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Prevention of Waste in the Circular Economy: Analysis of Strategies and Identification of Sustainable Targets

The food waste example

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Contents

Abstract

This report continues and further advances the work conducted by the JRC in the field of sustainable management of food waste, which resulted in the publication of the 2015 report "Improving Sustainability and Circularity of European Food Waste Management with a Life Cycle Approach".

It focuses on the broad European waste management context and, in particular, provides insight and analysis on the sustainability of food waste prevention strategies. Among other municipal waste streams, food waste gained prominence in the political debate in light of the recent Circular Economy (CE) package. In fact, the CE Action Plan included food waste within the so-called "priority areas", i.e. areas that should be carefully considered to strengthen the circularity of the European economy.

Against this background, this report analyses and evaluates the efficacy of some selected strategies for food waste prevention implemented at Member States' and regional levels. A streamlined 'stakeholder analysis' is also developed in order to identify the most relevant stakeholders along the food supply chain and analyse their influence/relation with the mechanisms that lead to food wastage. Moreover, the report presents a novel and straightforward life cycle based methodology that helps identifying sustainable targets for food waste prevention in different contexts.

The analysis of food waste prevention strategies being implemented by Member States and presented in this report seems to indicate that reducing food waste generation is a very complex to achieve in practice. The key reasons for this are the complexity of the food supply chain and the fact that a variety of integrated and well-coordinated measures that involve all stakeholders along the food supply chain need to be adopted to effectively tackle the problem. Moreover, sometimes the lack of reliable and coherent data is posing a threat to the successful identification of the most appropriate measures. It is also noted that food waste prevention measures are often set without considering how their implementation will influence the sustainability performance of food waste management.

On the other hand, this report stresses that the definition of food waste prevention targets should follow the definition of the desired improvement of the overall sustainability performance. Towards this goal, the methodology presented in this report tries to identify environmentally sustainable targets for food waste prevention that allows achieving a given reduction of the environmental impacts along the food supply chain.

1 Background and introduction

1.1 Scope, objectives and structure of the report

This report focuses on the European waste management context and, in particular, provides insight and analysis on the sustainability of food waste prevention. Among other municipal waste streams, food waste gained prominence in the political debate in light of the recent Circular Economy (CE) package (EC, 2015a). In fact, the CE Action Plan (EC, 2015b) included food waste within the so-called "priority areas", i.e. areas that should be carefully considered to strengthen the circularity of the European economy (more details are provided chapter 1.3.1).

Against this background, this report aims at analysing and evaluating the efficacy of some selected strategies for food waste prevention implemented at Member States' and regional levels. This analysis is expected to provide relevant insights for policy makers and waste managers, in terms e.g. of the type(s) of measures included in such prevention strategies that are more efficient in reducing food waste generation and are, at the same time, sustainable. Moreover, the report aims at advancing a straightforward, life cycle based methodology that helps identify sustainable targets for food waste prevention in different contexts.

Chapter 2 gives insights on the sustainability aspects related to food waste management. Chapter 3 provides an analysis of the key identified stakeholders within the food waste sector. Chapter 4 analyses and evaluates a number of selected food waste prevention measures and strategies, thus it helps to develop the knowledge base for the methodology presented in Chapter 5, which is meant to enable the calculation of sustainable food waste prevention targets.

1.2 Prevention of waste in the Circular Economy: policy context

The key principle upon which European waste management is based is the so-called "waste hierarchy". The waste hierarchy, established in article 4(1) of the Waste Framework Directive (WFD) 2008/98/EC (EC, 2008), is a legally binding priority order for waste management intended to ensure that the most environmentally sound waste management options are chosen (Figure 1). According to this principle, the preferable option from an environmental point of view is waste "prevention". Article 3(12) of the WFD defines "prevention" as the "*measures taken before a substance, material or product has become waste, that reduce: (a) the quantity of waste […], (b) the adverse impacts of the generated waste […], (c) the content of harmful substances […]".* Since an overarching goal of European waste management is to minimise its environmental impacts, article 4(2) of the WFD opens to deviations from the "waste hierarchy" when evidence based on Life Cycle Thinking (LCT) shows that these deviations lead to a better overall environmental outcome, i.e. are environmentally preferable to the preference indicated by the hierarchy (Figure 1).

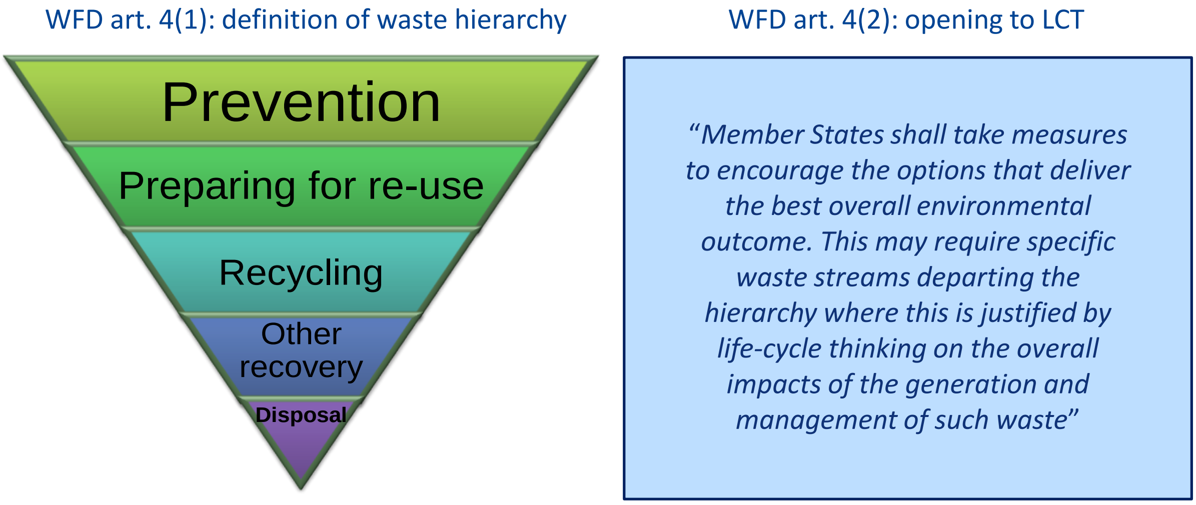

Figure 1: Waste hierarchy and Life Cycle Thinking (LCT) as introduced by the Waste Framework Directive 2008/98/EC

Before the WFD was released, other EC's policy documents explicitly stressed on the importance of waste prevention to achieve sustainable use of resources, such as the "Thematic Strategy on the prevention and recycling of waste" COM(2005)666 (EC, 2005). But, it is with the WFD that the first mandatory provisions are established. Article 28 of the WFD, for instance, requires Member States (MS) to prepare so-called "waste management plans". These should show how MS are tackling the implementation of the objectives and provisions made by the WFD and, in particular, the implementation of the waste hierarchy. In addition, further stressing on the strategic importance of waste prevention, MS are required to develop "waste prevention programme" (article 29), which shall clearly identify waste prevention measures and targets. To support MS in the development of their waste prevention programmes, the Commission prepared general guidelines (EC, 2012a), as well as guidelines specifically focused on food waste (EC, 2011a). The WFD also established a legal obligation for MS to adopt their waste prevention programmes by December 12th, 2013 and gave mandate to the European Environmental Agency (EEA) to annually review the progresses made by MS in the "*completion and implementation of the programmes*" (EEA, 2014 and 2015)

Several other European policy documents have stressed on the importance of designing European waste management in a way that effective prevention measures can be implemented.

On December 2nd 2015, the Circular Economy (CE) package (EC, 2015a) was launched. Its Action Plan (EC, 2015b) recognises that "*the transition to a more circular economy, where […] the generation of waste is minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy*". Taking a supply-chain approach, it stresses that "*waste management plays a central role in the circular economy: it determines how the EU waste hierarchy is put into practice*".

1.3 The food waste example

1.3.1 Overview

The CE Action Plan (EC, 2015b) also identifies a number of "priority areas" that should be carefully considered to strengthen the circularity of the European economy, and among these it includes "food waste" (the other being plastics, critical raw materials, construction and demolition waste, biomass and bio-based products).

Specifically, for food waste the CE Action Plan establishes a 50% reduction target of food waste generation to be achieved by 2030, in line with the target set by the United Nation General Assembly as part of the 2030 Sustainable Development Goals. It indicates that "*The Commission will elaborate a common EU methodology to measure food waste in close cooperation with Member States and stakeholders*". It recognises that "*Food waste is an increasing concern in Europe. The production, distribution and storage of food use natural resources and generate environmental impacts […] and cause financial losses for consumers and the economy. Food waste has also an important social angle […]".* Furthermore, the new package stresses that "*Action by Member States, regions, cities, and business along the value chain is essential to prevent food waste […]. The Commission supports […] the dissemination of good practices in food waste prevention."* The Circular Economy package, thus clearly recognises that preventing food wastage is a key step towards increasing the circularity of the European economy.

The Commission has actively supported several initiatives aimed at improving the sustainability of food waste management in Europe, as well as evaluating the environmental, economic and social consequences of food waste prevention. Among these, perhaps the FUSIONS (FP7)[1] project has produced the most comprehensive analytical outputs (an overview is provided in Section 2.6).

1.3.2 Definitions

European legislation includes food waste within the broader group of biodegradable wastes. The Landfill directive 1999/31/EC (EC, 1999) defined biodegradable wastes as "*any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and cardboard*". The Waste Framework Directive 2008/98/EC (EC, 2008) narrowed the definition to bio-waste as "[…] *biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants*". More recently, there have been attempts to define food waste including the concepts of edible which includes avoidable and possibly avoidable food waste and inedible (e.g. WRAP, 2009; EC, 2010).

It is clear that, in order to effectively mitigate food waste generation, the development of a widely agreed and legally binding definition of 'food waste' at European level (and beyond) is needed. A clear differentiation among unavoidable food waste, by-products and avoidable food waste is key to improve the quantification and the databases used in the food waste prevention studies (Priefer et al., 2016).

There are two main frameworks concerning food waste definition:

- FUSIONS' Definitional Framework (adopted in this report): FUSIONS (EC, 2016) has tried to harmonise the current definition within the EU28, making its perimeter wider and broader than many other existing definitions. "Food waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composed, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea) but not including food or inedible parts of food removed from the food supply chain to be sent to animal feed or bio-based material/chemistry processing".

[1] http://www.eu-fusions.org/

- FAO's Definitional Framework: food waste is delimited by the food loss, food waste and food wastage concepts (FAO, 2013).
    - Food loss – refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption.
    - Food waste – refers to food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil.
    - Food wastage – refers to any food lost by deterioration or waste. Thus, including both food loss and food waste.

Food wastage accounts for:

- products that are directed to human consumption (including food that originally grown in the perspective of human consumption but which unwittingly leave the human food chain).
- both edible and non-edible parts of the food.

But, it does not account for:

- feed and agricultural products given to animals.

1.3.3 Quantification of food waste generation

A reliable and accurate measurement of the amount(s) of food waste generated along the Food Supply Chain (hereinafter called "FSC") is obviously of crucial importance. As reported by the "Food waste quantification Manual" of the EC-funded "FUSIONS" project: "*Although food waste prevention efforts can be initiated without having detailed information on the amounts of food waste, food waste quantification would be necessary in order to get a better understanding of the magnitude and location of food waste arising within the food chain which may inform waste prevention measures. This will, in turn, allow better defining, prioritizing and targeting of prevention efforts, as well as tracking progress in food waste prevention over time*" (EC, 2016).

In addition to FUSIONS, there exist other initiatives on food waste quantification such as: the Food Loss & Waste Protocol of the World Resource Institute[2] (FLW Protocol, 2016) that presented The FLW Protocol Accounting and Reporting Standard (FLW Standard); the FAO's Global Data on Food Loses and Global Food Loss Index[3] (GFLI); and the 2014 Eurostat "Food waste plug-in", which is based on the voluntary contributions of 14 Member States.

Brautigam et al., (2014) reviewed the availability and reliability of food waste data for EU-27. The authors noticed that there are two main studies dealing with pan-European data on food waste in line with the two frameworks explained in the previous subsection: one by FAO and the other one by the European Commission.

- FAO includes the food waste generation at all stages of the supply chain, including agricultural production and with a detailed broken down to product groups. For the physical quantification of the production volumes for all commodities, the FAOSTAT database[4] is used. This offer the opportunity to calculate food waste generation in EU and globally without the availability of original food waste data. In order to determine the part of the production oriented to human consumption and the edible mass, allocation and conversion factors respectively were used. Food losses and waste are estimated using a

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2 http://www.wri.org/our-work/project/food-loss-waste-protocol
3 http://www.fao.org/platform-food-loss-waste/food-loss/food-loss-measurement/en/
4 http://faostat3.fao.org/home/E

mass flow model (FAO's Food Balance Sheet) at each stage of the food supply chain. In case of knowledge gaps, assumptions and estimations based on food waste levels in comparable regions, commodity groups and/or steps of the FSC are made.

- The EC addresses the generation of food waste along all stages of the food chain for EU27 excluding agricultural production. Besides, a number of product groups are also excluded. For the calculation of the food wastage amounts mainly EUROSTAT database is used. When knowledge gaps exist, national surveys and extrapolations are used. The accuracy of the calculations is mainly based on the consistency and comparability of the data reported by the Member States. The FUSIONS project presented a food waste quantification manual "to provide practical guidelines for a standard approach for EU Member States on how to quantify food waste in different stages of the food supply chain" (EC, 2016). This manual is in line with the FLW Standard and the quantification methodologies (in the appendix 3 of the manual) are in harmony with the Protocol approach.

