriting_Toolkit_June_2017.pdf

Non-energy benefits

- Impact of energy efficiency on asset valuation and external financing quality
- Asset value impacts
- Cash flow
- Capped valuation
- Price chipping / re-trade
- Loan to Value (LTV)
- Credit quality impacts
- Debt Service Coverage Ratio (DSCR)
- Default mitigation
- Lower tenant turnover/faster leasing or sale
- Modernisation/diminution of building obsolescence

Other non-Energy Impacts

- Reduced Operations and Maintenance costs.
- Improved health and safety
- Production increase
- Improved productivity
- Health and well-being

For any specific project, it is important to recognise all of these benefits and where possible value them and capture the value in any assessment." (EEFIG, 2017) Their report details these energy and non-energy benefits, however their benefits are linked to a specific project / investment on a micro / business scale and hence have not been analysed or monetised for the purpose of this report. It is important to note that these should be taken into account and reviewed when looking into the micro benefits of energy efficiency.

Annex B. Scenario Assumptions Described

COMBI Scenarios [28]

COMBI provides estimates of the major multiple impacts of the energy efficiency potential that goes beyond an existing policies scenario in the year 2030. Impacts are quantified by EU member state and by single energy efficiency improvement (EEI) action. Therefore, detailed input data on energy savings and investment costs are necessary: COMBI uses detailed stock models to this end. The COMBI input data modelling exercise produced a baseline scenario (based on existing EU legislation) and an efficiency scenario (based on ambitious assumptions on technology implementation following more ambitious policies), resembling the EUCO+33 scenario of the EU EED impact assessment.

In COMBI, energy efficiency improvement actions concerning the building shell, space heating and space cooling (air-conditioning) and/or ventilation, are lumped into one COMBI action. However, a clear distinction is made between existing (residential and non-residential) buildings on the one hand, and new buildings on the other hand. The rationale is that certain sub-actions, such as improvements of the buildings shell, are easier to accomplish for new constructions.
Although domestic hot water (DHW) is an important energy service, and in many cases directly related to space heating, it was decided during the COMBI project to not include actions related to DHW as a separate COMBI action, mainly because of severe data problems.
Actions concerning (artificial) lighting are important for both residential and non-residential buildings. Because of time and budget constraints street lighting was eliminated in the course of the project.
Appliances were omitted from the list of COMBI actions, with the exception of product cooling and/or freezing in both the residential and tertiary sectors.

#	End-use energy efficiency improvement action
Action 1	residential refurbishment of the building shell + space heating + ventilation + space cooling (air-conditioning)
Action 2	residential new dwellings
Action 3	residential lighting (all dwellings);
Action 4	residential cold appliances (all dwellings);
Action 5	non-residential refurbishment of building shell + space heating + ventilation + space cooling (air-conditioning)
Action 6	non-residential new buildings
Action 7	non-residential lighting (all buildings)
Action 8	non-residential product cooling (all buildings)

For both residential and commercial buildings the building envelope (a.k.a. building shell, fabric or enclosure) plays a key role in determining levels of heating, cooling, ventilation and natural lighting (Fraunhofer ISI 2009; 2012) An optimum design of the building envelope, or an improved energy related performance of the existing building envelope can minimise potential heating, cooling, ventilation and (artificial) lighting requirements. There are two perspectives on the relative importance of the building envelope and heating and cooling equipment (IEA, 2013b):

([28]) These assumptions are taken from the COMBI website and Final Report (D2.2).

- The passive design approach. This approach promotes high levels of energy efficiency in building envelope components. Any remaining need for heating or cooling is met by basic, efficient mechanical equipment;
- The smart technology approach. This approach promotes high energy efficiency in mechanical equipment (space & water heating, heat storage, cooling and dehumidification), because it is routinely replaced and installing it is easier than retrofitting old, inefficient building envelopes.

The building envelope will be in place for many years, and the most energy efficient building envelopes may provide greater comfort. Definitions of (very) high energy performance buildings tend to vary over Europe, but they define energy efficiency not only in terms of the building envelope, but also of the heating, cooling, ventilation, hot water and lighting systems. The space heating demand varies from 10 to 70 kWh/(m²․a). The PassivHaus standard defines a maximum of 15 kWh/m².a for heating demand, whereas cooling demand should not exceed 15 kWh/(m².a) + 0.3 W/(m².a.K) x DDH, with DDH is dry degree hours. Definitions of nearly Zero Energy Buildings (nZEBs) focus on a more or less equalized yearly energy balance between energy consumption and renewable energy generation.

For retrofits and new constructions improvements of the building envelope include:

- Compact shape, for new construction;
- A high level of insulation of the building envelope, in particular roof and walls for retrofits:
  - o typical U-values of ≤ 0.15 W/m².K in cold climates, and ≤ 0.35 W/m².K in hot climates. Insulation includes the use of: o typical materials such as mineral wool with glass padding or expanded polystyrene (EPS), with a thermal conductivity of 0.03 – 0.04 W/m.K;
  - o advanced technologies such as aerogels (0.012 – 0.022 W/m.K) or vacuum insulated panels (VIPs) (0.004 W/m.K). These are used for very high performance buildings, e.g. nearly Zero Energy Buildings (nZEBs); or for space constrained applications.
- Energy efficient windows, including the use of:
  - o Typical insulating windows with double low-e glazing and low conductive frames, with a whole window performance U-value ≤ 1.8 W/m².K;
  - o Highly insulating windows (e.g. triple glazing, low-e and low conductive frames), with a whole window performance U-value of 0.6 – 1.1 W/m².K (windows with a U-value of 0.8 W/m².K or better meet the passive house standard);
  - o Energy-plus windows, i.e. highly insulating windows with dynamic solar control and glass that optimises daylight. A whole window performance U-value ≤ 0.6 W/m².K in cold climates, and variable solar heat gain (SHG) coefficients of 0.08- 0.65;
- Optimal fenestration for (passive) solar gains and daylighting, for new construction; - Minimum thermal bridging. No (new construction) or reduced (retrofits) thermal bridges;
- High level of air tightness or air sealing. Restrict the (uncontrolled) passage of air through the building envelope, with air changes per hour (ACH) ≤ 3.0 for retrofits; and ≤ 0.5 with mechanical ventilation including efficient heat recovery for new construction.

<u>Space heating:</u>

The interactions between the components of a heating, air-conditioning and/or ventilation (HVAC) system and the building envelope and lighting system, imply that energy savings in one area may increase or reduce savings in another. Architectural and engineering concerns should thus be integrated in the design process: efficient, properly-sized HVAC equipment in an energy-efficient building envelope, coupled with a state-of-the-art lighting system. The true energy performance of a heating system is realized at the system level. The generation, storage, distribution, emission and control of heat should always be viewed as one system. Preventive and regular maintenance of the different heating system components also improve the efficiency of the heating systems.

<u>Heat generation systems</u>

Starting from 26 September 2015 a mandatory European energy label grades space heaters' performance from A++ (most efficient) to G (least efficient). This likewise applies to 'combination heaters', i.e. space heaters designed to also provide heat to deliver (domestic) hot water (see also domestic hot water heating). A "space heater" is defined as a device that provides heat to a water based central heating system in order to reach and maintain at a desired level the indoortemperature. It is equipped with one or more heat generators, who generate the heat a) by the combustion of fossil fuels and/or biomass fuels, b) by use of the Joule effect in electric resistance heating elements, or c) by capturing ambient heat from an air source, water source or ground source, and/or waste heat.

The energy labelling for space heaters also applies to "heating packages", i.e. space heater or combination heater with temperature control and solar thermal.
One should in principle select a space heater with the 'most efficient' label, when available.

Boiler space heater.

- Use a condensing boiler instead of a conventional boiler. Condensing boilers, typically fired with natural gas, have high(er) combustion efficiencies of 95%-96%, by extracting so much heat from the flue gases that the moisture in the gas condenses. Condensing boilers also operate more efficiently at part-load, and can be connected in modular installations (see heating controls);
- Heat pump space heater. Use a heat pump instead of a conventional or condensing boiler. Air-conditioning heat pumps extract heat from a conditioned space and reject it to a another space (e.g. outdoors) (see air-conditioning for the technical details). If the cycle is reversed, heat is moved from the outdoors to the conditioned space (indoors). There are two main types:
    - Air-source heat pumps. Heat is extracted from the outside air. Absorption heat pumps are air-source heat pumps powered by heat sources (rather than electricity), e.g. natural gas (gas-fired heat pumps), but also solar-heated water or geothermal-heated water;
    - Ground-source or water-source heat pumps. Heat is extracted from the ground or an underground body of water.
- Cogeneration space heater. Use micro combined heat and power (mCHP) instead of boilers. A micro-CHP unit generates heat and power simultaneously, with a typical electrical power output of 1-5 kWe for residential and 5-50 kWe for commercial buildings. The main output is heat for water or space heating, with electricity as a by-product. The main technologies are:
    - Internal combustion engine (ICE) mCHP. Total efficiency is 85-92%, electrical efficiency 20-30%;
    - Stirling (a.k.a. "external combustion") engine mCHP. Total efficiency is in the low 80s, electrical efficiency 10-20%; o Organic Rankine Cycle (ORC) mCHP. Total efficiency is 90+%, electrical efficiency ≈10%;
    - Fuel cell mCHP. Total efficiency is 77-80%, electrical efficiency 30-35%;
    - Micro-Turbine mCHP. Total efficiency is 80-92%, electrical efficiency mid 20's.
- Connect to a district heating (DH) system. District heating is not a generation technology in the strict sense, but provides the same function.

Heat distribution and emission

The efficiency of condensing boilers and heat pumps is higher when they supply heat at lower temperature. The majority of existing heating systems in the EU run with high system temperatures, between 50°C and 80°C inlet temperatures. The energy efficiency of these heating systems can be improved by modernizing them into low temperature heating systems, between 35°C and 50°C inlet temperature. In principle, the lower the system temperature, the more efficient the heating system. Low-temperature heating requires specific heat emitters.