Since different methods for quantifying food waste and different databases for the calculation are used (e.g. FAOSTAT and EUROSTAT), reported results and figures differ significantly as shown Table 1.

Table 1: Food waste estimations

Reference Study	Reference Year Of Data	Geographical Scope	Food Waste Generation (per year)	Food Waste Generation (per capita and per year)
EC, DG ESTAT, food waste plug-in[5]	2012	14 MS in the EU	-	127 kg
FAO[6]	2007	EU27+Rusia	245 Mt	335 kg
EC[7]	2006	EU27	89.2 Mt	179 kg
EUROSTAT[8]	2007	EU27	116 Mt	234 kg
FAO[9]	2006	EU27+Rusia	195 Mt	298 kg
Brautigam et al. 2014 – Table 2	2006	EU27	142.7 Mt	288.5 kg

[5] This is based on preliminary results (from 14 MS) from the "PLUG IN EXERCISE" on food waste coordinated by EUROSTAT in 2014/2015

[6] http://www.fao.org/docrep/018/ar429e/ar429e.pdf

[7] In this study the food waste generated during agricultural activities is not included in the reported data, which are shown with split by sector involved in the FSC instead of by FSC stage (e.g. the manufacturing sector is considered to include the post-harvesting and processing stages of the FSC). http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/Task%203-Food%20waste.pdf

[8] In this case estimations are calculated as tonnes of wastes reported in 'total animal and vegetal wastes' minus the ones reported in 'animal faeces, urine and manure'. There is some uncertainty in the estimations since green wastes could be accounted for.

[9] FAO considers allocation factors to determine the part diverted to human consumption and conversion factors to determine the edible part. This fact results in around 1.3 billion tonnes of food waste generated globally, approximately 15% of which are generated in Europe (195 million tonnes). Details of the calculation in Manfredi et a., (2016)

- FAO				

2 Analysis of sustainability aspects along the food supply chain

2.1 Overview

Extensive scientific literature has been produced to provide assessment of the environmental performance of waste management systems and strategies (e.g. Arafat et al., 2015; Pressley et al., 2014; Christensen et al., 2009). At the same time, research initiatives have also focused on specific waste streams, as opposed to focusing on e.g. the overall Municipal Solid Waste (MSW). For instance, a number of studies were undertaken to identify key drivers of food wastage and to quantify food waste generation (e.g. Priefer et al., 2016; EC, 2016 and 2010a; Brautigam et al, 2014; FAO 2011).

While these initiatives provided fairly accurate information over European food waste generation quantities and management routes, they did not always deliver comprehensive and comparable information on the sustainability of food waste management and on ways to mitigate negative consequences at the levels of the three so-called "sustainability dimensions": environmental, economic and social. Most studies, in fact, only focus on one specific sustainability dimension, e.g. only the environmental (Nakakubo et al., 2012) or the economic (Kim et al., 2011) dimension.

This is currently changing due to increasingly challenging sustainability targets and requirements enforced by recent legislation – such as the Communication "A resource-efficient Europe" under the EU 2020 Strategy (EC, 2011b) and the Communication on Circular Economy (EC, 2015a and 2015b) – which have boosted research also on the methodological side, e.g. towards developing methods to evaluate resource efficiency and sustainability. Room for improvements exists, especially to harmonize current assessment approaches and adapt them to the specific context of food waste management.

Building on the achievement made with the development of life-cycle indicators to quantify and monitor the environmental performance of European consumption and production (EC 2012b, 2012c, 2012d & 2012e), the Commission is currently developing indicators specifically focused on the food supply chains; sub-chapter 2.2.1 presents the latest development. Furthermore, initiatives such as the EC Product Environmental Footprint (PEF) pilot and the Sustainable Consumption and Production Food Round Table – although not specifically targeting food waste – inevitably integrate the issue of food waste and waste management in their studies. A description of these initiatives and their relation with food and food waste is given in sub-chapter 2.2.2 The Commission is also promoting evaluation of the social implications of food waste prevention and food waste management. A brief overview is provided in sub-chapter 2.3.

Towards providing a valuable tool to support science-based policy making and decision making, the European Commission presented a life-cycle based framework methodology that allows quantifying the environmental and economic performance of European food waste management (EC, 2015c; Manfredi & Cristobal, 2016). The methodology makes use of a comprehensive set of indicators that provide comprehensive assessment of environmental aspects (12 indicators) and economic aspects (3 indicators). Sub-chapter 2.4 provides an overview.

FAO produced the first ever global Food Wastage Footprint (FWF) using an LCA model to quantify and assess the magnitude of the environmental impacts of food wastage. The FWF is focused in the embedded water, soil, biodiversity and greenhouse gases in the food wastage at the global level. In addition to that, the FWF project translated the environmental impacts of food wastage into societal costs, measured in monetary terms, through a full-cost accounting methodology to evaluate the direct financial costs. A brief overview is provided in sub-chapter 2.5.

Moving towards a comprehensive assessment of all dimensions of sustainability, the EU-funded FUSIONS project has provided – among various outputs – also an impact assessment that covers the following topics (EC, 2015d):

- Impacts on health and nutrition of food waste;
- Socio-economic impacts of food waste;
- Social impacts from food redistribution organisations;
- Environmental impacts of food waste.

Sub-chapter 2.6 provides a brief overview of the FUSIONS initiative.

2.2 Evaluation of environmental impacts

2.2.1 Life cycle indicators (Basket on food)

In order to comprehensively assess the impact of food consumption at EU level, in 2012 the European Commission's Joint Research Centre developed a lifecycle-based methodology that focuses on specific representative products which are then up-scaled to overall EU consumption figures, named the Basket-of-Products (BoP) indicators (EC, 2012d). The project (called LC-IND) focused on indicators that measure the environmental impact of the consumption of goods and services by the average European citizen, focusing on housing, food and transport, via the identification and environmental assessment of the most representative products of each category (basket of products).

Concerning the basket on food, its scope is the consumption of food and beverage by EU citizens using as functional unit "the food consumption of an average EU citizen in one year". The composition of the basket reflects the relative importance of the products categories in terms of mass and economic value (

Table 2) and the 100% of the products in the BoP covers 58% of the foods consumed by and average EU citizen in one year.

Table 2: Basket of products on food

Product Groups	Basket product	Per-capita consumption (kg/pers.yr^{-1})	Per-capita consumption %
MEAT	Pig meat	41.0	*7.6%*
	Beef	13.7	*2.5%*
	Poultry	22.9	*4.2%*
DAIRY	Milk & Cream	80.1	*14.8%*
	Cheese	15.0	*2.8%*
	Butter	3.6	*0.7%*
CEREAL-BASED	Bread	39.3	*7.3%*
SUGAR	Sugar	29.8	*5.5%*
OILS	Sunflower oil	5.4	*1%*
	Olive oil	5.3	*1%*
VEGETABLES	Potatoes	70.1	*13%*
FRUIT	Oranges	17.4	*3.2%*

	Apples	16.1	*3%*
BEVERAGES	Mineral water	105.0 L	*19.4%*
	Roasted Coffee	3.5	*0.6%*
	Beer	69.8 L	*12.9%*
PRE-PREPARED MEALS	Meat based dishes	2.9	*0.5%*
Total		540.9	*100%*

Results obtained in the LC-IND project are interesting in the context of this report. Results are presented in many different ways such as contribution by life cycle stages in different impact categories, contribution by product group in different impact categories and relevance of impact categories in the whole basket. Very useful are the environmental impacts calculated by FSC and by stage of FSC in Europe for each product, as shown in Figure 2 (e.g. for the Climate change impact category).

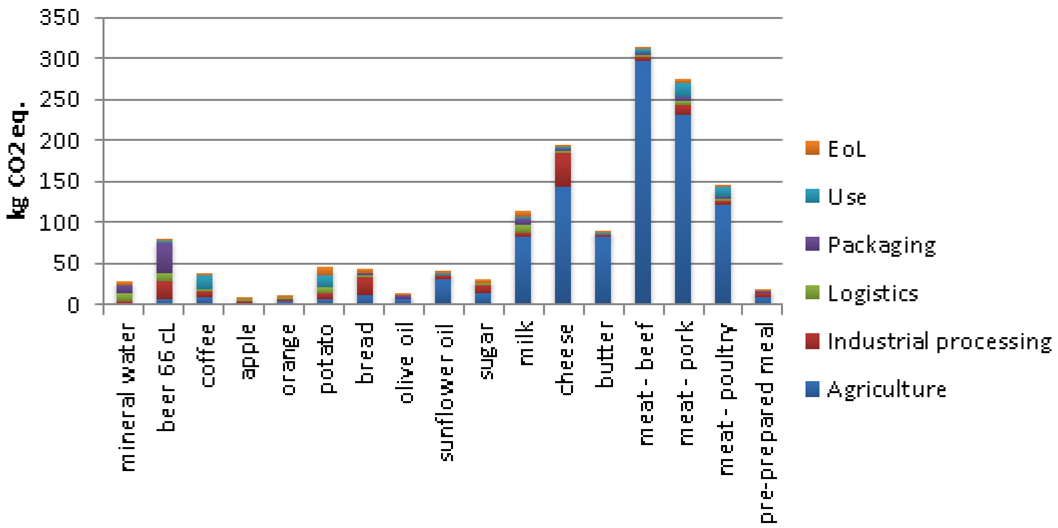

Figure 2: Climate change for one EU-27 citizen due to the consumption of food products

2.2.2 Product Environmental Footprint (PEF)

In the context of the Communication "Building the Single Market for Green Products" COM(2013)196 (EC, 2013a), the European Commission (EC) recommends a method to measure the environmental performance of products and organisations, named the Product Environmental Footprint (EC, 2013b) and Organisations Environmental Footprint (EC, 2013c).

The PEF is a multi-criteria measure of the environmental performance of goods and services from a life cycle perspective. PEF studies are produced for the overarching purpose of identifying and seeking to reduce the environmental impacts associated with goods and services, taking into account supply chain activities (from extraction of raw materials, through production and use, to final waste management). As the PEF guidelines are overall guidelines that have to be applicable to all products, additional product specific guidelines are needed. To address this issue, the EC launched in 2013 a three-year pilot project to develop Product Environmental Footprint Category Rules (PEFCRs) that provide category-specific guidance for calculating and reporting life cycle environmental impacts of products in a harmonised way.

The main reason for this activity is that existing life cycle-based standards do not provide sufficient specificity to ensure that consistent assumptions and measurements are made to potentially enable comparable environmental claims. In order to address that limitation, the use of PEFCRs will play an important role in increasing the reproducibility, relevance, and consistency of PEF studies (and therefore comparability among PEF calculations within the same product category).

The EC launched in January 2014 a call for volunteers from the food, feed and drink sectors to test the development process of PEF/OEF guides. Eleven pilots have been retained by the EC out of thirty applications. Most of them came from EU based organisations, but applications from Australia, New-Zealand, Sri Lanka and Tunisia demonstrate the interest of non EU countries to participate in this pilot phase. The food, feed and drink pilots selected are:

1. **Beer,** proposed by Brewers of Europe;
2. **Coffee,** proposed by the European Coffee Federation;
3. **Dairy,** proposed by the European Dairy Association;
4. **Feed for food-producing animals,** proposed by the European Feed Manufacturers' Federation;
5. **Fish for human consumption,** proposed by the Norwegian Seafood Federation;
6. **Packed fresh meat from bovine, pigs and sheep,** proposed by the European Livestock and Meat Trades Union;
7. **Uncooked pasta,** proposed by Union of Organizations of Manufactures of Pasta Products of the EU;
8. **Packed water,** proposed by the European Federation of Bottled Waters;
9. **Pet food (cats & dogs),** proposed by European Pet Food Industry Federation;
10. **Olive oil,** proposed by CO_2 consulting S.L.;
11. **Wine,** proposed by the Comité Européen des Entreprises Vins.

The first task of the pilots studies is to carry out a screening study to identify the elements that most contribute to the product overall impact, the analysed elements include: life cycle stages, processes, environmental impact categories and elementary flows of a representative product that describes the average product sold in the European markets. The results of the screening study are used as a basis for the drafting the PEFCR. Once the draft PEFCR has gone through a public stakeholder consultation10 and has been approved by the Environmental Footprint steering committee, it will be tested in supporting studies, which will apply the PEFCR for real products. During the supporting studies, also various ways of communicating the environmental footprint results to consumers and businesses will be tested. The PEFCR will be revised based on the lessons learned from the supporting studies, after which the stakeholders have another opportunity to provide comments on the PEFCR. Before final approval of the PEFCR by the EF steering committee, the PEFCR will be reviewed by external reviewers. The final PEFCRs are scheduled to be released by end of 2017.

2.2.3 The Sustainable Consumption and Production (SCP) Food Round Table

Since 2009, Food Round Table members have been working together on a commonly-agreed and science-based framework for assessment and communication of the environmental performance of food and drink products in Europe. An analysis of relevant data, methodologies and guidelines for assessing the environmental performance of food and drink has been conducted. The analysis led to a harmonised methodology for

[10] Stakeholders can register to follow pilots on Environmental Footprint wiki-page: https://webgate.ec.europa.eu/fpfis/wikis/display/EUENVFP/EU+Environmental+Footprint+Pilot+Phase

environmental assessment, the ENVIFOOD Protocol. The Protocol provides guidance to support environmental assessments of food and drink products conducted in the context of business-to-business and business-to-consumer communication and the identification of improvement options.