- Modern radiators with low system temperatures feature a slim-line profile and minimal water content in combination with large heat-transfer surfaces. They not only save energy but also create a comfortable room climate;
- Surface heating (and cooling) systems circulate water in pipes permanently embedded in floors, walls or ceilings. Embedded heating systems operate at temperature levels very close to the desired room temperature.
-

Heating controls

HVAC systems are sized to meet heating and cooling loads that historically occur only 1% to 2.5% of the time. Controls have to ensure that the HVAC system performs properly, reliably and efficiently during those conditions that occur 97.5% to 99.0% of the time.

- "Right-size" the heating system to ensure efficient operation (avoid oversizing);
- Select heating systems that can operate efficiently at part load, e.g. variable capacity boiler systems:
    - Step-fired (hi/lo) boilers: the heat input to the boiler changes in steps, usually high/low/off;
    - Modulating flame boilers: the heat input to the boiler can be adjusted continually (modulated) up or down to match the heating load required;

- Modular boiler systems: groups of smaller boilers are assembled into modular systems. As the heating load increases, a new boiler enters on-line. As the heating load decreases, the boilers are taken off-line one by one.
- Oxygen-trim boiler systems: the amount of combustion air is continuously adjusted to achieve high combustion efficiency. They are usually cost-effective for large boilers with modulating flame controls;
- For controlling heat pumps, see air-conditioning.

Modern control technologies based on micro-electronics efficiently control all the components of a central heating system, not only the burners but also the heat emitters. They also enable the integration of renewable energy sources in case of bivalent heating systems (i.e. heating systems that can be run with two energy sources at the same time). In combination with communication technologies they allow remote control of the heating systems (see ICT appliances)

Space cooling (air-conditioning) Sensible cooling involves control of the air temperature. Latent cooling involves control of air humidity. The first step is to avoid or reduce the need for air-conditioning (AC): - Prevent heat from entering the building: o Shade windows by using deciduous trees or climbing foliage for south-facing windows to take advantage of low-angle sun in winter; o Improve insulation and air sealing and reduce thermal bridging (see space heating – building envelope); o Use architectural shading, exterior shades in the window plane, and reflective surfaces (see space cooling - building envelope); o Replace or discard energy inefficient appliances; - "Cool" with air movement and ventilation. Fans cool people but don't actually reduce room temperature. Fans use less energy than air-conditioning and can be adequate for attaining he desired thermal comfort, by creating a low-level "wind chill" effect. If "passive cooling" and fans are not sufficient, the second step is to select a (more) energy efficient air-conditioning system (or an alternative); or to improve the efficiency of the existing AC system.

Building envelope improvements
The same technologies apply as for space heating. Additional technologies include:

Architectural shading. Structural changes to the building design (mostly new buildings) provide exterior shading. The shading devices are either attached to the building skin (e.g. overhangs, fins or light shelves), or they are an extension of the skin itself (e.g. windows set back in a deeper wall section); - Exterior shades in the window plane. The shading devices are industrially manufactured systems, e.g. exterior shade screens, roller shades or reflective retrofit films. Manufacturers also offer (fixed or adjustable) shading systems between glazing layers. Exterior shades are able to reduce solar heat gain to zero, but preferred options would have daylight features; - Low SHGC windows; - Reflective (exterior) surfaces. Use reflective roof and wall coatings or materials in hot climates or dense urban areas, with a long-lasting solar reflectance (SR) of ≥ 0.75 for white surfaces; and SR ≥ 0.40 for "cool-coloured" surfaces; Air-Conditioning (AC) systems Most vapour-compression air-conditioning (and refrigeration) systems have an evaporator, a compressor, a condenser and an expansion valve. Indoor air is cooled by blowing it over the evaporator. The evaporator contains a working fluid called "refrigerant". The refrigerant changes from a liquid to a gas as it absorbs heat from the air. The compressor moves ("pumps") the refrigerant between the evaporator and the condenser, and compresses the gas to a state of higher pressure and higher temperature. The working fluid thus enters the compressor as a low temperature, low pressure gas, and leaves the compressor as a hot, high pressure gas. A condenser fan blows outside air over the refrigerant. The ambient air absorbs heat from the refrigerant, which condenses from a high temperature, high pressure gas to a high pressure, high temperature liquid. The expansion valve regulates the flow of refrigerant into the evaporator. The expansion valve causes a pressure drop of the refrigerant. The working fluid "expands" and cools, and flows to the evaporator where the cycle starts all over again. Energy is required for driving the motor of the compressor, and also for the motors of the evaporator and condenser fans. Figure 1: Vapour-compression refrigeration cycle

Air conditioners transfer ("move") heat from the space being cooled (e.g. a room) to another environment (usually outside). Residential air-conditioning technologies consist mainly of "room air conditioners" (RACs), whereas tertiary sector air-conditioning technologies mostly involve "central air conditioners" (CACs). Single and double duct air-conditioners have a relative low energy efficiency ratio (EER). EER is the ratio of output cooling energy to electrical input energy. They consist of a single unit placed freely in the room, where for single duct systems the condenser is cooled with air taken from the room and the air is expelled through a duct; whereas double duct systems have separate ducts for air intake and exhaust. More energy efficient space cooling technologies include: - Ductless Split or Multi-Split Air-Conditioners [aka "room air conditioners"] with a high EER, instead of less efficient single or double duct AC. Each space (room) to be cooled has its own (dedicated) air handler, connected to an outside compressor/condenser unit via a conduit carrying the power, refrigerant and condensate lines. They make it easier to meet the varying comfort needs of different rooms; and by avoiding the use of ductwork, they also avoid energy losses. The most efficient RACs are fixed split air conditioners with a variable speed compressor and a permanent-magnet motor (inverter technology); with an EER of 5 to 6 and a COP of 5 to 6; - Heat pumps Heat pumps refer to easily reversible vapour-compression air-conditioning systems, optimized for high efficiency in both directions of heat transfer (see also space heating systems); - Evaporative coolers (a.k.a. "swamp coolers"). The outside air – in dry areas – is pulled through moist pads where the air is cooled by evaporation. Direct evaporative coolers add moisture to the building; indirect evaporative coolers do not add moisture to the building; The tertiary sector often uses "chillers". Chillers produce cool water, which is pumped to air handling units to cool the air. Mechanical refrigeration chillers use one or more compressors powered by electric motors, fossil fuel engines or turbines. Absorption chillers produce chilled water via an absorption cycle. Energy efficiency improvements for chillers include: - Improved controls for chillers in general: o Variable Speed Drives (VSD) that vary the speed of the compressor by matching the motor output to the chiller load; o Multiple compressor chillers: sequence multiple compressors by bringing compressors on or off line, to achieve a closer match to the load; o Water temperature reset controls: raise the water temperature as the demand decreases; - Improved controls for chillers with water-cooled condensers, where the water is cooled indirectly via a cooling tower (i.e. a rooftop cooling tower rejecting heat in the outside air): o Variable speed or multiple speed cooling tower fans; o Wet-bulb reset strategies: the temperature of the cooling water is adjusted according to the temperature and humidity of outside air (instead of keeping it constant); Waterside economizer: a waterside economizer consists of controls and a heat exchanger installed between the chilled water loop and the cooling tower water loop. When the wet-bulb temperature is low (i.e. the outdoor air temperature is low and/or the air is very dry), the temperature of the cooling tower water may be low enough to directly cool the chilled water loop without use of the chiller;

o Integrated chiller plant controls use monitoring and computational strategies to yield minimum energy consumption for chillers, cooling towers, fans and pumps;

o Thermal storage: Thermal storage is a system in which an ice storage tank allows ice to accumulate during one period, and thaw it for use in another. Thermal storage allows smaller chillers. Thermal storage systems are mainly used for buildings with a large cooling load during daytime and little or no cooling at night.

Domestic Hot Water (DHW)

Domestic hot water (DHW) systems or 'water heaters' deliver a minimum requested amount of hot water with a minimum temperature. They are differentiated into two general principles: "ondemand water heaters" (a.k.a. "tankless", "instantaneous" or "point-of-use" water heaters) (water is heated instantly as it flows through the appliance) and "storage (tank) water heaters" (the hot water is stored in a tank).

Starting from 26 September 2015 a mandatory European energy label grades water heaters' performance from A to G.

In very high energy performance buildings where space heating is primarily accomplished through high levels of insulation and passive solar gains, the energy consumption for (domestic hot) water heating can be higher than for space heating.

The first step is to reduce hot water demand. The next step is to eliminate water heating system inefficiencies, which include how the water is heated (e.g. combustion efficiency, standby losses) and distributed (primarily heat loss from pipes).

- Reduce hot water demand

- Reduce hot water use. Take a shower instead of a bath and use water-efficient or low flow showerheads; use tap aerators in the kitchen and bathroom; turn the hot water down or off while you shave or wash dishes; fix hot water leaks; turn off the water heater when the building is unoccupied for an extended period;

Efficient hot water generation

- [combination heater] Use an efficient combination space-water heating system, e.g. a condensing combi (combination) boiler (see space heating);

- [conventional water heater] Use an efficient conventional water heating system: ...

- [solar water heater] Use a solar domestic hot water (SDHW) heating system. A solar water heating system uses solar panels (collectors) which collect heat from the sun and use it to heat up water which is stored in a hot water storage tank. There may also be circulating pump(s) in the collector loop. A conventional water heater or back-up immersion heater can be used the heat the water further or to provide hot water when solar energy is unavailable. Larger solar panels could in principle contribute to space heating (see 'packages');

- [heat pump water heater] Use an efficient heat pump water heater (HPWH);
- Maintain a moderate tank temperature;
- Install a drain water heat recovery (DWHR) device to reduce the water heating load. DWHR pipes take advantage of the warm water flowing down the drains to preheat the water going into the hot water tank.

Reduce hot water distribution losses

- Eliminate distribution losses: Insulate the hot-water pipes; optimize the pipe diameter and the distance between the water heater and the tap. The smaller the pipe, the more quickly hot water reaches the tap. Larger-diameter pipes also waste heat because more hot water remains in the pipe after the tap is turned off.

Copenhagen Economics 2012 Scenarios[29]

We have considered two scenarios for investments in energy efficient renovation of buildings. These scenarios have been defined in an extensive study for DG Energy and Transport in 2009.10 This work established the potential penetration in the market of best available technologies under different conditions, such as the level of political ambition for breaking down barriers to energy efficiency investments. Based on this extensive work we focus on two scenarios: 1) Low Energy Efficiency scenario, and 2) High Energy Efficiency scenario. These scenarios take into account a baseline increase in energy efficient renovation of buildings based on a business-as-usual scenario. The potential defined in the two scenarios should therefore be considered in addition to business-as-usual.

The *low EE scenario* assumes a relatively high level of policy initiative, in order to break down barriers to otherwise cost-effective investment potential. However, the entire in-vestment potential is so called “cost-effective” meaning that under normal assumptions on for example energy prices and consumer’s discount rates, the energy savings following over time will be able to pay for the upfront investment cost.11 As an example, the scenario assumes that the heating systems, and windows, which can be cost effectively replaced by more efficient models (not necessarily *the* most efficient model) will be upgraded.

The *high EE scenario* on the other hand assumes full penetration of best available technologies. This should be seen as an upper limit for energy efficiency investments given the *current* level of technology. As an example, the scenario assumes that all windows will be upgraded to the most efficient models available on the market. While this implies that technologies will be deployed beyond what is cost effective from an energy savings point of view, it will bring additional benefits through e.g. improved health, which will improve the overall profitability of the investment. While this example specifies an upper level on the potential given current technologies, the potential for energy efficient renovation of buildings is expected to increase going forward, as technologies improve and cost of technologies are reduced.

([29]) These assumptions are taken directly from the Copenhagen Economics 2012 Report.

***EU Scenarios: 2016: The Macroeconomic and Other Benefits of Energy Efficiency*[30]**

The three policy options

Measures	Option 0: No-change option	Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive	Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions	Option III: Enhanced implementation and increased harmonization, while introducing substantial changes
Simplification measures			S1 S2	
Measure 1: Accelerate the decarbonisation of buildings by significantly increasing renovation rates			1A	1A 1B
Measure 2: Fine tune the implementation of minimum energy performance requirements		2A	2A	2A 2B
Measure 3: Modernisation using smart technologies and simplification of outdated provisions for the benefit of citizens			3A* 3B** 3C**	3A 3B 3C
Measure 4: Enhance financial support and information to users through reinforced energy performance certificates			4A	4A 4B

Source(s): European Commission

* This measure includes a simplification component addressing outdated provisions in Articles 6, 7, 14, 15 and 16 of the current Directive
** These two measures modernise current provisions in light of technical development and the need to support smart technologies and electro-mobility

([30]) The assumptions are taken directly from the Report: https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf
These scenarios can be found in Part II, page 10.

Annex C: Monetised Impacts per MS, Impact & Building Scenario

COMBI Figures (Selected monetary impacts by bn € and country)

Active Days								
bn €	Buildings Residential refurbishment	Buildings residential new homes	Buildings residential lighting	Buildings residential cold apps	Buildings tertiary refurbishment	Buildings tertiary new homes	Buildings tertiary lighting	Buildings tertiary cold apps
Austria	1.2203	0	0	0	0.5054	0	0	0
Belgium	0.4601	0	0	0	0.3831	0	0	0
Bulgaria	0.0751	0	0	0	0.1039	0	0	0
Croatia	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	0.5128	0	0	0	0.3393	0	0	0
Denmark	0.2017	0	0	0	0.2627	0	0	0
Estonia	0.0549	0	0	0	0.0167	0	0	0
Finland	0.2545	0	0	0	0.0556	0	0	0
France	2.5879	0	0	0	1.597	0	0	0
Germany	5.7985	0	0	0	5.8199	0	0	0
Greece	0.5107	0	0	0	0.4075	0	0	0
Hungary	0.4304	0	0	0	0.1958	0	0	0
Ireland	0.3035	0	0	0	0.3731	0	0	0
Italy	1.8795	0	0	0	0.925	0	0	0
Lithuania	0.0595	0	0	0	0.0272	0	0	0
Luxembourg	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0
Netherland	0.7794	0	0	0	0.9184	0	0	0
Poland	0.8303	0	0	0	0.7018	0	0	0
Portugal	0.2347	0	0	0	0.1808	0	0	0
Romania	0	0	0	0	0	0	0	0
Slovakia	0.1968	0	0	0	0.1367	0	0	0
Slovenia	0.1283	0	0	0	0.0807	0	0	0
Spain	1.5302	0	0	0	1.1301	0	0	0
Sweden	0.6733	0	0	0	0.1435	0	0	0
United Kingdom	2.0626	0	0	0	1.4524	0	0	0

Asthma								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold apps
Austria	0.1038	0.162	0	0	0	0	0	0
Belgium	0.1316	0.4207	0	0	0	0	0	0
Bulgaria	0.0352	0.1562	0	0	0	0	0	0
Croatia	0.0261	0.1218	0	0	0	0	0	0
Cyprus	0.0233	0.1028	0	0	0	0	0	0
Denmark	0.0607	0.2141	0	0	0	0	0	0
Estonia	0.0195	0.0273	0	0	0	0	0	0
Finland	0.0366	0.0574	0	0	0	0	0	0
France	0.7567	1.2175	0	0	0	0	0	0
Germany	0.7853	1.7321	0	0	0	0	0	0
Greece	0.0827	0.5177	0	0	0	0	0	0
Hungary	0.1102	0.6367	0	0	0	0	0	0
Ireland	0.0666	0.1658	0	0	0	0	0	0
Italy	0.7971	1.2494	0	0	0	0	0	0
Latvia	0.027	0.2203	0	0	0	0	0	0
Lithuania	0.0234	0.1803	0	0	0	0	0	0
Luxembourg	0.0066	0.0393	0	0	0	0	0	0
Malta	0.0042	0.0092	0	0	0	0	0	0
Netherland	0.2287	0.4558	0	0	0	0	0	0
Poland	0.2292	0.4878	0	0	0	0	0	0
Portugal	0.2596	0.9941	0	0	0	0	0	0
Romania	0.2213	0.4642	0	0	0	0	0	0
Slovakia	0.0184	0.0469	0	0	0	0	0	0
Slovenia	0.025	0.0567	0	0	0	0	0	0
Spain	0.488	2.7858	0	0	0	0	0	0
Sweden	0.058	0.1041	0	0	0	0	0	0
United Kingdom	1.5586	3.4342	0	0	0	0	0	0

Avoided Electricity Generation								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold apps
Austria	0.2452	0.1225	0.2202	0.178	0.2615	0.1359	0.3037	0.2165
Belgium	0.2515	0.1041	0.3042	0.1886	0.2942	0.1507	0.4048	0.1961
Bulgaria	0.2069	0.014	0.1023	0.0709	0.3991	0.0603	0.2532	0.1135
Croatia	0.0504	-0.0048	0.051	0.0262	0.1055	0.0065	0.0714	0.0368
Cyprus	0.0319	0.0172	0.0298	0.0155	0.0886	0.0132	0.0268	0.0226
Czech Republic	0.2272	0.0695	0.1806	0.1619	0.4852	0.0909	0.3779	0.2017
Denmark	0.15	0.0827	0.1953	0.1229	0.1275	0.0996	0.2521	0.132
Estonia	0.0138	0.0114	0.0327	0.0195	0.0387	0.0168	0.044	0.0246
Finland	0.4012	0.0801	0.2511	0.1288	0.2406	0.1002	0.4267	0.1534
France	1.3502	0.4697	0.8527	0.7091	2.814	0.5352	2.212	0.8126
Germany	1.5473	-0.4653	1.3101	0.8257	2.5109	0.0104	8.9874	1.227
Greece	0.2636	0.1062	0.2665	0.1746	0.5985	0.1474	0.283	0.2076
Hungary	0.0931	0.012	0.1967	0.0915	0.2025	0.0658	0.256	0.1104
Ireland	0.0906	0.0389	0.1344	0.0677	0.118	0.0485	0.1712	0.0889
Italy	1.8946	0.6692	1.3736	0.962	3.5723	0.7001	1.7796	1.2227
Latvia	0.0055	0.0005	0.0221	0.0122	0.0275	0.0104	0.025	0.0168
Lithuania	-0.0079	0.0056	-0.0214	-0.012	-0.0226	-0.008	-0.0361	-0.0151
Luxembourg	0.0049	0.0008	0.0055	0.0025	0.0021	0.0022	0.0068	0.0049
Malta	0.0097	0.0013	0.0044	0.002	0.0086	0.0008	0.008	0.0033
Netherland	0.4544	0.3607	0.5225	0.4509	0.6485	0.392	0.8501	0.4833
Poland	0.4505	0.1277	0.7145	0.3517	0.7203	0.2149	1.2691	0.4678
Portugal	0.107	0.1028	0.2258	0.1464	0.5978	0.0897	0.3695	0.192
Romania	0.1486	0.0581	0.3764	0.2147	0.1479	0.1133	0.2848	0.2291
Slovakia	0.019	0.0218	0.0712	0.0614	0.1941	0.0181	0.1755	0.0869
Slovenia	0.0348	-0.0101	0.0329	0.021	0.1437	0.0004	0.119	0.0309
Spain	0.8669	0.4889	1.0981	0.7067	3.1547	0.5371	1.4505	1.0496
Sweden	0.4964	0.1267	0.4803	0.2272	0.4643	0.1796	0.5355	0.3029
United Kingdom	1.2886	0.2706	1.3999	0.8447	0.7038	0.4005	3.6517	0.9522