The Round Table (RT) is co-chaired by the EC and food supply chain partners on equal footing and supported by the UN Environment Programme (UNEP) and European Environment Agency (EEA). When applying a life cycle approach, the RT's unique structure based on transparency and dialogue facilitates an open, results-driven and evidence-based dialogue among all players along the food chain which leads to further harmonization. The RT has delivered the publication of the ten "Guiding Principles on the voluntary provision of environmental information along the food chain" (European Food SCP Roundtable, 2010), the Reports on "Communicating environmental performance along the food chain" (European Food SCP Roundtable, 2011) and "Continuous Environmental Improvement" (European Food SCP Roundtable, 2012) and the ENVIFOOD Protocol (European Food SCP Roundtable, 2013).

In the EU Commission PEF Food Pilot phase, the ENVIFOOD Protocol is used as a complementary guidance to the PEF/OEF guides (EC, 2013b and 2013c). The RT supports the PEF/OEF testing by:

- Facilitation of coordination and consistency between pilots, including through participation in PEF pilot consultations and organisation of technical workshops;
- Providing technical support for the interpretation of the ENVIFOOD Protocol, in relation with the EF Technical Helpdesk;
- Participation of the WG1 industry co-chair in the PEF Technical Advisory Board;
- Help PEF pilot testers to come up with a common approach on cross cutting issues.

2.3 Elements of social assessment

Social Life Cycle Assessment (S-LCA) focuses on identifying and assessing social impacts associated with product life cycles (UNEP/SETAC, 2009). S-LCA tries to quantify social aspects that may affect stakeholders, such as workers or communities, either negatively or positively. It attempts to shed light on the social dimensions of product supply chain stages and the possible impacts they have on social conditions. Together with environmental LCA and Life cycle costing (LCC), the three strive towards a holistic assessment of sustainability impacts in supply chains. As these are complementary to each other, S-LCA has an important role in sustainability assessment.

Food waste produced during the consumption stages accounts for a relatively high share within the supply chain. Prevention of this food loss can be tackled through communication and behavioural change aimed at consumers and retailers. When food waste is generated, its treatment has social impacts. Environmental LCA has been widely used and recognized for its utility in assessing waste treatments options. LCA studies of waste management are present in literature and they often cite the need of assessing social aspects (Cherubini et al., 2009; Del Borghi et al., 2009; Ekvall et al., 2007; Manfredi et al., 2011).

Studies in the broader social literature mainly focus on waste prevention campaigns (Bartl, 2014; Cox et al., 2010; Dururu et al., 2015; Wilson et al., 2012) and the attitude of people towards a specific treatment (Bernad-Beltrán et al., 2014; del Cimmuto, 2014; Spies, 1998). However, only few studies address waste treatment using S-LCA and make use of indicators (e.g. Rybaczewska-Blazejowska, 2013). These studies highlight the importance of encompassing social impacts into assessments of various waste treatment options. Moreover, more studies are needed in order to increase the robustness of indicators and social impact assessments of waste in different contexts. These studies also indicate the necessity for more indicators to be developed and tested, although they converge on some main issues/indicators.

Framework methods for social assessment of food waste management is recently been presented by the Joint Research Centre (JRC) of the European Commission (EC, 2015c), as well as within the EC funded project FUSIONS (EC, 2015d). Sub-chapter 2.6 provides an overview of sustainability assessment framework proposed by FUSIONS.

2.4 Environmental and economic assessment of food waste management options

2.4.1 Overview and scope

The methodology presented hereafter provides a straightforward tool for the identification of the most sustainable management options for food waste from an environmental and economic perspective. It consists of six mandatory steps and one optional step that lead to the identification of best performing scenarios (among those considered), i.e. those that are preferable from both an environmental and economic perspective (Figure 3). A thorough presentation of such methodology and a numerical application can be found in the report "Improving sustainability and circularity of European food waste management with a life cycle approach (EC, 2015c) and in a paper by Manfredi & Cristobal (2016).

The evaluation of the environmental impacts is conducted based on Life Cycle Assessment (LCA). The evaluation of economic impacts is conducted based on a life-cycle approach and also making use of so-called "gate-fees" for a straightforward estimation of the costs for waste treatment to be paid by e.g. a municipality. Since elements of the "optimization theory" are also utilized, environmental impacts and economic impacts (i.e. costs) will be considered and referred to as "objective functions".

In line with the prescription of the Waste Framework Directive (EC, 2008), the starting assumption of the framework methodology presented hereafter is that the "waste hierarchy" is an environmentally sound decision support principle (Figure 1). Deviations from such principle that result in lower environmental impacts can, however, be accepted if justified by LCT. Waste prevention and reuse (the top two priorities indicated by the waste hierarchy) are not explicitly addressed in the framework methodology. The area of focus in fact includes the subsequent steps of the waste hierarchy, thus specifically addresses the flow of food waste that could neither be prevented nor reused, but needs to be managed/treated.

2.4.2 Methodological steps

As shown in Figure 3, first of all, the identification of all treatment options for food waste management that are going to be evaluated is required (Step 1). This includes both the options that are already in place and those that could be installed. Depending on the decision context, an appropriate functional unit (FU) must be defined to describe quantitatively and qualitatively the exact functions and services provided by the scenarios considered. Along with the FU, the system boundaries of the study can be defined, including all relevant processes needed to provide the functions and services included in the FU (Step 2).

Once the options are identified and the FU and system boundaries stablished, the environmental and economic performance are evaluated (Step 3 and Step 4, respectively). For the former, LCA modelling is required giving as outputs different environmental impact scores to be subsequently used in Step 5 as indicators for the environmental performance. For the latter, different approaches can be selected depending on the decision context. Typically, two approaches or a combination of both is used: the approach based on "actual costs" and the one based on "gate-fees".

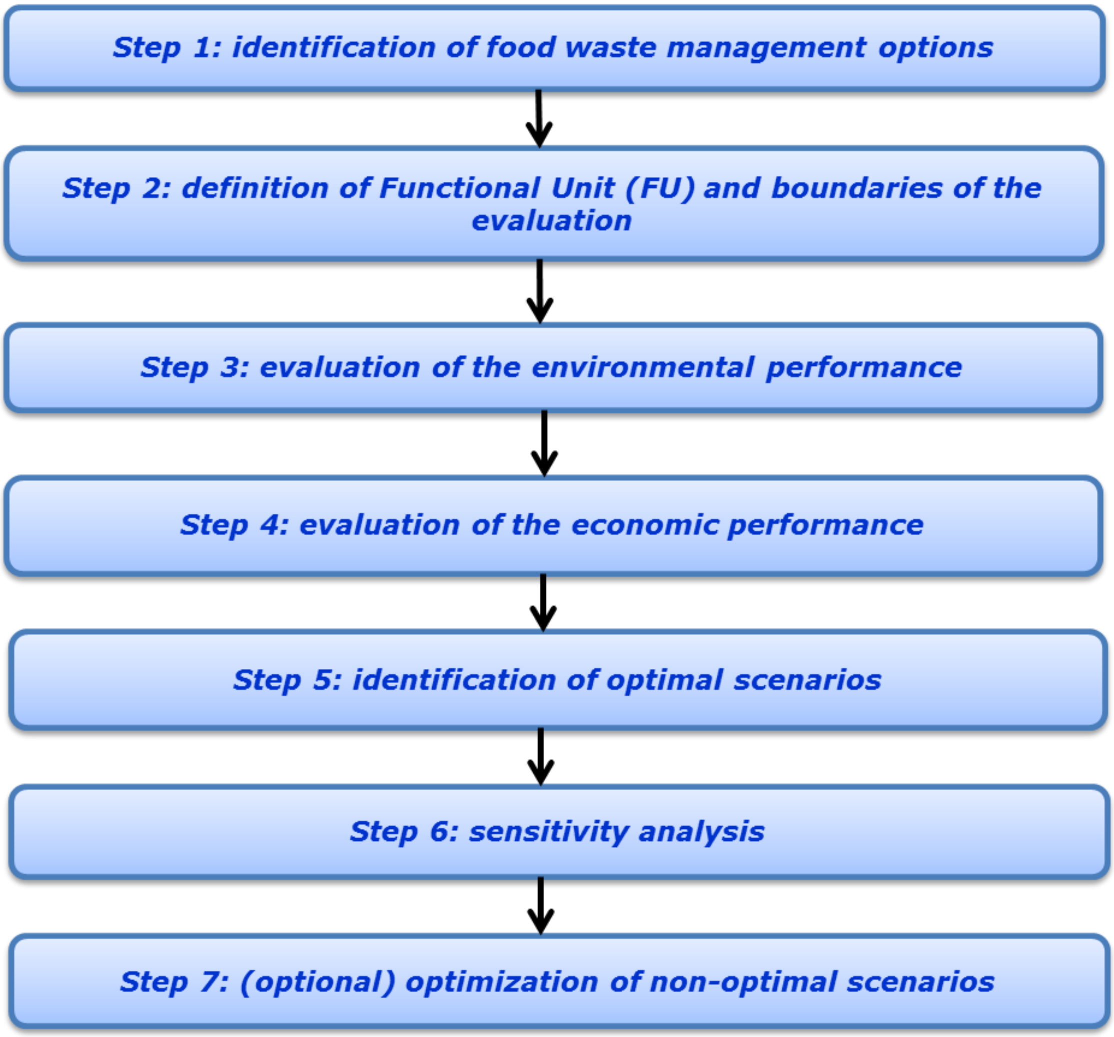

Figure 3: Overview of the proposed methodological framework for sustainability assessment of food waste management

Finally, based on the indicators chosen in Step 3 and Step 4, the objective space can be visualized and the "Pareto-front" plotted in order to identify the optimal scenarios (Step 5), i.e. those that minimise at the same time both objectives. Due to the uncertainty inherent to the data and the measures, a sensitivity analysis (Step 6) is crucial to base the decision-making process upon a more solid ground and avoid misleading or biased decisions.

In an optional 7^{th} step, the methodology could be enlarged combining Data Envelopment Analysis (DEA), life cycle assessment and process retrofit into a single consistent framework (Cristobal et al., 2016). In essence, this starts by assessing the food waste management options in terms of a given set of environmental indicators. With this information at hand, the DEA methodology is then applied to identify efficient and inefficient options. For the latter group, improvement targets are calculated (that could, if achieved, make them efficient) that are finally used in the last stage of the method to guide retrofit actions to be implemented in the inefficient options.

2.5 FAO's Food Waste Footprint (FWF)

The FWF[11] project aims to provide a worldwide account of the environmental footprint of food wastage along the food supply chain, focusing on impacts on climate, water, land and biodiversity. The FWF model is based on a life cycle approach (see Figure 4), covering the entire food cycle from cradle to grave, and uses impact factors for the assessment of quantifiable components on each phase of the life cycle (see generic equation in box 2.1)

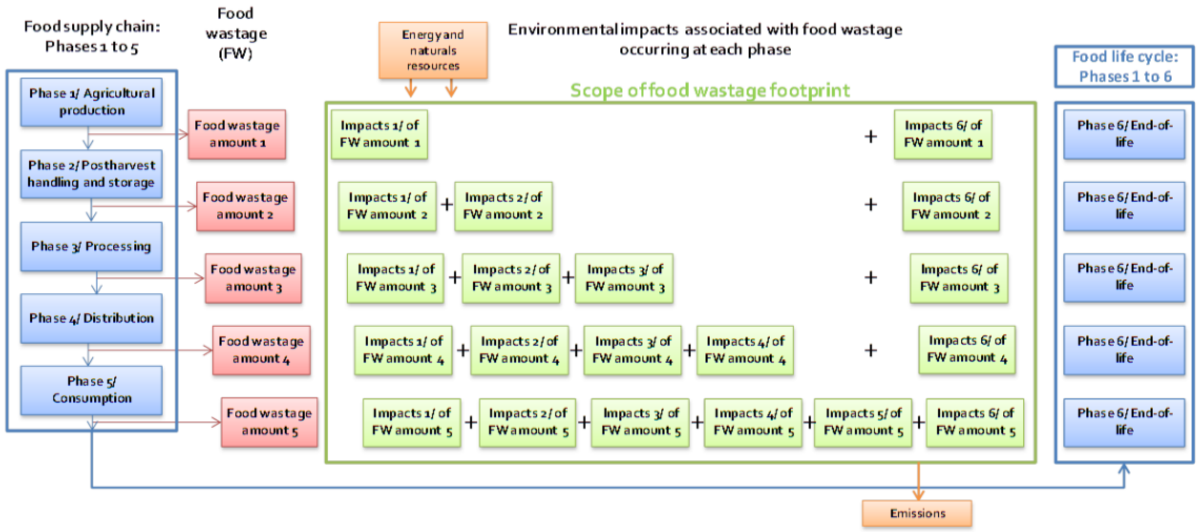

Figure 4: FAO's Food waste footprint calculation

The FWF model is divided into 6 components in order to quantify or quantitative/qualitative assess:

- Food wastage volumes – gather data on food production and food wastage percentages.
- Environmental footprint for carbon – translate the food wastage volumes into tonnes of CO_2eq.
- Environmental footprint for water – calculate impact factors that will translate the food wastage volumes into cubic meters of water, as well as give an overview of the level of water scarcity in the world regions where food wastage was produced.
- Environmental footprint for land – assess land-related environmental impacts coming from food that is produced but not eaten because of wastage, quantify the amount of agricultural surfaces occupied to produce lost/wasted food and give an overview of the level of degradation of the land on which lost/wasted food is produced.
- Biodiversity issues – assess the impacts of global food wastage on biodiversity, through both a qualitative evidence-base and quantitatively through carefully selected indicators (extent of natural areas, redlist index, coverage of protected areas and trends in mean trophic levels).
- Economic cost related to agricultural production – quantify, focused on the agricultural production phase and based on producer prices, of the cost of food wastage.