Direct GHG emissions								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	1.0792	0.1389	0.0094	0.0042	0.3846	0.0637	0.0197	0.009
Belgium	1.4272	0.363	0.0439	0.0145	0.7409	0.0986	0.0695	0.0164
Bulgaria	0.2052	0.2051	0.0106	0.0049	0.1206	0.0305	0.038	0.0126
Croatia	0.1304	0.1362	0.0069	0.0029	0.1147	0.0064	0.0102	0.0046
Cyprus	0.0258	0.0093	0.0053	0.0007	0.0313	0.0047	0.0043	0.003
Czech Republic	0.8706	0.1897	0.0174	0.0127	0.6187	0.0908	0.067	0.0227
Denmark	0.8345	0.1832	0.0142	0.0034	0.0926	0.0197	0.0227	0.0048
Estonia	0.0665	0.0191	0.0092	0.002	0.0687	0.0073	0.0153	0.0048
Finland	1.0919	0.0836	0.0158	0.003	0.0507	0.0044	0.034	0.0056
France	6.679	1.1912	0.0044	0.0026	1.2899	0.2472	0.0214	0.0039
Germany	9.1725	1.415	0.1997	0.123	3.3476	0.5778	1.4149	0.1865
Greece	0.7196	0.1974	0.037	0.0084	0.1768	0.0463	0.0422	0.0187
Hungary	0.5875	0.6948	0.0096	0.0019	0.3802	0.062	0.014	0.0033
Ireland	0.407	0.0552	0.0204	0.0045	0.3316	0.0453	0.0291	0.0095
Italy	6.1742	0.5572	0.1399	0.0528	1.9468	0.479	0.2257	0.108
Latvia	0.1091	0.0705	0.0032	0.0007	0.0607	0.0105	0.0039	0.0019
Lithuania	0.1426	0.1712	0.0022	0.0007	0.0368	0.0018	0.0046	0.0012
Luxembourg	0.0717	0.0233	0.0027	0.0005	0.0035	0.0349	0.0036	0.0022
Malta	0.0082	0.0059	0.0016	0.0006	0.0051	0.0028	0.0032	0.0011
Netherland	1.7205	0.3813	0.0519	0.0232	1.2823	0.2217	0.1832	0.0362
Poland	3.3155	0.6636	0.2174	0.0562	0.8452	0.1454	0.4637	0.1078
Portugal	0.0325	0.2779	0.0059	0.0021	0.0885	0.0159	0.0126	0.0043
Romania	0.7125	0.359	0.0256	0.0099	0.2811	0.0299	0.0167	0.0113
Slovakia	0.2003	0.0993	0.0009	0.0006	0.5502	0.1323	0.0036	0.0013
Slovenia	0.1259	0.05	0.0031	0.0019	0.0966	0.0027	0.0119	0.0029
Spain	1.088	2.8483	0.0492	0.0128	0.89	0.2459	0.0819	0.0446
Sweden	1.1046	0.1694	0.0066	0.0011	0.0516	0.01	0.0078	0.0027
United Kingdom	6.8282	0.7917	0.0881	0.0385	1.292	0.3486	0.2891	0.0481

Energy Savings								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	6.5182	0.5984	0.1749	0.0784	2.3688	0.2542	0.3656	0.1665
Belgium	7.7526	1.672	0.3426	0.1134	3.4399	0.4875	0.542	0.1282
Bulgaria	1.4301	0.9418	0.0658	0.0304	0.731	0.1671	0.2355	0.0784
Croatia	0.9286	0.6199	0.0737	0.0314	0.6456	0.0292	0.1084	0.0494
Cyprus	0.0562	0.0514	0.0352	0.0046	0.1913	0.023	0.029	0.02
Czech Republic	5.1508	0.8713	0.0871	0.0636	3.0346	0.3526	0.335	0.1136
Denmark	5.0021	0.8103	0.2693	0.0646	0.5073	0.0664	0.43	0.0905
Estonia	0.57	0.0904	0.0293	0.0065	0.3718	0.0402	0.0489	0.0154
Finland	6.8743	0.3569	0.245	0.0469	0.3753	0.0234	0.5295	0.0869
France	40.3254	5.5381	0.968	0.5731	12.0811	1.2164	4.7063	0.8577
Germany	50.9754	6.4147	1.1127	0.6856	15.0532	1.9466	7.8839	1.0394
Greece	4.2215	0.8296	0.2829	0.0644	1.2656	0.2324	0.322	0.143
Hungary	3.6051	3.1158	0.3006	0.0602	2.0849	0.2529	0.4358	0.1035
Ireland	2.0933	0.25	0.1397	0.0309	1.4309	0.1805	0.1999	0.0654
Italy	35.7594	2.6008	1.0029	0.379	10.9179	2.3793	1.6182	0.7741
Latvia	0.8845	0.3071	0.0366	0.0082	0.4704	0.062	0.0449	0.0215
Lithuania	1.0063	0.7405	0.0528	0.016	0.2813	0.01	0.1099	0.0281
Luxembourg	0.3759	0.1073	0.0169	0.0028	0.0111	0.161	0.0227	0.0139
Malta	0.0386	0.0283	0.0087	0.0029	0.0239	0.013	0.0169	0.006
Netherland	9.5875	1.7373	0.3465	0.1549	6.0974	0.8748	1.2235	0.2417
Poland	17.6212	3.1131	0.7793	0.2014	3.622	0.3925	1.6623	0.3863
Portugal	0.3753	1.3303	0.1831	0.067	1.0021	0.0203	0.393	0.1337
Romania	5.0682	1.6173	0.3247	0.1257	1.2119	0.1207	0.212	0.1434
Slovakia	1.2007	0.4423	0.0416	0.0292	3.0627	0.5286	0.1742	0.0615
Slovenia	0.857	0.2252	0.0277	0.0167	0.4955	0.0109	0.1069	0.0258
Spain	7.0206	13.3037	0.8076	0.2096	6.5872	0.9686	1.3461	0.7334
Sweden	7.1914	0.6946	0.428	0.0684	0.555	0.0516	0.5063	0.1759
United Kingdom	37.7699	3.5599	1.353	0.5915	6.0332	1.181	4.4416	0.739

Excess Winter Mortalities								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	66.8791	84.5937	0	0	0	0	0	0
Belgium	140.3996	351.0579	0	0	0	0	0	0
Bulgaria	209.3129	742.0898	0	0	0	0	0	0
Croatia	61.7039	224.9873	0	0	0	0	0	0
Cyprus	9.2992	33.1273	0	0	0	0	0	0
Czech Republic	113.9478	178.0184	0	0	0	0	0	0
Denmark	29.9337	81.0661	0	0	0	0	0	0
Estonia	12.6828	14.7963	0	0	0	0	0	0
Finland	27.6197	33.5591	0	0	0	0	0	0
France	790.9257	997.4668	0	0	0	0	0	0
Germany	485.7521	838.3695	0	0	0	0	0	0
Greece	121.2417	601.3073	0	0	0	0	0	0
Hungary	237.8635	1090.9089	0	0	0	0	0	0
Ireland	55.5006	108.4755	0	0	0	0	0	0
Italy	1499.5827	1851.7524	0	0	0	0	0	0
Latvia	61.257	391.0269	0	0	0	0	0	0
Lithuania	64.7481	385.2622	0	0	0	0	0	0
Luxembourg	1.2576	7.1746	0	0	0	0	0	0
Malta	9.1975	15.2862	0	0	0	0	0	0
Netherland	76.2068	118.1363	0	0	0	0	0	0
Poland	665.313	1112.1739	0	0	0	0	0	0
Portugal	317.1725	954.3788	0	0	0	0	0	0
Romania	1097.2442	1824.0387	0	0	0	0	0	0
Slovakia	42.2504	81.6096	0	0	0	0	0	0
Slovenia	25.6868	45.385	0	0	0	0	0	0
Spain	467.6471	2100.7751	0	0	0	0	0	0
Sweden	67.6518	96.2516	0	0	0	0	0	0
United Kingdom	1180.0456	2037.9451	0	0	0	0	0	0

Fossil Fuel Imports								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.0048	0.0015	0.001	0.001	0.0022	0.0012	0.0012	0.001
Belgium	-0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0	0.0001
Bulgaria	0.0028	0.002	0.0012	0.001	0.0021	0.0011	0.002	0.0012
Croatia	0.0008	0.0006	0.0007	0.0007	0.0007	0.0007	0.0008	0.0007
Cyprus	-0.0044	-0.0003	-0.0005	-0.0005	-0.0063	-0.0005	-0.0005	-0.0005
Czech Republic	0.0033	0.0013	0.0006	0.0006	0.0026	0.001	0.0006	0.0006
Denmark	0.0069	0.003	0.0016	0.0015	0.0022	0.0017	0.0016	0.0015
Estonia	0.002	0.001	0	0	0.0005	0.0001	0	0
Finland	0.0048	0.0009	0.0006	0.0005	0.0007	0.0005	0.0006	0.0005
France	0.0045	0.0015	0.0005	0.0006	0.0004	0.0008	0.0001	0.0006
Germany	0.0063	0.0017	0.0009	0.0007	0.0023	0.0009	0.0027	0.0008
Greece	0.0019	0.0011	0.0007	0.0005	-0.0001	0.0005	0.0008	0.0006
Hungary	0.0034	0.0044	0.0014	0.0013	0.0025	0.0015	0.0015	0.0013
Ireland	-0.0002	0.0001	0.0002	0.0002	0.0001	0.0001	0.0002	0.0002
Italy	0.0012	0.0009	0.0005	0.0005	0	0.0008	0.0006	0.0005
Latvia	0.0048	0.0043	0.0004	0	0.0024	0.0004	0.0005	0.0002
Lithuania	0.0027	0.0051	0.0004	0.0005	0.0003	0.0006	0.0002	0.0005
Luxembourg	0.0039	0.0018	0.0003	0.0002	0.0004	0.0025	0.0004	0.0003
Malta	0.0001	0.0019	-0.0001	0	0	0.0007	-0.0001	0
Netherland	0.0027	0.0017	0.0014	0.0014	0.0023	0.0015	0.0016	0.0014
Poland	0.0041	0.0019	0.0018	0.0015	0.0021	0.0015	0.0023	0.0016
Portugal	0.0005	0.0054	-0.0003	0.0005	-0.005	0.0018	-0.0017	0.0001
Romania	0.0047	0.0025	0.0014	0.0011	0.0023	0.0011	0.0012	0.0011
Slovakia	0.0025	0.0017	0.0007	0.0007	0.0067	0.0023	0.0006	0.0007
Slovenia	0.0016	0.0008	-0.0001	-0.0001	0.0001	0	0	-0.0001
Spain	0.0014	0.0039	0.001	0.0009	0.0007	0.0011	0.0011	0.001
Sweden	-0.0003	0.0003	0.0004	0.0003	0.0005	0.0003	0.0005	0.0004
United Kingdom	0.0082	0.0015	0.0008	0.0006	0.0018	0.0008	0.0016	0.0007