Apart from the analysis of the results obtained, in the FWF project the causes of food wastage and the levers for food wastage volumes and subsequent impacts reduction are

[11] http://www.fao.org/nr/sustainability/food-loss-and-waste/en/

presented. This study is divided in three broad categories of countries: developing countries, high-income countries and emerging countries.

BOX 2.1 – Environmental impacts of food waste: a comparison

The calculation models used for quantifying the environmental impacts of food waste are based on the general equation shown below in which activity data (i.e. food waste volumes) are multiplied by specific factors to characterise their impacts in each life cycle phase:

for a product *i:* Enviornmental footprint=activity data*impact factor (EFi=ADi*IFi)

In Table 3, the reported quantities are shown.

Table 3: Environmental impacts of food waste – European figures

REFERENCE STUDY	FOOD WASTE VOLUMES	CARBON FOOTPRINT	WATER FOOTPRINT	LAND FOOTPRINT
FAO[12]	245 Million tonnes (335 kg per capita an per year)	500 Million tonnes CO2 eq. (690 kg CO2 eq. per capita)	19 km^3 (26 m3 per capita)	95 million ha (1300 m^2 per capita)
EC[13]	89.2 Mt	226 Mt CO2 eq.	7.01 km^3	39575 x1000 ha

The FWF project, in its phase 2, is developing a full-cost accounting methodology to evaluate the real societal costs of food wastage. It internalizes the external costs in order to account for the cumulative effects that decreased production resources represent for food availability and livelihoods. It includes the direct financial costs, the lost value of ecosystems, goods and services (e.g. cost of land degraded or deforested unduly, the cost water polluted or overused), and the loss of well-being associated with natural resource degradation (e.g. social cost of wasted human efforts and food insecurity). Results show that the total cost is USD 2.46 trillion being hidden costs (i.e. socio-environmental costs = USD 1.614 trillion) twice the market price of the food wastage (USD 845 billion). The breakdown of the figures shown by the FWF are the following (see Figure 5): for the environmental costs the carbon footprint would be USD 429 billion, the water footprint USD 172 billlion, the land footprint USD 42 billion and the biodiversity footprint USD 32 billion; for the social costs the livelihoods cost would be USD 280 billion, the health cost USD 150 billion, the conflicts cost USD 390 billion and the subsidies (from the OECD countries) USD 119 billion.

[12] http://www.fao.org/docrep/018/ar429e/ar429e.pdf

[13] http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/Task%203-Food%20waste.pdf

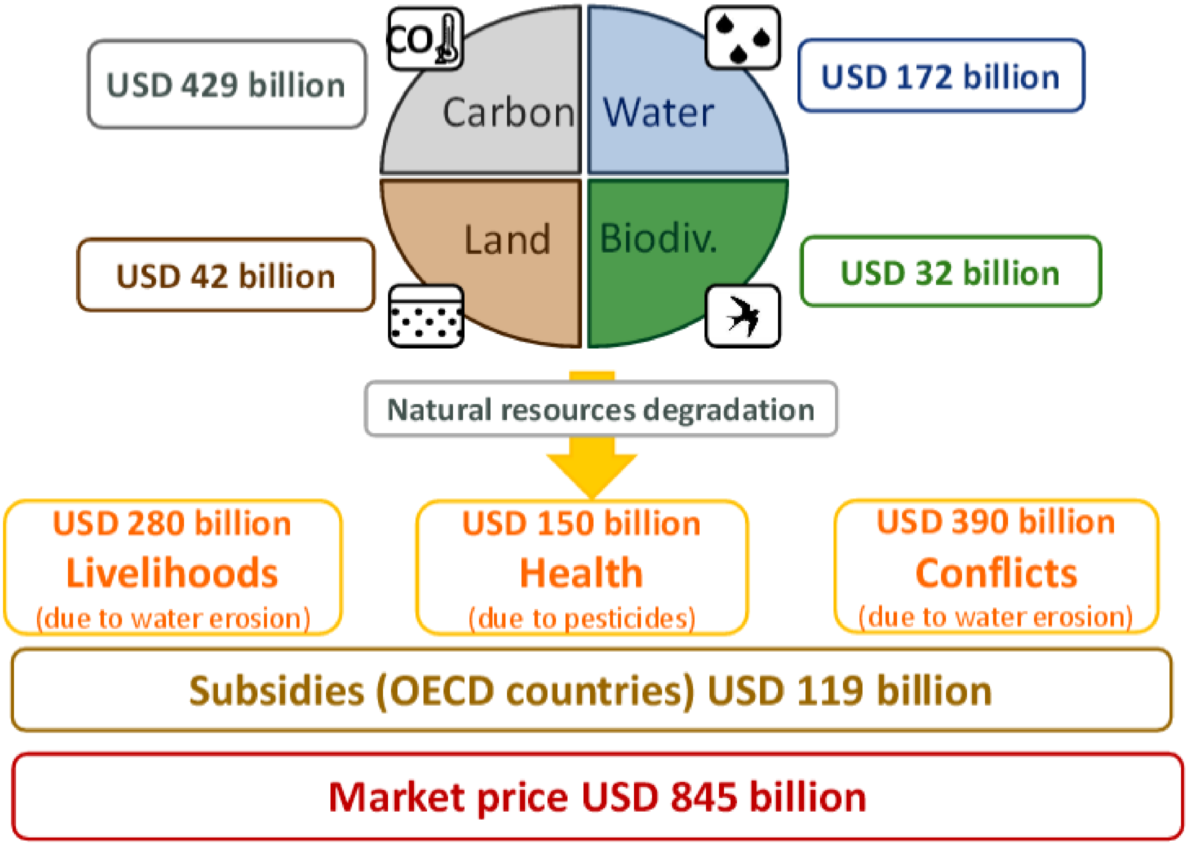

Figure 5: Real societal costs of food wastage in the FWF project

2.6 Towards sustainability assessment: the FUSIONS example

The EC funded project FUSIONS [14] provided a framework for multi-criteria impact assessment method that aims at covering all so-called sustainability pillars, or dimensions: environmental, economic and social. In the report "*Criteria for and baseline assessment of environmental and socio-economic impacts of food waste*" (EC, 2015d), the following assessment criteria are considered:

- Environmental impacts of food waste;
- Socio-economic impacts of food waste;
- Impacts on health and nutrition of food waste[15];
- Social impacts from food redistribution organisations, such as food banks or social supermarkets.

With respect to the assessment of socio-economic impacts from food waste prevention (and associated reduction measures), these are calculated based on the foreseeable changes that could take place in food markets (including: supply, demand, trade, prices) and welfare of the different stakeholders along the FSC. Towards this end, different studies were analysed to evaluate social and economic impacts. From the analysis of

[14] http://www.eu-fusions.org/

[15] *"The impact on* ***health and nutritional factors*** *was analysed on the subjects nutrients, micronutrients and partly anti-nutritional factors. Selected nutrients and micronutrients included vitamin A (retinol), beta-carotene, vitamin C, fibre, iron, zinc, n-3 fatty acids, lysine and methionine. Nutrient losses were calculated based on food compositional data of the selected indicator products."* (EC, 2015d)

these studies and the applications of the analytical models on which they are based, it was found that socio economic impacts associated with food waste prevention can be considerable at both intra- and inter-regional levels: "*For instance, households may waste more if food becomes cheaper, counteracting the positive impact of reducing food losses on the supply side or trade-up and spend the saved income from the reduction of food waste for other services or higher quality food. High level considerations on the socio-economic impacts of food loss and waste need to be balanced with a value chain analysis that includes data on costs related to the prevention and reduction measures to be implemented for the short, medium and long term return on investments along the food supply chains, including for the end consumption level.*" (EC, 2015d).

Evaluation of social impacts from food banks and other initiatives was based on the "social capital" methodology elaborated by the World Bank [16]. In particular, this methodology was used to analyse six dimensions: groups and networks, trust and solidarity, collective actions and cooperation, social cohesion and inclusion, information and communication, food security and food safety. Each of these dimensions was evaluated on the basis of specific indicators. "*The results showed that food redistribution can have a rather positive effect on the basic components of social capital, in particular when trust, networks, and cooperation are regarded. Less influence was perceived in terms of information and social inclusion. […] the largest effect was registered on the food security and safety aspects*" (EC, 2015d).

Evaluation of environmental sustainability aspects was based on LCA, and most steps of the FSC were accounted for[17]. Both bottom-up and top-down approaches were tested on the basis of the same LCA function unit: 1kg of food consumed. While the impact category Global Warming Potential (GWP) was calculated for both approaches, acidification and eutrophication were only considered in the classic bottom-up approach. "*Results for the total GWP associated with food consumed in the EU in 2011 arrive at a very similar figure for both approaches (around 1380 Mt CO_2 eq.). Yet, the share of food waste related emissions is different in the two approaches used. Food waste related emissions estimated at 16% to 22% of the total emissions of consumed food, which is 227 Mt CO_2 eq. in the bottom-up approach and 304 Mt CO_2 eq. in the top-down approach respectively. Most of the emissions can be attributed to the production stage, followed by the food consumption stage. Distribution and End of Life play a rather insignificant role. When it comes to an attribution of emissions to the polluter pays principle, the consumption stage shows the most impacts*" (EC, 2015d).

[16] http://siteresources.worldbank.org/INTSOCIALCAPITAL/Resources/Social-Capital-Initiative-Working-Paper-Series/SCI-WPS-24.pdf

[17] Food valorization and conversion step (e.g. animal feed) were excluded due to lack of consistent data.

BOX 2.2 – Food waste and its impact on climate change

Food losses and waste do not only represent, from a global perspective, a missed opportunity to feed and nourish a growing world population and some of the most disadvantaged people. In fact, in addition to the ethical and nutritional problems involved, the environmental impacts arising from food wastage are considerable. The main impacts are typically measured in terms of the amount of finite natural resources (e.g. water, fertilisers, soil or other marine resources used for the production of food that will be wasted), but climate change and other impacts also play a major role.

If food waste were a country, with respect to its contribution to climate change, it would sit third in the table of international greenhouse gas (GHG) emitters, behind China and the USA (FAO, 2013). For instance, consumption of food by the UK population is responsible for emissions of 150 million of tonnes of CO_2 eq. every year. This is the 20-30% of the total anthropogenic emissions in UK. (ESTA, 2014).

Worldwide, food wastage is responsible for emitting 3.3 billion tonnes of greenhouse gases. This is associated with 28 % of the world's agricultural area being used annually to produce food that is lost or wasted, while using a volume of water equivalent to the annual flow of Russia's Volga River.

It has been observed that the 220 million tonnes of food wasted on average in developed countries each year roughly equals the total net food production of Sub-Saharan Africa (Gustavsson et al., 2011). Social and ethical motivations for reducing food waste are strongly highlighted in this example.

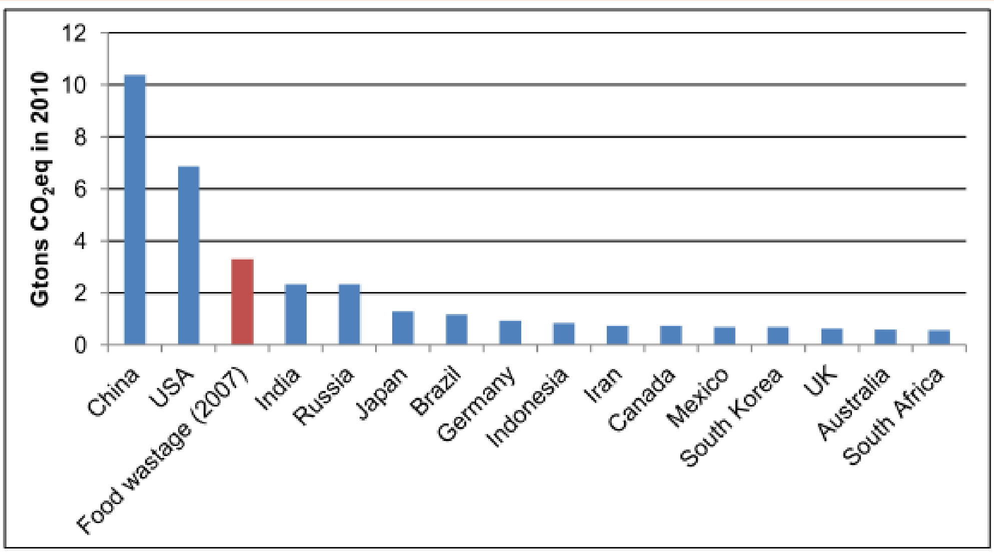

Figure 6: Top 15 of GHG emitting countries vs. food wastage (total GHG emissions excluding LUCF, 2010) (adapted from FAO 2013 , WRI 2013)

About EU figures (EC, 2014a), the impact on greenhouse gases due to food waste (around 3% of total GHG emissions) is estimated to rise from 170 Mt of 2006 to 240 Mt of 2020 and the economic value of this food waste is expected to rises from €180 billion in 2006 (89M tonnes) to more than €260 billion (126m tonnes) by 2020.