Fossil Fuels								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.4187	0.049	0.0101	0.0045	0.1459	0.0245	0.021	0.0096
Belgium	0.5643	0.134	0.0467	0.0155	0.332	0.0427	0.0739	0.0175
Bulgaria	0.0534	0.0788	0.0014	0.0006	0.0289	0.0114	0.0049	0.0016
Croatia	0.045	0.0506	0.005	0.0021	0.0518	0.0023	0.0074	0.0034
Cyprus	0.009	0.0051	0.0054	0.0007	0.0284	0.002	0.0044	0.003
Czech Republic	0.2898	0.0731	0.0022	0.0016	0.2193	0.0394	0.0086	0.0029
Denmark	0.3138	0.068	0.0063	0.0015	0.041	0.0091	0.01	0.0021
Estonia	0.019	0.0077	0.0006	0.0001	0.0197	0.0024	0.001	0.0003
Finland	0.4051	0.0302	0.0068	0.0013	0.0224	0.0015	0.0147	0.0024
France	2.5963	0.4622	0.0079	0.0047	0.5577	0.0956	0.0386	0.007
Germany	3.3907	0.5295	0.0486	0.03	1.3291	0.2698	0.3446	0.0454
Greece	0.2839	0.0626	0.0182	0.0041	0.0859	0.0196	0.0207	0.0092
Hungary	0.204	0.2624	0.0042	0.0008	0.164	0.0256	0.0061	0.0015
Ireland	0.1405	0.0193	0.0173	0.0038	0.1492	0.0203	0.0247	0.0081
Italy	2.4675	0.21	0.0995	0.0376	0.9945	0.1974	0.1605	0.0768
Latvia	0.0345	0.0249	0.0027	0.0006	0.0255	0.0039	0.0033	0.0016
Lithuania	0.0479	0.0614	0.002	0.0006	0.0137	0.0006	0.0042	0.0011
Luxembourg	0.0288	0.0084	0.0023	0.0004	0.0017	0.0153	0.0031	0.0019
Malta	0.0054	0.0025	0.0017	0.0006	0.0042	0.0012	0.0032	0.0011
Netherland	0.6498	0.1399	0.0338	0.0151	0.5849	0.0998	0.1192	0.0236
Poland	0.9603	0.2596	0.0272	0.007	0.2777	0.0712	0.058	0.0135
Portugal	0.0044	0.11	0.01	0.0037	0.0672	0.0051	0.0215	0.0073
Romania	0.2614	0.1349	0.0108	0.0042	0.1207	0.0123	0.0071	0.0048
Slovakia	0.0625	0.0375	0.0003	0.0002	0.1966	0.0554	0.0011	0.0004
Slovenia	0.0455	0.0188	0.0006	0.0004	0.0343	0.0009	0.0023	0.0006
Spain	0.3951	1.0987	0.0401	0.0104	0.4656	0.0978	0.0668	0.0364
Sweden	0.4057	0.0589	0.007	0.0011	0.0267	0.0033	0.0083	0.0029
United Kingdom	2.6215	0.289	0.0875	0.0383	0.5557	0.1603	0.2874	0.0478

GDP (max)								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.2472	0.1007	0.0027	0.0389	0.2735	0.0428	0.0028	0.0065
Belgium	0.8944	0.1207	0.0031	0.0508	0.3968	0.0352	0.0022	0.0045
Bulgaria	0.2672	0.0285	0.0003	0.0063	0.1366	0.0051	0.0014	0.0028
Croatia	0.1445	0.0298	0.0006	0.0086	0.1004	0.0014	0.0006	0.0017
Cyprus	0.0183	0.0086	0.0003	0.0017	0.0624	0.0038	0.0002	0.0007
Czech Republic	0.5839	0.0364	0.0033	0.0157	0.344	0.0148	0.0018	0.0036
Denmark	0.8589	0.0495	0.0029	0.0402	0.0871	0.0041	0.0028	0.0033
Estonia	0.039	0.0027	0.0008	0.0024	0.0254	0.0012	0.0003	0.0006
Finland	0.7029	0.0161	0.005	0.0287	0.0384	0.0011	0.0029	0.0036
France	6.8738	0.8747	0.0189	0.3314	2.0593	0.1921	0.0246	0.0383
Germany	9.9359	0.383	0.024	0.3783	2.9341	0.1162	0.0409	0.0464
Greece	0.4433	0.0205	0.0053	0.0276	0.1329	0.0058	0.0029	0.006
Hungary	0.4822	0.1302	0.0038	0.0157	0.2789	0.0106	0.0024	0.0038
Ireland	0.5308	0.013	0.0023	0.014	0.3628	0.0094	0.0009	0.002
Italy	2.7498	0.1796	0.0164	0.2121	0.8395	0.1643	0.0109	0.0353
Latvia	0.0498	0.0065	0.0006	0.0028	0.0265	0.0013	0.0004	0.0008
Lithuania	0.1388	0.0169	0.001	0.0052	0.0388	0.0002	0.0008	0.0012
Luxembourg	0.0399	0.0066	0.0001	0.0013	0.0012	0.0099	0.0001	0.0004
Malta	0.0109	0.001	0.0001	0.0011	0.0068	0.0005	0.0001	0.0002
Netherland	2.5146	0.2048	0.0051	0.0773	1.5992	0.1031	0.0064	0.0093
Poland	1.6215	0.1145	0.0066	0.0529	0.3333	0.0144	0.0106	0.0149
Portugal	0.1319	0.1107	0.0066	0.0265	0.3521	0.0017	0.0024	0.0053
Romania	0.7897	0.0448	0.0048	0.0348	0.1888	0.0033	0.0014	0.0061
Slovakia	0.2842	0.0216	0.0004	0.0079	0.725	0.0258	0.0009	0.002
Slovenia	0.0743	0.0092	0.0003	0.0058	0.043	0.0004	0.0006	0.0009
Spain	2.611	1.1491	0.0161	0.1019	2.4498	0.0837	0.0094	0.032
Sweden	1.2453	0.0453	0.0084	0.0412	0.0961	0.0034	0.0044	0.007
United Kingdom	8.0203	0.3042	0.0285	0.372	1.2811	0.1009	0.0203	0.0329

Indoor Air Pollution								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.8977	0	0	0	0	0	0	0
Belgium	0.6961	0	0	0	0	0	0	0
Bulgaria	0.2855	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0	0
Cyprus	0.0475	0	0	0	0	0	0	0
Czech Republic	0.8108	0	0	0	0	0	0	0
Denmark	0.2863	0	0	0	0	0	0	0
Estonia	0.1	0	0	0	0	0	0	0
Finland	0.2385	0	0	0	0	0	0	0
France	2.9078	0	0	0	0	0	0	0
Germany	4.0622	0	0	0	0	0	0	0
Greece	0.5768	0	0	0	0	0	0	0
Hungary	1.6573	0	0	0	0	0	0	0
Ireland	0.1823	0	0	0	0	0	0	0
Italy	4.6718	0	0	0	0	0	0	0
Latvia	0.0727	0	0	0	0	0	0	0
Lithuania	0.0967	0	0	0	0	0	0	0
Luxembourg	0.0237	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0
Netherland	0.9263	0	0	0	0	0	0	0
Poland	1.9843	0	0	0	0	0	0	0
Portugal	0.4342	0	0	0	0	0	0	0
Romania	1.9929	0	0	0	0	0	0	0
Slovakia	0.2655	0	0	0	0	0	0	0
Slovenia	0.1603	0	0	0	0	0	0	0
Spain	1.5401	0	0	0	0	0	0	0
Sweden	0.4314	0	0	0	0	0	0	0
United Kingdom	3.137	0	0	0	0	0	0	0

Metal Ores								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.1177	-0.0019	0.0184	0.0083	0.0613	-0.0002	0.0385	0.0175
Belgium	0.1457	-0.0513	0.0434	0.0143	0.1095	-0.0088	0.0686	0.0162
Bulgaria	0.0366	-0.0253	0.0077	0.0035	0.0606	0.0029	0.0275	0.0091
Croatia	0.014	-0.0161	0.0079	0.0033	0.0297	-0.0027	0.0116	0.0053
Cyprus	-0.0362	0.0094	0.0043	0.0006	0.0566	0.0022	0.0035	0.0024
Czech Republic	0.0754	-0.0172	0.0081	0.0059	0.0842	-0.0051	0.0311	0.0106
Denmark	0.092	-0.0239	0.0446	0.0107	0.0234	-0.002	0.0713	0.015
Estonia	0.0051	-0.0011	0.0029	0.0006	0.0097	0.0004	0.0049	0.0015
Finland	0.1374	-0.004	0.0238	0.0046	0.0301	-0.0004	0.0515	0.0084
France	0.8852	-0.1784	0.1257	0.0744	1.045	-0.1005	0.6113	0.1114
Germany	0.8627	-0.1731	0.1463	0.0902	0.6323	-0.0373	1.0368	0.1367
Greece	0.1216	0.016	0.0467	0.0106	0.2515	0.008	0.0531	0.0236
Hungary	0.049	-0.0771	0.0308	0.0062	0.0647	-0.0066	0.0446	0.0106
Ireland	0.0381	-0.0082	0.0182	0.004	0.0474	-0.0024	0.0261	0.0085
Italy	0.7531	-0.0707	0.1186	0.0448	0.79	-0.0652	0.1913	0.0915
Latvia	0.0089	-0.0031	0.0034	0.0008	0.0125	0.0006	0.0042	0.002
Lithuania	0.0123	-0.0075	0.0055	0.0017	0.0107	-0.0001	0.0115	0.0029
Luxembourg	0.0074	-0.0026	0.0017	0.0003	0.0004	0.0004	0.0023	0.0014
Malta	0.0024	-0.0011	0.0009	0.0003	0.0029	-0.0008	0.0017	0.0006
Netherland	0.1437	-0.0356	0.0399	0.0178	0.1817	-0.0078	0.1407	0.0278
Poland	0.2541	-0.0696	0.0766	0.0198	0.1453	-0.0239	0.1635	0.038
Portugal	0.0009	-0.0581	0.0302	0.011	0.1401	-0.0227	0.0648	0.022
Romania	0.0698	-0.0401	0.0405	0.0157	0.0249	-0.0025	0.0264	0.0179
Slovakia	0.0091	-0.0103	0.0041	0.0028	0.0556	-0.0072	0.017	0.006
Slovenia	0.0142	-0.0046	0.0027	0.0016	0.0251	-0.0019	0.0103	0.0025
Spain	0.1963	-0.538	0.1201	0.0312	0.8737	-0.08	0.2001	0.109
Sweden	0.1412	-0.0088	0.0452	0.0072	0.0553	-0.0008	0.0535	0.0186
United Kingdom	0.6551	-0.1205	0.1607	0.0703	0.1426	-0.0555	0.5275	0.0878

Mortality Ozone								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	1.3728	0.126	0.0368	0.0165	0.4989	0.0535	0.077	0.0351
Belgium	0.8843	0.1907	0.0391	0.0129	0.3923	0.0556	0.0618	0.0146
Bulgaria	1.07	0.7046	0.0492	0.0227	0.5469	0.125	0.1762	0.0586
Croatia	0.9433	0.6298	0.0749	0.0319	0.6558	0.0297	0.1101	0.0502
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	1.2819	0.2168	0.0217	0.0158	0.7553	0.0878	0.0834	0.0283
Denmark	0.757	0.1226	0.0408	0.0098	0.0768	0.01	0.0651	0.0137
Estonia	0.1644	0.0261	0.0084	0.0019	0.1072	0.0116	0.0141	0.0044
Finland	0.1823	0.0095	0.0065	0.0012	0.01	0.0006	0.014	0.0023
France	9.6583	1.3264	0.2318	0.1373	2.8935	0.2913	1.1272	0.2054
Germany	10.593	1.333	0.2312	0.1425	3.1281	0.4045	1.6383	0.216
Greece	1.9059	0.3746	0.1277	0.0291	0.5714	0.1049	0.1454	0.0645
Hungary	2.3847	2.061	0.1988	0.0398	1.3791	0.1673	0.2882	0.0685
Ireland	0	0	0	0	0	0	0	0
Italy	17.7777	1.293	0.4986	0.1884	5.4278	1.1829	0.8045	0.3849
Latvia	0.1521	0.0528	0.0063	0.0014	0.0809	0.0107	0.0077	0.0037
Lithuania	0.1666	0.1226	0.0087	0.0026	0.0466	0.0017	0.0182	0.0047
Luxembourg	0.0762	0.0217	0.0034	0.0006	0.0022	0.0326	0.0046	0.0028
Malta	0.1137	0.0835	0.0256	0.0085	0.0703	0.0382	0.0499	0.0177
Netherland	0.8068	0.1462	0.0292	0.013	0.5131	0.0736	0.103	0.0203
Poland	5.8674	1.0366	0.2595	0.0671	1.206	0.1307	0.5535	0.1286
Portugal	0.1605	0.569	0.0783	0.0286	0.4286	0.0087	0.1681	0.0572
Romania	2.5452	0.8122	0.1631	0.0631	0.6086	0.0606	0.1065	0.072
Slovakia	0.3497	0.1288	0.0121	0.0085	0.8921	0.154	0.0507	0.0179
Slovenia	0.4351	0.1143	0.0141	0.0085	0.2516	0.0055	0.0543	0.0131
Spain	1.9234	3.6447	0.2212	0.0574	1.8046	0.2654	0.3688	0.2009
Sweden	0.7194	0.0695	0.0428	0.0068	0.0555	0.0052	0.0507	0.0176
United Kingdom	4.1141	0.3878	0.1474	0.0644	0.6572	0.1286	0.4838	0.0805

Mortality PM2.5								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	23.4752	2.1553	0.6301	0.2825	8.5313	0.9155	1.3167	0.5996
Belgium	55.2028	11.9059	2.4398	0.8072	24.4938	3.4711	3.8595	0.913
Bulgaria	12.0373	7.927	0.5537	0.2558	6.1531	1.4066	1.9824	0.6595
Croatia	8.7254	5.8253	0.6926	0.2952	6.066	0.2745	1.0187	0.464
Cyprus	0.031	0.0283	0.0194	0.0025	0.1054	0.0127	0.016	0.011
Czech Republic	26.0234	4.4019	0.44	0.3214	15.3318	1.7814	1.6925	0.5739
Denmark	18.167	2.9431	0.9782	0.2345	1.8424	0.241	1.5616	0.3287
Estonia	1.9729	0.3131	0.1013	0.0225	1.2869	0.1393	0.1691	0.0532
Finland	8.3843	0.4353	0.2988	0.0572	0.4578	0.0286	0.6458	0.106
France	229.2786	31.4882	5.5039	3.2583	68.69	6.916	26.7589	4.8767
Germany	314.4788	39.5737	6.8647	4.2294	92.8663	12.0087	48.6376	6.4126
Greece	57.9381	11.3863	3.882	0.8839	17.3699	3.1901	4.4195	1.962
Hungary	36.1917	31.2792	3.0173	0.6044	20.9302	2.5388	4.3745	1.0395
Ireland	2.8488	0.3402	0.1901	0.0421	1.9473	0.2456	0.272	0.089
Italy	349.7335	25.4366	9.8085	3.7062	106.7791	23.2697	15.826	7.5713
Latvia	6.8425	2.3759	0.2828	0.0634	3.6393	0.4797	0.3471	0.1666
Lithuania	4.7481	3.4942	0.249	0.0754	1.3272	0.0474	0.5186	0.1327
Luxembourg	0.6854	0.1957	0.0308	0.0052	0.0202	0.2935	0.0414	0.0254
Malta	0.2274	0.1669	0.0511	0.0171	0.1407	0.0764	0.0998	0.0354
Netherland	37.5181	6.7985	1.3561	0.6063	23.8603	3.4234	4.7879	0.9459
Poland	199.4922	35.244	8.8223	2.2803	41.0046	4.4436	18.8197	4.3731
Portugal	1.8729	6.6379	0.9134	0.3341	5.0005	0.1014	1.9613	0.6669
Romania	40.9345	13.0624	2.6226	1.0155	9.788	0.9751	1.7122	1.1582
Slovakia	4.5964	1.6931	0.1594	0.1117	11.725	2.0236	0.6668	0.2355
Slovenia	5.3304	1.4007	0.1723	0.1039	3.0818	0.0677	0.665	0.1607
Spain	24.8289	47.0495	2.856	0.7413	23.2961	3.4255	4.7604	2.5939
Sweden	13.4889	1.3029	0.8028	0.1284	1.041	0.0968	0.9497	0.3299
United Kingdom	303.4754	28.6036	10.8708	4.7526	48.4757	9.4892	35.6876	5.9378

Public Budget (max)								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.1434	0.0584	0.0016	0.0226	0.1586	0.0248	0.0016	0.0038
Belgium	0.5456	0.0736	0.0019	0.031	0.2421	0.0215	0.0014	0.0027
Bulgaria	0.0828	0.0088	0.0001	0.002	0.0423	0.0016	0.0004	0.0009
Croatia	0.0679	0.014	0.0003	0.004	0.0472	0.0007	0.0003	0.0008
Cyprus	0.0095	0.0045	0.0002	0.0009	0.0324	0.002	0.0001	0.0004
Czech Republic	0.2511	0.0157	0.0014	0.0067	0.1479	0.0063	0.0008	0.0015
Denmark	0.5325	0.0307	0.0018	0.0249	0.054	0.0025	0.0018	0.0021
Estonia	0.0172	0.0012	0.0003	0.001	0.0112	0.0005	0.0001	0.0003
Finland	0.4007	0.0092	0.0028	0.0164	0.0219	0.0006	0.0016	0.0021
France	4.1243	0.5248	0.0113	0.1988	1.2356	0.1153	0.0148	0.023
Germany	4.3718	0.1685	0.0106	0.1664	1.291	0.0511	0.018	0.0204
Greece	0.2128	0.0099	0.0025	0.0132	0.0638	0.0028	0.0014	0.0029
Hungary	0.2363	0.0638	0.0019	0.0077	0.1366	0.0052	0.0012	0.0019
Ireland	0.2813	0.0069	0.0012	0.0074	0.1923	0.005	0.0005	0.0011
Italy	1.4849	0.097	0.0089	0.1145	0.4534	0.0887	0.0059	0.0191
Latvia	0.0189	0.0025	0.0002	0.0011	0.0101	0.0005	0.0002	0.0003
Lithuania	0.0569	0.0069	0.0004	0.0021	0.0159	0.0001	0.0003	0.0005
Luxembourg	0.0176	0.0029	0.0001	0.0006	0.0005	0.0044	0.0001	0.0002
Malta	0.005	0.0005	0	0.0005	0.0031	0.0002	0.0001	0.0001
Netherland	1.6345	0.1331	0.0033	0.0503	1.0395	0.067	0.0042	0.006
Poland	0.8432	0.0595	0.0035	0.0275	0.1733	0.0075	0.0055	0.0078
Portugal	0.0672	0.0565	0.0034	0.0135	0.1796	0.0009	0.0012	0.0027
Romania	0.2685	0.0152	0.0016	0.0118	0.0642	0.0011	0.0005	0.0021
Slovakia	0.1108	0.0084	0.0001	0.0031	0.2827	0.0101	0.0004	0.0008
Slovenia	0.0357	0.0044	0.0001	0.0028	0.0206	0.0002	0.0003	0.0004
Spain	1.4099	0.6205	0.0087	0.055	1.3229	0.0452	0.0051	0.0173
Sweden	0.7347	0.0267	0.005	0.0243	0.0567	0.002	0.0026	0.0041
United Kingdom	4.732	0.1795	0.0168	0.2195	0.7559	0.0595	0.012	0.0194