3 Stakeholder Analysis

As a social research tool, stakeholder analyses allow individuals and organizations to gain additional knowledge of the topic being analysed. This knowledge may be useful for different purposes, e.g. to better understand the most relevant groups in the context of food waste prevention and management. Stakeholder Analysis can be performed by surveying many different people, or groups, through a variety of methods (in person, on the phone, online, and in roundtables) in order to collect information and identify the food system's most influential actors.

Hereafter, this is done by pinpointing key stakeholders, policy makers and actors in a particular field and/ or geographic area.

3.1 Main stakeholders

In the food waste field, the following list of stakeholders can be identified; in broad categories[18]:

- Consumers (households)
- Farmers
- Processors
- Policy makers, at various levels
- Retailers, restaurants
- Social enterprises
- Environmental NGOs
- Citizens
- Educational institutions
- Financing institutions
- Research institutes
- Waste collectors
- Food waste treatment plants
- Media

Some key groups can be identified, starting from **consumers in households**, which are involved in the prevention and minimisation of waste wherever possible. They are the main generators of avoidable food waste. According to recent research (WRAP, 2013), 60% of household food waste is avoidable. **Businesses and industries** (including several of the above groups) want to work in harmony with both customers and suppliers, so they need to implement the best practices relating to waste prevention, minimisation, recycling and disposal, according to the requests they receive and to their Corporative Social Responsibility. The implementation of greener policies in-house is also typical as a marketing strategy.

Retailers are already proving more effective than private households in terms of food loss rates (Lebersorger and Schneider, 2014). However, there is still potential for a further reduction, by focusing on internal optimization, training, information and education of employees, raising awareness and producing information for customers, and increasing cooperation with social services.

Policy makers are key players here as they are responsible for the development of waste policies and their subsequent enforcement. They prepare waste management strategies and plans, including implementation and monitoring.

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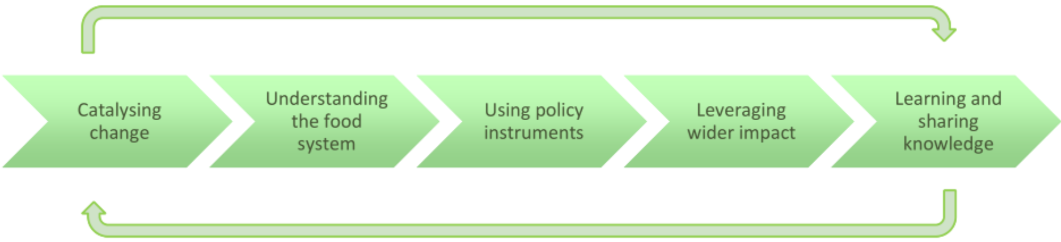
[18] A series of documents of the meetings of the ECWorking Group on Food Losses and Food Waste, with a list of stakeholders consulted is available at http://ec.europa.eu/food/safety/food_waste/eu_actions/stakeholders/index_en.htm .

Collaborative research projects in pursuit of new knowledge can be organized by **universities, research institutes and NGOs**. The resulting information is important for community needs, and is often communicated through NGOs, who initiate waste management schemes with help from local decision makers.

In this report we focus on food waste prevention, so we are able to state that waste collectors and food waste treatment plants are considered as minor stakeholders. However, it is also true that preventative actions are affecting the final recycling operations, in the plausible case that they are so effective that they reduce the need of a final composting or anaerobic digestion plant.

3.2 Key stakeholders for closing the loop

The framework provided by City Regions Food Systems (FAO, 2015) is a valuable tool for the preliminary analysis of the role of different stakeholders. It identifies five key areas to focus on, in order to change the *status quo* and strengthen food systems in a region (see Figure 7).



Key areas	Key stakeholders
Catalysing change	Policy makers
Understanding the food system	Citizens, Educational institutions
Using policy instruments	Farmers, Processors, Retailers, Social enterprises
Leveraging wider impact	NGO, Financial institutions
Learning and sharing knowledge	Educational institutions ,NGO, Social enterprises, Researchers

Figure 7: Key areas to focus on to strengthen food systems in a region

3.3 Stakeholders categorization

3.3.1 Overview

Stakeholder analysis is a process that usually requires specific steps aimed at clearly identifying and characterising their role in any project or strategy. After a potential list of stakeholders has been identified, it is refined, going through several preliminary steps such as the analysis of needs and interests, a classification of responsibility, and an evaluation of the potential impact on project outcome expectations.

A stakeholder analysis is more usable and practical when performed at a local level, or in other words with actors that can easily get in contact among themselves and develop joint actions on a multi-stakeholder approach.

The power/interest matrix is typically used to visualize stakeholders, when talking about environmental actions. It classifies them in relation to their power and the extent to which they are likely to show interest in the actions to be implemented (see Figure 8).

C - Meet their needs: **Keep satisfied**	D - Observe closely: **Key players**
A - Minimal effort / least important: **monitor**	B - show consideration: **keep informed**

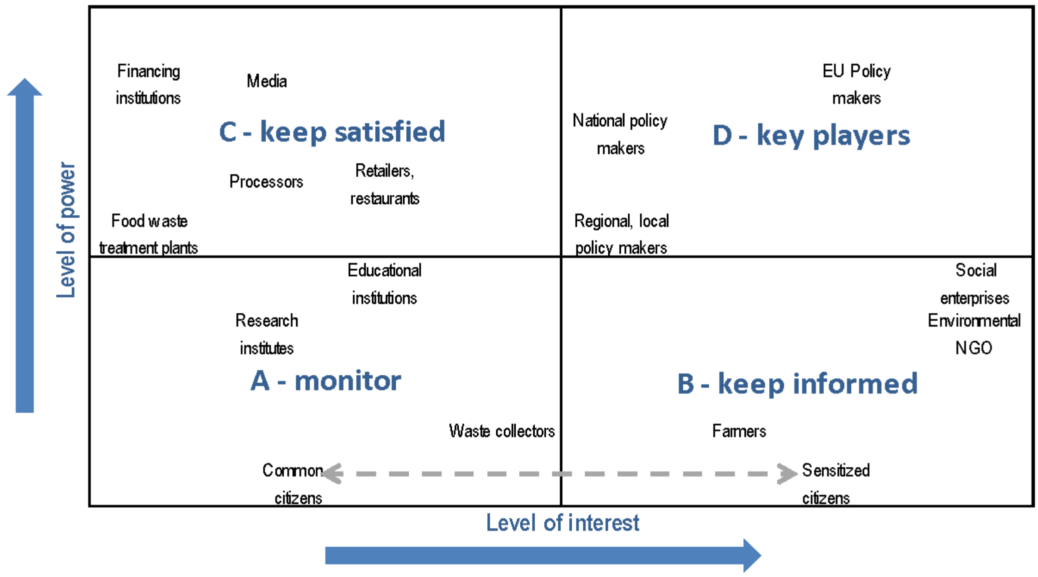


Figure 8: Categorization of stakeholders according to the level of interest and of power

Some stakeholders can actually spread their categorization into more than one group. It is for instance, the case of citizens, which includes a vast majority of people being unconscious to the realities of food waste issues. Nevertheless, the importance of implementing consumer programmes on food waste, starting with selected groups of individuals – i.e. the individuals most at risk – may have a 'cascade effect', in order to not only raise their interest but also to include other groups (Secondi et al., 2015)

3.3.2 Group A (minimal effort)

Stakeholders of this group should be informed via general communications, such as newsletters, and websites etc., without boring them. The aim is to move some of them to group B.

Most of consumers & households are part of this group, because, according to many studies, food wastage prevention is not a daily life priority. The fact is that consumers might be crucially influenced by their surroundings, including general social norms that they might learn from the debate in the media or. Alternatively, the presence of simple food prevention actions implemented in their area, may allow them to be easily shifted towards group B.

Research institutions have recently shown an increased interest in food wastage issues, even if it's generally a marginal research field for them. They have to be observed because the results of their investigations can significantly influence the decisions of the stakeholders in group C and D.

Waste collectors often don't show a high interest in waste prevention initiatives. They are typically cooperative in implementing them, only when stakeholders with higher power, such as local authorities, push them to collaborate.

Educational institutions like schools, although not very interested in this issue, can play a good role in influencing social behaviours, so they have to be monitored and informed.

3.3.3 Group B (keep informed):

They have to be constantly informed and consulted. They can also act as potential supporters or goodwill ambassadors.

We can include farmers in this group, as they have a direct interest in reducing food wastage, but often don't have enough power to influence policies in this respect. Citizens that have been sensitized and become more conscious can fit into this group, as well as environmental NGOs, which have probably the highest interest in promoting effective actions, but still don't have enough power to belong to group D.

Also social enterprises, such as food banks and their organizations, have a large interest and quite a high power.

3.3.4 Group C (keep satisfied)

They always have to be consulted and even if their interest is low, these stakeholders should be moved as much as possible towards group D.

Food processors are part of this group, especially thinking about the marketing strategies. For instance, they essentially decide the standard, discarding odd-sized vegetables, despite the high level policies that tend to reduce this practice. Retailers such as supermarkets and restaurants are in group C because they can be very influential to their customers, but typically are not prone to changing their logistics and marketing strategies affecting the economics. For instance, supermarkets are reluctant to incentivize the purchase of suboptimal food by lowering prices, fearing a reputational damage (Aschemann-Witzel et al., 2015). Most importantly, financing institutions can be put here because they have the ability to really push for innovation in the FSC, leveraging the impact of researches and small-scale trials.

In group C we can imagine food waste treatment plants, which show a lower interest in food waste prevention measures, as they act against the interests of their business model, but have a high influence in decision making. Also, the media is part of this broad group.

3.3.5 Group D (key players)

The focus must be regularly on members of Group D; involving them in governance/decision making bodies.

All policy makers are certainly part of this group. The European Commission plays a major role, for both having the overarching legislative power, and for coordinating different working groups on this issue. Nonetheless, the food wastage issue is gaining momentum amongst policy makers at all levels because, besides the real need for action, most food waste prevention actions are quite appealing and can raise consensus, even if their factual results are often not so easily monitored.

3.4 Different perspectives

When entering into discussions regarding waste reduction, it is broadly assumed that there are three particular perspectives that most concern stakeholders.

1. The economic perspective - It is acknowledged by the economic and environmental community that waste reduction, reuse and recycling could have the potential to lower food production costs, increase farmer and business incomes and reduce consumer prices.
2. The natural resources and environmental perspective - Land, water and energy are exhausted by food production, and thus food waste reduction would free up more natural resources for other uses. Additionally, less greenhouse gases would be emitted if food wastage were to be significantly reduced.
3. The ethical and social perspective - If less food is wasted, there will be more food to be shared amongst the population, therefore increasing food security for those with a shortage.

Different motivations for waste reduction can be distinguished by examining who holds these perspectives. For example, the moral and ethical incentive of food security directly affects a huge number of people whose access to food is at threat. The environmental perspective concerns planetary protection over human security, and often appeals to those who already live in comfort. In this respect, it could be true that the economic driver is the most effective motivation for citizens.

Recent surveys (e.g. Graham-Rowe et al. 2014) have revealed that the desire not to waste money is the biggest motivation that will drive consumers to reduce food wastage, while concern for the environment comes a close second.

3.5 Causes of food waste

Better identification of the underlying causes of food wastage helps to address stakeholders properly. In Figure 9 there is a summary of the causes by stage of the FSC.

	Manufacturing & Processing	Wholesale & Retail		Food Service and Restaurants			Households
		Distribution & Wholesale	Retail	Hospitality industry	Schools	Hospitals	
Awareness				●	●	●	●
Knowledge			●	●	●	●	●
Attitudes				●	●		●
Preferences					●	●	●
Portion size			●	●	●	●	●
Planning				●	●	●	●
Storage		●	●				●
Socio-economic factors							●
Labelling			●	●	●		●
Packaging	●	●	●				●
Handling		●	●				
Stock management		●	●				
Logistics	●			●	●	●	
Product quality requirements	●		●				
Technical malfunctions	●						

Figure 9: Key causes of food wastage. Source: Preparatory Study on Food Waste across EU 27 (EC, 2010)

From this overview, we have the immediate perception that this is a multi-stakeholders field where cross influences are important, with a view to the actions that can be potentially implemented. For instance, discussing marketing standards on fruit and vegetables, the actions of the policy makers are addressed to the processors and to the retailers, but in order to make "odd fruit" acceptable, the prevention actions must be addressed to the final consumers.

3.6 Behaviour analysis: barriers and benefits

The following behaviour analysis is here conducted as an example for three selected groups of stakeholders: citizens, policy makers and enterprises.

3.6.1 Citizens

In an experiment conducted in U.S. (Yue et al., 2009) it was found that consumers show little tolerance for visual imperfections on vegetables, but those with higher environmental concerns are more tolerant. Nevertheless, most of the behavioural changes of consumers are more related to the marketing strategies of retailers than to their own decision making. There are many behavioural barriers to minimising food waste, such as:

- the desire to be a ‘good’ parent, partner or host, fulfilled by over-purchasing
- the desire to shop, cook and prepare food with convenience and time constraints in mind as a primary driver
- the belief that tackling food waste is not a priority in their life and not such an environmental concern
- the perception that the responsibility for food waste lays within the food industry and supermarkets, rather than the individual.

It is also true that consumers do not carelessly waste food (Evans, 2012). In fact, they make conscious decisions contemplating different goals, especially regarding food safety, the environment and ethics. It may be assumed that being aware of an environmentally safe final treatment of food waste, such as composting instead of landfilling, could paradoxically hamper the push for food waste prevention; one could be gratified knowing that its scraps will be converted into a beneficial fertilizer. It was also understood that allegedly negative health effects can immediately push for actions or dietary changes, like organic farming instead of traditional. However, the inner driver that may push for less food waste besides morality (feed the hungry) is something still to be better understood.

An interesting insight has been provided by Cecere et al., (2014): while waste recycling is mainly a "visible action" that may be visible to ‘neighbours' eyes’, also because of the easiness of monitorization with respect to the legislative targets, prevention is mainly a "hidden" or private behaviour. This also reflects the fact that preventative actions within households cannot be proposed as mandatory actions but rather as guidelines accompanied by proper training, whilst recycling can be imposed as an obligation.

3.6.2 Policy makers

Food waste is a relatively new issue that has been gaining momentum. In terms of behaviours, it can be argued that addressing this issue is somehow a win-win option. It is very beneficial for politicians, because there is no apparent negative side effect in promoting food waste prevention, as it is already accepted as a common best practice by all stakeholders. Additionally, the difficult thing is that the effects of most prevention policies are to some extent difficult to be measured, certainly more difficult than the recycling rate on which there is a set of specific targets. This is why it is easier to present the food waste issue with a high resonance in the media, even without a strict follow up.

One of the important barriers is that policy makers are often not able to intervene efficiently on food waste in the supply chain, for instance on quality standards and contractual issues. It is more usual that retailers impose quality standards for size, shape, and colour (to name a few) on suppliers, thus producing huge amounts of edibles that are being discarded.

A noticeable barrier is represented by the lack of communication concerning the environmental impact of food wastage.

As will be described in chapter 5, most of the environmental impact of food wastage is coming from the consumption stage.

3.6.3 Enterprises (food processors, retailers, etc.)

Businesses that can be involved in reducing waste are mainly driven by an economic goal for greater efficiency, and sometimes by a motivation for saving natural resources. In many situations, the role of these stakeholders may be simply to implement some "nudges" to gently push towards food waste prevention.

For instance, in food service environments, initiatives such as the reduction of plate size, the removal of trays (Thiagarajah et al., 2013) and the option to begin with less food and return for further helpings (Kallbekken & Sælen, 2013) act as nudges in this respect.

The behaviour of retailers drastically influences food wastage, due to the power they hold in the food market. They are able to refuse stocks at short notice because of changes to their supply needs or quality standards, and are able to penalise suppliers for failure to supply sufficient quantities of fresh produce. The business risks involved in supplier issues act as an incentive to overproduce and overstock; this leads to unnecessary wastage.

Talking about behaviours, the limit between "Greenwashing" and really effective actions is subtle.

According to one of the FUSIONS partners, there are a lot of initiatives, which don't contribute to the prevention itself, but only to symptom treatment. There is a lot of symbolic action and greenwashing going on as well, and top retail trendsetters of the world place the fight against food waste among the top five CSR priorities for every company with a CSR Policy.

Barriers in this stakeholders group may include, for instance, food hygiene rules in food donation programmes, difficult data collection/monitorization (Priefer et al., 2016), reluctancy and opposition to the removal of marketing standards.

Regarding side benefits, food waste reductions are a relatively efficient way of increasing global food supplies to meet increasing demand and the common thought that this could result in lower food prices is widespread. However, these claims are not backed-up by a lot of evidence.

4 Food waste prevention: analysis of measures and strategies

4.1 Introduction

As already observed, food loss and food waste can occur along all the food chain. The causes are not always the same and vary depending on the type of product, the production system, storage, transport, packaging and finally, bad habits or the lack of consumer awareness. Quantifying food waste and assessing its environmental impact (for example, its contribution to climate change), is a first step towards suggesting and prioritising strategies for prevention and reuse.

Although in this report we focus on food waste prevention with the objective of reducing the environmental impact of this waste, generally two kinds of strategies or approaches to the "food waste issue" can be identified:

1. Those that focus on minimizing the environmental impact of food waste even if the quantity of waste is not reduced. This is done by calculating the food needs of a system and proposing actions such as changing diet (e.g. reducing the amount of meat or promoting organic food), promoting local consumption with less transport, or by incorporating the best technologies that reduce the impact associated with each tonne of waste generated.
2. Those that focus on reducing the amount of waste generated and subsequently reducing the quantity of impact associated with the avoided production. These strategies enable less food waste to be generated throughout all stages of the food chain and this saving is food that could be considered to replace the same amount of equivalent food for human consumption.

Regarding the impact calculation of the different strategies, there is a clear need to improve monitoring and methodological consensus in order to enhance comparability and interpretation of the analysis. Albeit, in recent years, a great breakthrough has been detected that will allow recommendations to be set out for future food waste reduction policies and their impact (e.g. EU Council, 2016).

There are several studies (e.g. Notarnicola et al., 2016) determining the environmental impact of the food supply chain for different types of food in different geographical areas, and there are more and more studies using LCA, incorporating the food waste phase in the calculation of impacts. On the other hand, there are fewer studies (e.g. Bernstad Saraiva Schott and Cánovas, 2015; Bernstad Saraiva Schott and Andersson 2015; Gentil, 2011) evaluating the impact of prevention and here, again, it is necessary to progress in the methodological consensus and in the transparency of the studies carried out, in order to use the results with the strongest outcomes possible.

4.2 Existing policies about food waste prevention

4.2.1 EU policies

As stated in chapter 1, most of the EU initiatives towards food waste reduction are included in a broad framework of EU waste policies, including, for example, the biodegradable waste diversion targets of the Landfill Directive 1999/31/EC (EC, 1999), and the National Waste Prevention Programmes to be prepared as established by the Waste Framework Directive 2008/98/EC (EC, 2008), currently under revision.

A specific Guidance Document (EC, 2011a) accompanied by a number of best practice examples, has been prepared by the EC to include food waste prevention in those programmes.

According to the "Preparatory study on food waste in the EU" (EC, 2010), at that time the EU was not yet able to stimulate food waste prevention in an active way. Food waste reduction was achieved through regulatory measures regarding recovery and disposal (i.e. in the lower part of the waste hierarchy, see Figure 10), such as diversion from landfill.

Targets on food waste prevention such as that in the Roadmap to a Resource Efficient Europe (EC, 2011b), in which the EC aimed for 50% less food wastage in 2020, never entered into force. Now the revision of the Waste Framework Directive currently under discussion in the EU Parliament may introduce some new targets.

Recently, the food waste issue has gained momentum: the Advisory Group on the Food Chain, Animal and Plant Health– Working Group on Food Losses and Food Waste was established in 2012 to support the Commission in sharing the best practices in food waste prevention and in identifying possible EU actions. In 2016 an EU Platform on Food Losses and Food Waste[19] was established with more than 40 members, including EU and national public and private entities.

On the 28th June 2016, the European Council highlighted FUSIONS outcomes and adopted conclusions (EU Council, 2016) expressing its high concern and setting out a series of initiatives to reduce food waste and losses in the future. These initiatives include calls on member states and the Commission to improve monitoring and data collection to better understand the problem, to focus on preventing food waste and losses, to enhance the use of biomass in future EU legislation, and to facilitate the donation of unsold food products to charities.

4.2.2 Best practices from national policies

Several national governments in Europe have developed policies, interdepartmental teams or regulations on reducing food waste (UK, Germany, Denmark, Netherlands, Belgium, France, and Spain). According to EEA (EEA, 2015), in 2014 the following states/regions had already set targets on food waste reduction: Brussels, England, Malta, the Netherlands, Poland and Sweden.

Some of these national targets are listed in the EC impact assessment on food waste, updated in the following list. It is not clear in all cases exactly what the scope of the targets is, nor from what baseline they are starting, and what definition of food waste is being used:

- Austria 20% (2016) non-binding (households only). The proposed 20% food waste reduction target for 2016 was announced by the Ministry of Environment but no baseline year has yet been stated.
- France 50% (2025) non-binding. It proposes a national pact against food waste, signed by a wide range of leading stakeholders to signal their shared commitment.
- Germany 50% (2020) non-binding.
- Netherlands 20% by 2015 (non-binding) (households and 'agri-food chain'). In the case of the Netherlands the goal of the Ministry of Economic Affairs is greater economic efficiency, so this is the rationale for reducing food waste. It was listed as one of the priorities in the 2013 policy paper Sustainable Food Production, and a target of 20% has been set for 2015, compared to 2009.
- Sweden: Food waste shall be reduced by at least 20% by 2020 compared to 2010 throughout the entire food value chain (except for primary production).
- United Kingdom 4% by 2012, and 20% by 2025.

[19] More info on the EU Platform on Food Losses and Food Waste available online at http://ec.europa.eu/food/safety/food_waste/eu_actions/eu-platform/index_en.htm

It is interesting to highlight other national policies, aside from including targets in national regulations or planning. For example, France has a new legislation abolishing best-before product labelling on non-perishable foods such as dried pastas, rice, and sugar. Italy passed, in August 2016, an advanced law on food donation updating a previous one of 2003; it basically eases donation from retailers to charities and NGO, making more complicated the disposal of food waste and clarifying the expiry date issue. Notably these donation laws, like for instance the pioneer Good Samaritan Food Donation Act (USA, 1996), simply remove bureaucracy and, for instance, protects donors from liability when they donate to a non-profit organization.

Also, the use of agreements within the sectors involved has proven to be an effective policy. For example, the Courtauld Commitment, which is the voluntary agreement that brings together 98 organisations from across the food system to improve the sustainability of food and drink production, agreed to a 20% reduction in food and drink waste arisings by 2025. The Commitment also set out a 20% target to reduce greenhouse gas emissions from food and drink production and retail, as well as a reduction in water use.

4.2.3 Regional and local planning in the EU and beyond

The fight against food waste has had special consideration at regional and local levels, where practical actions were developed, based, for instance on the recovery of surplus food or unmarketable but perfectly edible waste that would be destined for disposal. The most common objective is the use of these foods for social help purposes in coordination with food banks or non-profit organisations through local networks.

There are also many local or regional initiatives that have developed specific communication and awareness campaigns for the population or other specific targets (mainly food services and catering).

BOX 4.1 – Love Food Hate Waste

One of the most remarkable awareness initiatives is the "Love Food Hate Waste" campaign, started by the UK Waste and Resources Action Program. The campaign works with food manufacturers and retailers on customer-focused in-store waste reduction initiatives as well as with local authorities, community groups, and other businesses to reduce food waste. For instance, more than 300 local authorities in England run localized "Love Food Hate Waste" initiatives to encourage and assist residents in reducing waste. Activities run by these initiatives include hosting interactive events—such as cooking demonstrations and recipe-sharing gatherings—that help reduce waste stemming from the need to improve home economics skills and unused leftovers. These initiatives also prepare leaflets and newspaper advertisements that provide information about how to reduce food waste.

In some cases, large cities have also developed their own regulations, either by transferring national targets or upon their own initiative. For example, New York City has set a target for reducing food waste by 50% by 2030. On the other hand, Hestal, a small municipality in Belgium, obliges supermarkets to donate surplus food to food banks to receive the environmental permit.

There are several municipalities across Europe that have developed their own local plans for waste prevention, where generally the target is introduced for food waste prevention, basically with the fight against food waste.

Raising awareness in cities and regions with respect to food waste was formalised in the Milan Urban Food Policy Pact[20], signed in 2015 by 116 cities across the world. It aims to support policy coherence and was launched together with its Action Plan and Selected Good Practices.

Some of the agreements for achieving food waste prevention and monitoring are the following:

- Convene food system actors to assess and monitor food loss and waste reduction at all stages of the city region food supply chain, and ensure holistic planning and design, transparency, accountability and policy integration.
- Raise awareness of food loss and waste through targeted events and campaigns; identify focal points such as educational institutions, community markets, company shops and other solidarity or circular economy initiatives.
- Collaborate with the private sector, along with research, educational and community-based organisations to develop and review, as appropriate, municipal policies and regulations (e.g. processes, cosmetic and grading standards, expiration dates, etc.) to prevent waste or safely recover food and packaging using a "food use-not-waste" hierarchy.
- Save food by facilitating recovery and redistribution for human consumption of safe and nutritious foods, if applicable, that are at risk of being lost, discarded or wasted from production, manufacturing, retail, catering, wholesale and hospitality.

Furthermore, quantitative 'food footprint' research has been enacted by a collection of cities and regions globally to find data that could suggest a baseline for future food systems interventions. In 2010, The Greater Philadelphia Food System Study (Delaware Valley Regional Planning Commission, 2010) was published, providing data relating to agricultural production, distribution logistics for food imports and exports and a valuation of the regional food economy. A stakeholder analysis (as mentioned in Chapter 3) was provided to identify key actors in the food chain that could have the power to force change.

London also began publishing GHG emissions in 2008 due to food consumption in the city and the strategies for reducing this impact. Shortly afterwards, a British project called the Foodprinting Oxford study (Curtis, 2013) used food consumption data for people of differing income levels to model and estimate many factors. Some of those factors included the greenhouse gas impact of the food supply chain, as well as land, water and energy consumption.