Workforce performance								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0	0	0	0	0.059	0	0	0
Belgium	0	0	0	0	0.0645	0	0	0
Bulgaria	0	0	0	0	0	0	0	0
Croatia	0	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	0	0	0	0	0.0466	0	0	0
Denmark	0	0	0	0	0.0522	0	0	0
Estonia	0	0	0	0	0.004	0	0	0
Finland	0	0	0	0	0.0113	0	0	0
France	0	0	0	0	0.3094	0	0	0
Germany	0	0	0	0	0.604	0	0	0
Greece	0	0	0	0	0.055	0	0	0
Hungary	0	0	0	0	0.0488	0	0	0
Ireland	0	0	0	0	0.0398	0	0	0
Italy	0	0	0	0	0.2949	0	0	0
Latvia	0	0	0	0	0.0054	0	0	0
Lithuania	0	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0
Netherland	0	0	0	0	0.1594	0	0	0
Poland	0	0	0	0	0.1938	0	0	0
Portugal	0	0	0	0	0.0486	0	0	0
Romania	0	0	0	0	0	0	0	0
Slovakia	0	0	0	0	0.025	0	0	0
Slovenia	0	0	0	0	0.0133	0	0	0
Spain	0	0	0	0	0.1995	0	0	0
Sweden	0	0	0	0	0.0215	0	0	0
United Kingdom	0	0	0	0	0.3929	0	0	0

YOLL PM2.5								
bn €	Buildings Residential refurbishment	Buildings residential new dwellings	Buildings residential lighting	Buildings residential cold appliances	Buildings tertiary refurbishment	Buildings tertiary new dwellings	Buildings tertiary lighting	Buildings tertiary cold appliances
Austria	0.5236	0.0481	0.0141	0.0063	0.1903	0.0204	0.0294	0.0134
Belgium	1.2266	0.2645	0.0542	0.0179	0.5443	0.0771	0.0858	0.0203
Bulgaria	0.1657	0.1091	0.0076	0.0035	0.0847	0.0194	0.0273	0.0091
Croatia	0.157	0.1048	0.0125	0.0053	0.1092	0.0049	0.0183	0.0083
Cyprus	0.0017	0.0015	0.001	0.0001	0.0057	0.0007	0.0009	0.0006
Czech Republic	0.5739	0.0971	0.0097	0.0071	0.3381	0.0393	0.0373	0.0127
Denmark	0.4013	0.065	0.0216	0.0052	0.0407	0.0053	0.0345	0.0073
Estonia	0.0357	0.0057	0.0018	0.0004	0.0233	0.0025	0.0031	0.001
Finland	0.1891	0.0098	0.0067	0.0013	0.0103	0.0006	0.0146	0.0024
France	5.7509	0.7898	0.1381	0.0817	1.7229	0.1735	0.6712	0.1223
Germany	5.7299	0.721	0.1251	0.0771	1.6921	0.2188	0.8862	0.1168
Greece	1.1901	0.2339	0.0797	0.0182	0.3568	0.0655	0.0908	0.0403
Hungary	0.6339	0.5479	0.0529	0.0106	0.3666	0.0445	0.0766	0.0182
Ireland	0.103	0.0123	0.0069	0.0015	0.0704	0.0089	0.0098	0.0032
Italy	6.7081	0.4879	0.1881	0.0711	2.0481	0.4463	0.3036	0.1452
Latvia	0.114	0.0396	0.0047	0.0011	0.0606	0.008	0.0058	0.0028
Lithuania	0.0819	0.0603	0.0043	0.0013	0.0229	0.0008	0.0089	0.0023
Luxembourg	0.0194	0.0055	0.0009	0.0001	0.0006	0.0083	0.0012	0.0007
Malta	0.0055	0.0041	0.0012	0.0004	0.0034	0.0019	0.0024	0.0009
Netherland	0.9372	0.1698	0.0339	0.0151	0.596	0.0855	0.1196	0.0236
Poland	4.8895	0.8638	0.2162	0.0559	1.005	0.1089	0.4613	0.1072
Portugal	0.0377	0.1337	0.0184	0.0067	0.1007	0.002	0.0395	0.0134
Romania	0.7863	0.2509	0.0504	0.0195	0.188	0.0187	0.0329	0.0222
Slovakia	0.1153	0.0425	0.004	0.0028	0.2941	0.0508	0.0167	0.0059
Slovenia	0.1234	0.0324	0.004	0.0024	0.0714	0.0016	0.0154	0.0037
Spain	0.5759	1.0914	0.0663	0.0172	0.5404	0.0795	0.1104	0.0602
Sweden	0.2858	0.0276	0.017	0.0027	0.0221	0.0021	0.0201	0.007
United Kingdom	7.2844	0.6866	0.2609	0.1141	1.1636	0.2278	0.8566	0.1425

EU Figures

Energy imports as a share of GDP			**Source: E3ME, Cambridge Econometrics**	
BE	0.092	0.091	0.091	0.09
DK	0.015	0.014	0.014	0.014
DE	0.031	0.031	0.03	0.029
EL	0.045	0.043	0.041	0.039
ES	0.025	0.025	0.024	0.023
FR	0.04	0.039	0.038	0.038
IE	0.02	0.02	0.02	0.02
IT	0.029	0.027	0.027	0.027
LU	0.033	0.033	0.033	0.033
NL	0.092	0.091	0.091	0.089
AT	0.033	0.033	0.032	0.03
PT	0.051	0.051	0.05	0.049
FI	0.013	0.012	0.012	0.011
SE	0.036	0.036	0.035	0.034
UK	0.024	0.023	0.021	0.02
CZ	0.028	0.025	0.023	0.021
EE	0.057	0.057	0.055	0.053
CY	0.054	0.052	0.051	0.047
LV	0.174	0.173	0.173	0.16
LT	0.293	0.294	0.294	0.295
HU	0.032	0.031	0.03	0.028
MT	0.047	0.034	0.029	0.028
PL	0.046	0.045	0.045	0.043
SI	0.044	0.04	0.038	0.036
SK	0.069	0.066	0.065	0.063
BG	0.045	0.044	0.044	0.043
RO	0.059	0.058	0.058	0.058
HR	0.057	0.054	0.051	0.05
EU	0.037	0.036	0.035	0.034

Change in health-related costs, scenario S1, m€ per year						
	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-0.1	0	0	-0.7	0	-0.1
DK	0	0	0	-0.2	0	0
DE	-0.4	0	0	-4.1	-0.2	-0.3
EL	0.2	0	0	-0.1	0	0
ES	-0.1	0	0	-1.2	-0.1	-0.1
FR	-0.3	0	0	-3.5	-0.2	-0.3
IE	0	0	0	-0.2	0	0
IT	-0.2	0	0	-2.4	-0.2	-0.3
LU	0	0	0	-0.1	0	0
NL	-0.1	0	0	-0.8	-0.1	-0.1
AT	0	0	0	-0.5	0	0
PT	-0.1	0	0	-1.3	-0.1	-0.1
FI	0	0	0	-0.4	0	0
SE	0	0	0	-0.4	0	0
UK	-0.4	0	0	-4.8	-0.2	-0.3
CZ	-0.1	0	0	-0.6	0	-0.1
EE	0	0	0	-0.1	0	0
CY	0	0	0	0	0	0
LV	0	0	0	-0.1	0	0
LT	0	0	0	-0.1	0	0
HU	-0.1	0	0	-0.6	0	-0.1
MT	0	0	0	0	0	0
PL	0	0	0	-0.3	0	0
SI	0	0	0	-0.2	0	0
SK	0	0	0	-0.1	0	0
BG	0	0	0	-0.2	0	0
RO	-0.1	0	0	-0.7	0	-0.1
HR	0	0	0	-0.3	0	0
EU	-2	-0.1	-0.2	-24	-1.4	-2.3

Change in health-related costs, scenario S2, m€ per year						
	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-2.6	-0.1	-0.2	-5.8	-0.3	-0.4
DK	-0.6	0	-0.1	-1.6	-0.1	-0.2
DE	-15.1	-0.7	-1.2	-41.2	-2	-3.3
EL	-1.8	-0.1	-0.1	-5	-0.3	-0.4
ES	-4.5	-0.3	-0.6	-12.2	-0.9	-1.6
FR	-13.2	-0.8	-1.3	-35.8	-2.1	-3.5
IE	-0.9	0	-0.1	-2.5	-0.1	-0.2
IT	-9.1	-0.8	-1.3	-24.7	-2.1	-3.4
LU	-0.2	0	0	-0.6	0	0
NL	-3.2	-0.2	-0.4	-8.6	-0.6	-1.1
AT	-1.9	-0.1	-0.1	-5.3	-0.2	-0.4
PT	-5	-0.3	-0.5	-13.5	-0.7	-1.2
FI	-1.3	-0.1	-0.2	-3.6	-0.2	-0.4
SE	-1.4	-0.1	-0.1	-3.7	-0.2	-0.4
UK	-17.7	-0.7	-1.2	-48.3	-2	-3.3
CZ	-2.4	-0.2	-0.3	-6.6	-0.4	-0.7
EE	-0.3	0	0	-0.8	-0.1	-0.1
CY	-0.1	0	0	-0.4	0	-0.1
LV	-0.5	0	-0.1	-1.5	-0.1	-0.2
LT	-0.5	0	-0.1	-1.3	-0.1	-0.2
HU	-2.2	-0.1	-0.2	-6	-0.3	-0.5
MT	0	0	0	-0.1	0	0
PL	-0.9	-0.1	-0.2	-2.6	-0.3	-0.5
SI	-0.9	-0.1	-0.1	-2.5	-0.2	-0.3
SK	-0.4	0	0	-1.1	-0.1	-0.1
BG	-0.8	-0.1	-0.1	-2.2	-0.2	-0.4
RO	-2.6	-0.2	-0.3	-7	-0.4	-0.7
HR	-1	0	-0.1	-2.6	-0.1	-0.2
EU	-91.1	-5.2	-8.7	-246.8	-14.2	-23.7