This methodology has also been used for other UK big cities such as Great Manchester (ESTA, 2014). Although the point of view of these studies is not so much the reduction of food waste, but an analysis of the ability of the territory to feed the metropolis and to analyse the impact that this need entails on several levels. It is useful to determine some actions to reduce this impact and the methodology itself in which the analysis is performed, especially those which refer to various stakeholders.

4.3 Food waste management priorities: the food waste hierarchy

One way to define priorities and strategies is to have a background of the food waste hierarchy (Figure 10), which was defined and supported by a number of organizations and stakeholders worldwide.

[20] More info on http://www.milanurbanfoodpolicypact.org/

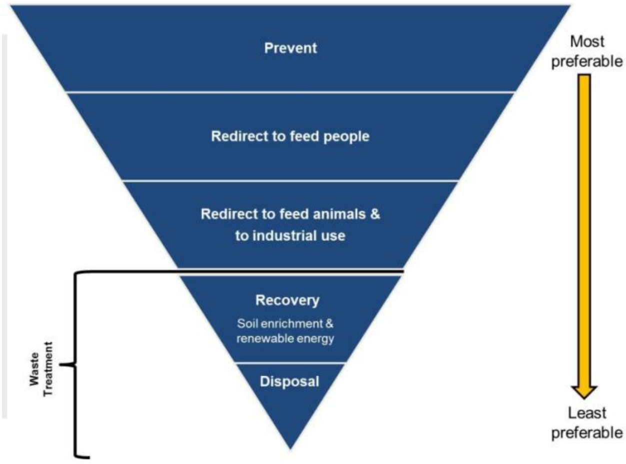


Figure 10:The food waste hierarchy, supported by a number of notable organizations including WRAP.

According to FAO (FAO, 2013), prevention of food wastage is by far the best way of reducing the loss of natural resources, as the impact of food production on natural resources is substantial and increases along the food value chain. For example, if the supply-demand balance can be better adjusted on the front end, it means not using the natural resources to produce the food in the first place, thus avoiding pressure on natural resources, or using them for other purposes. Reuse of food waste means to keep food surplus in the human food chain. This may call for finding secondary markets or donating it to feed vulnerable members of society, so that it conserves its original purpose and prevents the use of additional resources to grow more food.

If the food is not fit for human consumption, the next best option is to divert it for livestock feed, thus conserving resources that would otherwise be used to produce commercial feedstuff.

However, one always has to consider a more holistic approach. Some literature argues that a fixation on wastage reduction is not the right way forward, due in part because they see wastage as a symptom of the underlying causes rather than a problem that stands on its own. Any future interventions should therefore target these underlying causes and seek to reduce waste at source.

Therefore, the actions related to sustainability and efficiency in the production and distribution of food cannot be limited, but they should also examine patterns of food consumption and the organisation of the food system itself.

4.4 Calculation of the quantities of food waste prevented

Increased awareness and sensitisation regarding food waste has led to an increase in the actions that have been carried out and which, in the best of cases, have been monitored and therefore present data on the level of success. In other cases, theoretical data or estimates are given, which are also useful for establishing future policies for food waste reduction.

In order to calculate the efficiency of prevention actions, the following factors have to be known: the quantity of food waste generated and, if possible, the percentage of avoidable and possibly avoidable food waste that is generated in both the baseline situation and once the action has been applied.

In this context, this chapter proposes a novel approach to evaluate the quantities of food waste prevented as a result of the implementation of one or more food waste prevention actions.

4.4.1 Quantitative prevention

It has to be noted that rigorous data on the extent of food waste (including the avoidable and possibly avoidable part) across the supply chain is currently lacking. This is primarily due to the lack of a universal method of measuring food waste at the country level and across the different levels of the food production and consumption. Equally, nations and corporations are under no obligation to report their food wastage data. (FAO, 2013)

However, significant efforts towards quantification of food waste generation have been made in the last five to ten years at international, national and sub-national levels, thus there is a relative abundance of bibliographic data. This is also reflected in large-scale scientific activity, e.g. starting from the first FAO reports and private initiatives such as that of Tristram Stuart (BOX 4.2), or economic and environmental analysis initiatives of food systems in large cities, such as the already mentioned Greater Manchester (ESTA, 2014) or Foodprinting Oxford (Curtis, 2013).

A starting point to help decision makers when it comes to establishing new policies to reduce the environmental impact associated with food waste may be to look into a literature list of strategies and actions to prevent food waste and improve the efficiency in the FSC, including a quantification of the absolute or relative quantities and their goal.

However, there is an even greater need to monitor and publish the results obtained from the various initiatives, in terms of food waste actually reduced, in order to compare with the initial goals and further explore initiatives which prove to have greater efficiency. Worth noting is the effort made in the actions undertaken by WRAP in this regard, as most of their data provides results. One of the last documents produced by FUSIONS Project, the Food Waste Quantification Manual, (EC, 2016), will be helpful in this sense as it provides some practical guides on quantification of food waste at different stages of the FSC. These methodologies are in harmony with the ones developed by the World Research Institute – FLW Protocol (FLW Protocol, 2016).

BOX 4.3 – Qualitative food loss

Food loss may also be "qualitative". It consists in a decrease of food attributes such as nutritional value, economic value, food safety or consumer appreciation. Qualitative food loss should be considered, according to FAO (FAO, 2014). However, as these attributes can't be, for the moment, measured objectively (nutritional aspects could be calculated in terms of calories, but other aspects as vitamins content is more difficult), we suggest to focus on quantitative prevention and continue working on qualitative measures of food loss.

4.4.2 Potential and actual prevention, scope and participation factors

To evaluate the quantitative result (Q) of the different actions (*i*) in the food system boundaries (see Figure 11), we should differentiate between $Q_{generated_j}$, $Q_{potential_{i,j}}$ and $Q_{prevented_{i,j}}$. They are all related to a specific Food Supply Chain (FSC) (*j*) and they can be broken down into each stage of the FSC (*k*) (i.e. $Q_{generated_{j,k}}$, $Q_{potential_{i,j,k=p}}$, $Q_{prevented_{i,j,k=p}}$). They are always expressed as tonnes of food waste. $Q_{potential_{i,j,k=p}}$ and $Q_{prevented_{i,j,k=p}}$ only occur in a certain stage of the FSC *k=p* where a specific waste prevention action is implemented.

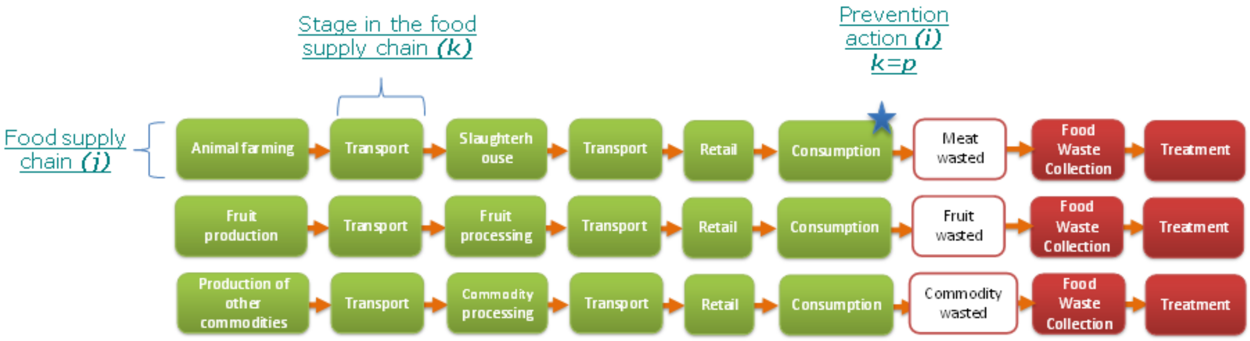


Figure 11: Definition of different food supply chains and stages where prevention action may apply. Food system boundaries are in green.

$Q_{generated_j}$ is the total food waste generated in a FSC *j* by a specific group or target, e.g. residential food waste. It includes all kind of food waste: edible and non-edible, avoidable, possibly avoidable and unavoidable food waste. It can be calculated from the relative $q_{generated_j}$ expressed in kg/capita (Eq. 1).

$$Q_{generated_j} = q_{generated_j} * number\ of\ inhabtants \qquad (1)$$

$Q_{potential_{i,j}}$ is the total amount of food waste that can be potentially prevented in a FSC *j* when action *i* is put in place, which corresponds to the sum of avoidable and possibly avoidable parts of food waste, based on the constraints of the solution. $Q_{potential_{i,j}}$ can also be calculated from the relative $q_{potential_{i,j}}$ (e.g. kg/capita) found in literature or from specific surveys.

$Q_{prevented_{i,j}}$ is the total amount of food waste that actually can be prevented when action *i* is put into place. It corresponds to the part of $Q_{potential_{i,j}}$ that each target group participating in and applying action *i* manage to prevent. It can also be calculated from the relative $q_{prevented_{i,j}}$ (e.g. kg/capita) given in literature or in previous experiences.

As shown in Figure 12: $Q_{prevented} \leq Q_{potential} \leq Q_{generated}$.

To calculate the final amount of food waste potentially or actually prevented, two other factors need to be taken into consideration:

1. The Scope factor (S, 0<S<1)

   The absolute amount potentially or actually prevented depends on the extent of the target of the action compared to the size of the system, which for example, for actions targeting citizens, is the total population of the area. S defines the target group as a percentage of the potential total target.

   To define the scope (S), it is necessary to consider what resources are available (for example in terms of budget, personnel and organization, etc.). It should be kept in mind that if, for example, a pilot or a general strategy want to be implemented to all the system boundaries, the final results would be different and also the participation factor will change.

2. The Participation rate (P, 0<P<1)

   The participation rate defines the users in the target group effectively participating to the action. To estimate participation (P), some approaches could be followed. For example, a survey about the possibility of changing small habits (change of diet; accepting a change in the size of menus, etc.) could be done, or some references about the participation reached in the same activities carried out in other places could also be useful.

So the total amount potentially (Eq. 2 and 4) and actually prevented (Eq. 3 and 5) can be calculated with the following equations depending on the available data:

- If total quantities expressed in tonnes are given:

$$Q_{potential_{i,j}} = Q_{generated_j} * S \qquad (2)$$

$$Q_{prevented_{i,j}} = Q_{potential_{i,j}} * P \qquad (3)$$

- If relative data expressed in kg per capita is given:

$$Q_{potential_{i,j}} = q_{potential_{i,j}} * number\ of\ inhabitants * S \qquad (4)$$

$$Q_{prevented_{i,j}} = q_{prevented_{i,j}} * number\ of\ inhabitants * S * P \qquad (5)$$

Most of the time in literature, the reported relative quantity of food waste prevented ($q_{prevented_{i,j}}$) already includes the participation rate ($q'_{prevented_{i,j}}$), or at least an estimation referring to people supposed to be participating. In this case, to calculate the total quantity in another context, we can just assume the same participation without applying the factor P again (Eq. 6):

$$Q_{prevented_{i,j}} = q'_{prevented_{i,j}} * number\ of\ inhabitant * S \qquad (6)$$

When in literature $q'_{prevented_{i,j}}$ is given for a specific area (area 1) in relative terms, and already includes the participation rate of that case study, then in order to calculate $Q_{prevented_{i,j}}$ in a different area (area 2) with a different scope factor, assuming the same participation, we can use Eq. 7:

$$Q_{prevented-area2_{i,j}} = q'_{prevented-area1_{i,j}} * number\ of\ inhabitants * S \qquad (7)$$

A real example could be used to better explain these factors and how to use them for decision-making, regarding food waste prevention. WRAP has collected a lot of data about its consumer's training and awareness strategy (*i*) on food waste (*j*). In literature (WRAP, 2008) the following relative, $q_{potential_{i,j}}$, $q_{prevented_{i,j}}$ and $q'_{prevented_{i,j}}$ can be found:

$q_{potential_{i,j}}$ = 130 kg/inhab (total avoidable and possibly avoidable)

$q_{prevented_{i,j}}$ = 50% of potential

$q'_{prevented_{i,j}}$ = 15-21% of potential

Box 4.4 provides an example that may help to clarify the difference between those concepts.

BOX 4.4 – Cooking broccoli leftovers

In the example in Figure 12, let's consider a region of 10000 inhabitants that has implemented action *i* – a consumer education campaign on cooking broccoli stalks (j).

$q_{potential_{i,j}}$ is the total amount per capita of broccoli stalks that can be potentially reduced when action *i* is in place. We could assume, for instance estimating per capita broccoli stalks consumption:

$q_{potential_{i,j}}$= 2 kg/capita.

Taking into account that sometimes stalks cannot be cooked because of domestic issues like the visit of guests who don't like this recipe or because the family goes out for a weekend, we can consider a 5% decrease:

$q_{prevented_{i,j}}$= 1.9 kg/capita.

To know the absolute amount of food waste that could be potentially or actually prevented with this action, we need the S and P factors. S is the percentage of households that receive training on how to cook broccoli leftovers. P is the percentage of households that after receiving the training, effectively applies the action at home (remember that not always, but usually, this factor is included in the calculation of $q_{prevented}$)

In our example:

S = 1% (people that receive training) in a region of 10,000 inhab.