Change in health-related costs, scenario S3, m€ per year						
	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-10.5	-0.5	-0.8	-21.3	-1	-1.6
DK	-2.3	-0.2	-0.3	-5.9	-0.4	-0.6
DE	-61.1	-2.9	-4.9	-154.7	-7.4	-12.3
EL	-6.8	-0.3	-0.5	-18.5	-0.9	-1.5
ES	-18.1	-1.4	-2.3	-45.9	-3.5	-5.8
FR	-53.2	-3.1	-5.2	-134.5	-7.9	-13.2
IE	-3.7	-0.2	-0.3	-9.3	-0.4	-0.7
IT	-36.7	-3.1	-5.1	-92.7	-7.7	-12.9
LU	-0.8	0	-0.1	-2.1	-0.1	-0.2
NL	-12.7	-0.9	-1.6	-32.2	-2.4	-4
AT	-7.8	-0.4	-0.6	-19.8	-0.9	-1.5
PT	-3.8	-0.4	-0.7	-9.6	-1.1	-1.8
FI	-5.4	-0.4	-0.6	-13.6	-0.9	-1.5
SE	-5.5	-0.3	-0.5	-13.8	-0.8	-1.3
UK	-71.6	-2.9	-4.9	-181.2	-7.4	-12.4
CZ	-9.8	-0.6	-1.1	-24.7	-1.6	-2.7
EE	-1.2	-0.1	-0.1	-3	-0.2	-0.4
CY	-0.6	-0.1	-0.1	-1.5	-0.2	-0.3
LV	-2.2	-0.1	-0.2	-5.5	-0.3	-0.6
LT	-1.9	-0.1	-0.2	-4.8	-0.4	-0.6
HU	-8.9	-0.5	-0.8	-22.6	-1.2	-1.9
MT	-0.1	0	0	-0.3	0	0
PL	-20.1	-1.1	-1.9	-50.9	-2.8	-4.7
SI	-3.6	-0.3	-0.5	-9.2	-0.8	-1.3
SK	-1.7	-0.1	-0.1	-4.2	-0.2	-0.4
BG	-3.2	-0.3	-0.5	-8.2	-0.8	-1.4
RO	-10.4	-0.6	-1	-26.3	-1.6	-2.7
HR	-3.9	-0.2	-0.3	-9.8	-0.4	-0.7
EU	-367.6	-21.2	-35.3	-925.9	-53.4	-88.9

Final energy consumption in 2030, % difference from reference case			
	For the whole economy		
	S1	**S2**	**S3**
BE	-0.3	-1.6	-5.4
DK	-0.2	-1	-3.4
DE	-0.4	-1.8	-6.2
EL	-1	-3.4	-10
ES	-0.3	-1.5	-4.9
FR	-0.4	-2.1	-7.1
IE	-0.3	-2.1	-7.3
IT	-0.4	-1.8	-6
LU	-0.2	-1	-3.6
NL	-0.3	-1.5	-5.5
AT	-0.3	-1.8	-6.5
PT	-0.3	-1.3	-4.3
FI	-0.1	-1.1	-4.3
SE	-0.1	-0.9	-3.4
UK	-0.6	-3.6	-12.4
CZ	-0.5	-2.6	-8.2
EE	-0.7	-2.9	-9.1
CY	-0.8	-2.5	-7.3
LV	-0.3	-2.2	-8.9
LT	0.1	-1	-4.3
HU	-0.5	-2.7	-9.5
MT	-0.6	-1.7	-4.9
PL	-0.2	-1.4	-5.1
SI	-0.8	-4.8	-16.7
SK	-0.1	-0.9	-3.2
BG	-0.9	-3.1	-8.2
RO	-2.9	-7.4	-13.5
HR	-0.8	-3.7	-12.1
EU	-0.4	-2.1	-6.9

Impact on CO2 and GHG emissions in 2030, % difference from reference case			
	For the whole economy		
	S1	**S2**	**S3**
BE	-0.4	-2	-7
DK	-0.2	-0.8	-2.9
DE	-0.4	-1.6	-5.4
EL	-0.9	-2.7	-7.9
ES	-0.4	-1.6	-4.5
FR	-0.6	-2.4	-7.7
IE	-0.2	-1.1	-3.9
IT	-0.5	-1.8	-5.3
LU	-0.2	-1.3	-4.8
NL	-0.3	-1.7	-6.1
AT	-0.3	-1.6	-5.6
PT	-0.4	-1.3	-3.9
FI	-0.2	-0.8	-2.5
SE	-0.2	-0.8	-1.4
UK	-0.4	-2.9	-10.2
CZ	-0.5	-2.7	-7.6
EE	-0.4	-1.6	-4.7
CY	5.2	2.6	-5
LV	-0.1	-0.1	-0.3
LT	-0.2	-1.1	-3.7
HU	-0.3	-2.5	-8.7
MT	3.1	1.6	-3.2
PL	-0.1	-0.7	-2.7
SI	-1	-5.3	-15.5
SK	-0.1	-0.8	-2.9
BG	-1	-3.1	-8.3
RO	-2.2	-5.8	-10.7
HR	-1.4	-3.6	-10
EU	-0.4	-1.9	-6

Impacts on material consumption			
DMC in 2030, % difference from reference case			
	S1	**S2**	**S3**
BE	-0.03	-0.03	-0.02
DK	0.42	0.65	1.34
DE	-0.02	-0.03	-0.04
EL	0.2	0.38	0.7
ES	0.09	0.2	0.31
FR	0.05	0.16	0.48
IE	0.11	0.24	0.51
IT	0.17	0.48	0.73
LU	0.16	0.36	0.77
NL	0.02	0.09	0.25
AT	0.02	0.1	0.38
PT	0.59	1.28	1.77
FI	0.01	0.03	0.07
SE	1.7	3.06	5.37
UK	-0.02	-0.06	-0.13
CZ	0.46	0.98	1.63
EE	0.42	0.89	2.07
CY	0.21	0.5	1.08
LV	0.3	0.75	1.28
LT	-0.03	0.34	1.24
HU	1.08	2.2	4.29
MT	0.09	0.16	0.29
PL	0.25	0.57	1.3
SI	2.44	5.29	10.4
SK	0.37	0.83	1.68
BG	-0.76	-1.56	-3.17
RO	8.22	28.11	38.16
HR	-0.07	-0.19	-0.29
EU	0.26	0.81	1.21

Air pollution			
CO Emissions in 2030, % difference from reference scenario			
	S1	**S2**	**S3**
BE	-0.2	-1.2	-4.1
DK	-0.2	-1.1	-3.8
DE	-0.2	-1.1	-4.2
EL	-0.7	-2.4	-7
ES	-0.4	-1.6	-5.1
FR	-0.4	-2.4	-8.5
IE	-0.3	-2.2	-7.9
IT	-0.1	-0.6	-2
LU	0	-0.1	-0.6
NL	-0.3	-1.2	-3.8
AT	-0.4	-2.4	-8.6
PT	-0.5	-2.5	-8.6
FI	-0.1	-1.7	-6.7
SE	-0.1	-1.1	-4.1
UK	-0.2	-1.5	-4.7
CZ	-0.3	-1.9	-6.3
EE	-0.7	-2.8	-9.1
CY	0.4	0.2	-0.5
LV	-0.4	-3.2	-12.5
LT	0.3	-1.4	-6.7
HU	-0.2	-0.8	-2.6
MT	0.7	0.3	-1
PL	-0.2	-1.7	-6.4
SI	-1.3	-7.6	-26.4
SK	-0.1	-0.2	-0.9
BG	-0.9	-3	-7.8
RO	-3.4	-8.6	-15.5
HR	-0.3	-1.4	-4.9
EU	-0.5	-2.1	-6.3

SO2 Emissions in 2030, % difference from reference scenario			
	S1	**S2**	**S3**
BE	-0.4	-2.2	-6.5
DK	0	-0.5	-1.8
DE	-0.3	-1.5	-5.3
EL	-1.6	-4.5	-15.7
ES	-0.4	-1.9	-6.6
FR	0	-3.1	-10.8
IE	-0.2	-2.2	-7.2
IT	0.5	-0.5	-2.7
LU	-0.2	-1.1	-4
NL	-0.2	-1.1	-4.2
AT	-0.2	-0.9	-3.2
PT	0.3	-0.7	-5
FI	-0.3	-2.5	-9.7
SE	0	-0.6	-2.4
UK	-0.3	-2.2	-6.4
CZ	-0.4	-2.4	-7.5
EE	-0.7	-2.5	-8.7
CY	12.5	7.9	-5.2
LV	0	-2.6	-11.9
LT	0.3	-1.9	-8
HU	0	-2.1	-7.3
MT	6.5	4.3	-2.6
PL	0.1	-1.2	-4.9
SI	-1.2	-7.1	-32.8
SK	0.1	-0.7	-2.7
BG	-1.9	-5.5	-15.8
RO	-3.1	-8.2	-13
HR	0.2	-3	-12.8
EU	-0.2	-2.2	-7.5

KJ-NA-30280-EN-N

The European Commission's science and knowledge service

Joint Research Centre

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

EU Science, Research and Innovation

EU Science Hub

Publications Office
of the European Union

doi:10.2760/314081

ISBN 978-92-76-19983-0