P = 30% (estimation of trained households that start cooking broccoli stalks)

$$Q_{potential} = 2\frac{kg}{capita} * 1\% * 10000\ inhab = 200\ kg$$

$$Q_{prevented} = 1.9\frac{kg}{capita} * 1\% * 30\% * 10000\ inhab = 57\ kg$$

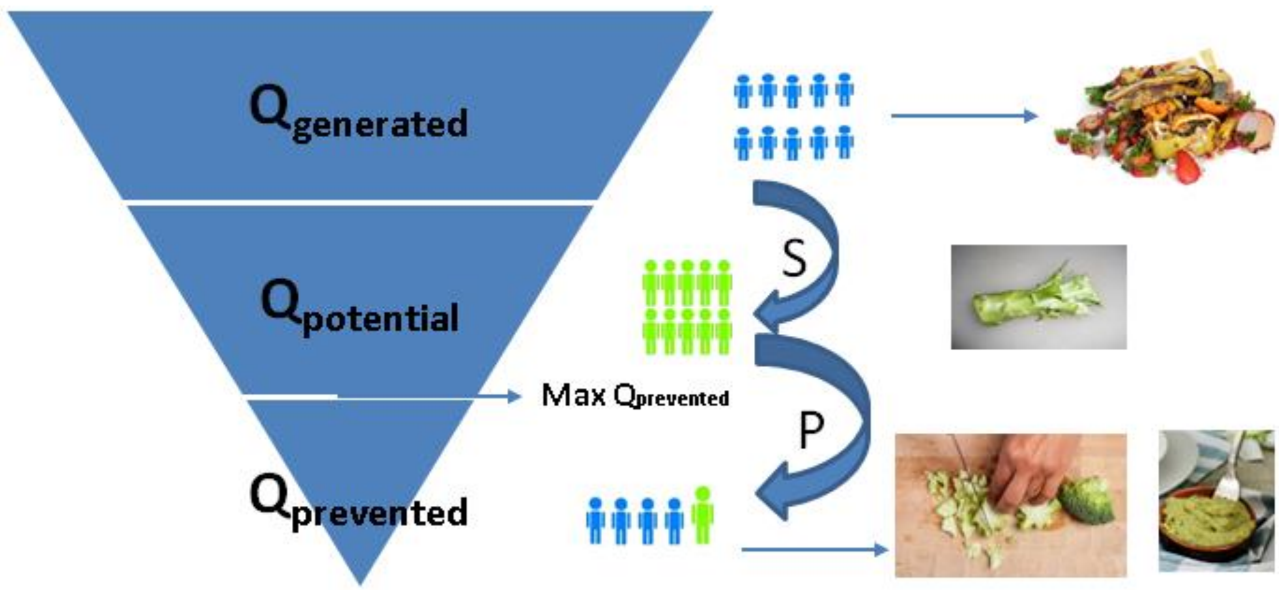


Figure 12: Representation of the different quantities in a food waste prevention actions: cooking broccoli leftovers

If S and P were 100%, then the prevented quantity would be maximum, max $Q_{prevented_{i,j}}$ and equal to $Q_{potential_{i,j}}$ as shown in Figure 12, but usually it is lower.

When it is not possible to normalize $q_{potential_{i,j}}$ or $q_{prevented_{i,j}}$ on inhabitants, more detailed information is needed to calculate the final $Q_{prevented_{i,j}}$ amount. For example: the number of students in schools; number of restaurants or menus served; number of employees, etc. Even though population is not a good proxy for comparing some stages of the FSC between different countries, sometimes this assumption is needed in order to fill the gaps. In fact, no normalisation factor is 'perfect' for filling in missing data (examples in EC (2014b)).

The clear understanding of the scope and participation factors in existing literature actions is important in order to help decision makers understand about the type of strategies to be developed (voluntary, mandatory or others). The choice of these factors also reflects the level of engagement of the municipality, country or region to reduce food waste in order to achieve the proposed target, which should be challenging, but achievable and predictable according to the existing experiences and the allocated budget.

The calculation of the partial contribution of each action to the desired target involves a combination of decisions, where the decision maker needs to have clearly in mind, the generation of food waste for each specific FSC stage, the capacity for action, the expected participation, the needed exemplarity of public administration (e.g. green purchasing).

A specific analysis on the parameters that lie behind the results reported in literature, such as participation and scope, is strongly needed when looking at a proper combination of actions.

4.5 Prevention & Reuse Actions

4.5.1 Evaluation of results of selected actions

Food waste prevention and reuse actions can be classified depending on:

- The stage at which food waste occurs: Production, handling and storage, processing and packaging, distribution, consumption, end-of-life (e.g. shown in Figure 13).
- Targets to which the action is addressed: Producers, food industry, retailers, consumers, policy makers, NGOs, food services, etc.
- Type of action: informational, collaborative, organisational, regulatory, economic and technical instruments (Priefer, 2016).

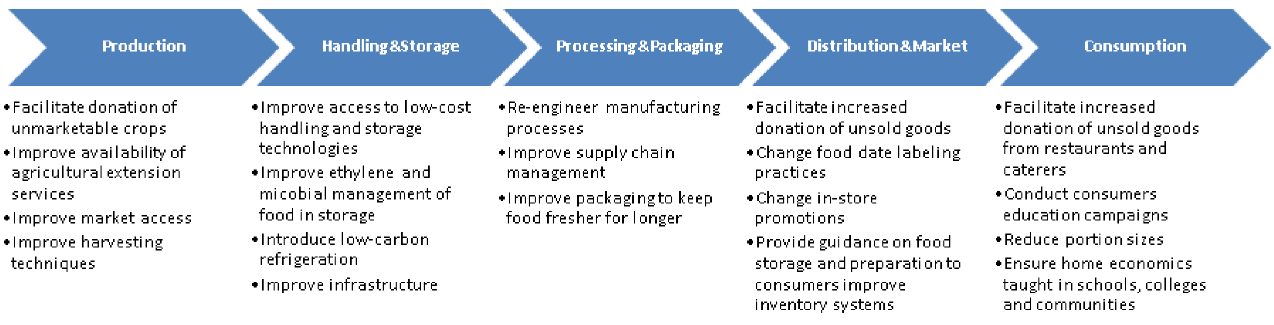


Figure 13: Possible approaches for reducing Food Loss and Waste (Lipinski et al., 2013).

According to the Preparatory study on food waste across EU27 (EC, 2010), more than a hundred food waste prevention initiatives have been launched across EU countries over the last few years.

In Annex 1, a compilation of literature from EU and US examples can be found. Only examples that include a quantification of food waste have been introduced, in order to make it useful when it comes to evaluating an action programme for reducing its impact.

The included examples have been selected from a review of several compilations, including the world's most important references regarding the fight against food waste and waste prevention in general (FAO, FUSIONS, ReFED (2016), etc.). Although the data obtained is in some cases calculated differently, attempts have been made to standardise it in order to facilitate later use.

Summarized results can be found in Table 4. To use this data, some considerations have to be made, since some constraints and context factors are not described. For example, detected prevention actions have various scopes, from small pilot tests in very specific points in the food chain, to national or international campaigns. In the case of the prevention solutions analysed in ReFED (2016), four are estimated to have less than 5% market penetration or to still be in the pilot phase. Two have an estimated 5% to 25% market penetration, and the other six have a 25% or greater penetration.

In some examples, data quality allows to use such data to predict future results of similar actions in other regions. In other cases, the poor quality of data recommends a cautious use of these results, just to be taken as a reference for the order of magnitude.

Table 4: Summary of actions for food waste prevention and reuse and quantities reduced

TARGET		q GENERATED (1)	TYPE OF ACTION	q POTENTIAL	q PREVENTED	DATA QUALITY (3)
		kg/inhab*y		kg/inhab*y	kg/inhab*y	
Primary production		18±3	Technical (storage, handling, etc.)	11		Low
Processing and manufacturing		33±25	Technical (optimization, packaging, etc.)		0.063-0.65	Low
Wholesale& & retailing		9±2	Economic (discounts, last minute, etc)		3.3	Low
			Organisational (inventory)		0.186	Low
			Collaborative (Donation)	9-36 (2)	1-14 (2)	High
Food preparation and consumption	**Food Services**	21±3	Technical (trayless, small plates, quantity adequation)		0.26-0.56	Medium
			Informational (awareness to kitchen+customers)		5.5	Low
			Organisational (waste tracking, internal audit)		1.8	Medium

	Households	92±9	Informational (awareness campaigns, coaching and training)	20-130 (4)	6-60 (4)	High
			Technical (date labelling)		1.25	Low
			Technical (conservation, granel shoping, shopping, adjustment of quantities)		5-10	Medium

(1) EC, 2016
(2) Given data refers sometimes to retail + manufacturing, that's why $q_{prevented}$ and $q_{potential}$ is reported in some exampleswith higher values than $q_{generated}$
(3) Data quality depends on the quantity of sources detected and the strenghth of data given
(4) Lower for informational campaigns, higher for training. High dependence on country habits. UK data for generated food waste is higher than EU average data given by FUSIONS.
NOTE: some possible actions have not been added, specifically regulation or transversal actions that are difficult to allocate in a specific stage of the FSC

There is need to focus on the actions with high impact and feasibility, not neglecting the "challenges" and "quick wins", according to Figure 14 (DEFRA, 2007)

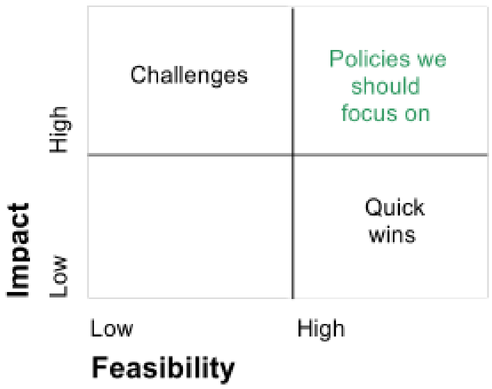


Figure 14: The Johari grid model used to short-list the actions and policies.

To exemplify Figure 14: The Johari grid model used to short-list the actions and policies.Figure 14, the WRAP research about households' food waste can be used. According to WRAP, 50-60% of food wasted by households is avoidable; that's why it makes sense to focus on actions specifically targeted at improving citizens' behaviours. By applying the participation factor, the results show a range between 15-21% of actual prevention.

In the data given by ReFED it can also be deducted that actions on consumers' behaviour and food habits are the ones that can reach the highest quantity of food waste reduced. But if we add up all of the actions that are aimed at promoting donation, they would even exceed communication campaigns. Regarding this, donations are increasing throughout the world and are being legislated in many countries, either through regulations clarifying the responsibilities of donors, obliging supermarkets to donate surpluses or even including tax incentives for the donation.

However, new prevention technologies are emerging, including waste-tracking tools, new monitoring consensual methodology, packaging innovations etc. ReFED refers that these technologies have reduced waste by 5% to 35% in initial pilots.

4.5.2 Cross-cutting actions

Apart from the actions referred to in the previous point, there are other actions which barely result in direct reduction of food waste or its impact, but indirectly can contribute significantly to this reduction. These are called cross-cutting actions or strategies because they affect the FSC in various ways. It is very difficult to measure the specific impact of their implementation.

Different types of cross-cutting actions can be described. We can find an example in non-specific actions that affect the footprint of the food system. Strategies that seek a change in the population diet by reducing the consumption of food commodities that have a high impact in terms of GHG or land use could be included in this group. Also, those that pretend to increase the consumption of locally-sourced foods, thus reducing transport and food independence in a region.

Another group of cross-cutting strategies are those that involve the implementation of specific actions throughout the food chain, regarding aspects such as food safety or economic viability in the food sector that indirectly improve food waste generation. An example of these actions could be found in Priefer et al., (2016). On the other side, reduction targets are helpful to raise awareness, stimulate innovation, focus attention and to mobilise political action, besides helping to evaluate effectiveness of actions and pushing for a better and consensual monitoring.

Cross-cutting actions also open the scenario to a more holistic approach. For instance, reviewing the current food safety regulations could be highly recommended in order to avoid unnecessary food waste. Also, when thinking about setting new EU food marketing standards more related to nutritional value than to aesthetics, this may result in being effective on food waste prevention actions, even more than actions specifically created for this latter purpose.

4.5.3 DPSIR analysis framework

DPSIR is a Framework methodology for describing the interactions between society and the environment. The components of this model are Driving forces, Pressures, States, Impacts and Responses (see Figure 15). Using it for displaying food waste pressure on the environment and the response of the actions allows us to visually identify the main interrelations among those components.

Prevention can be considered as a policy response interacting with mainly Driving forces and Pressures, and in case of harm prevention also with State, and Impact.

For instance, there are some actions (like home composting, or in general composting instead of landfilling) that aim at reducing the **impact** of food waste without reducing its quantity. Those highlighted in Annex 1 of this report are actions targeting quantities and subsequently their environmental impact, acting on both **drivers** (e.g. regulatory actions on "ugly food", donation etc.) and **pressures.**

Another way to better understand this DPSIR interrelation is to think about the indicators that are needed to measure the output or the outcome of the **response** (EC, 2010). For instance, the size or degree of participation on specific actions is considered an output indicator. An indirect assessment of the results of the action on pressure (e.g. food waste prevented quantity) and state is an outcome indicator.

An output indicator provides detailed information on the instrument, but you do not know its real impact on the environment. With an outcome indicator measuring the impact directly, you have detailed information on the impact but you are uncertain of the relationship between the instrument and the impact. Both categories of indicators are necessary to make meaningful judgements on the applied prevention policies.

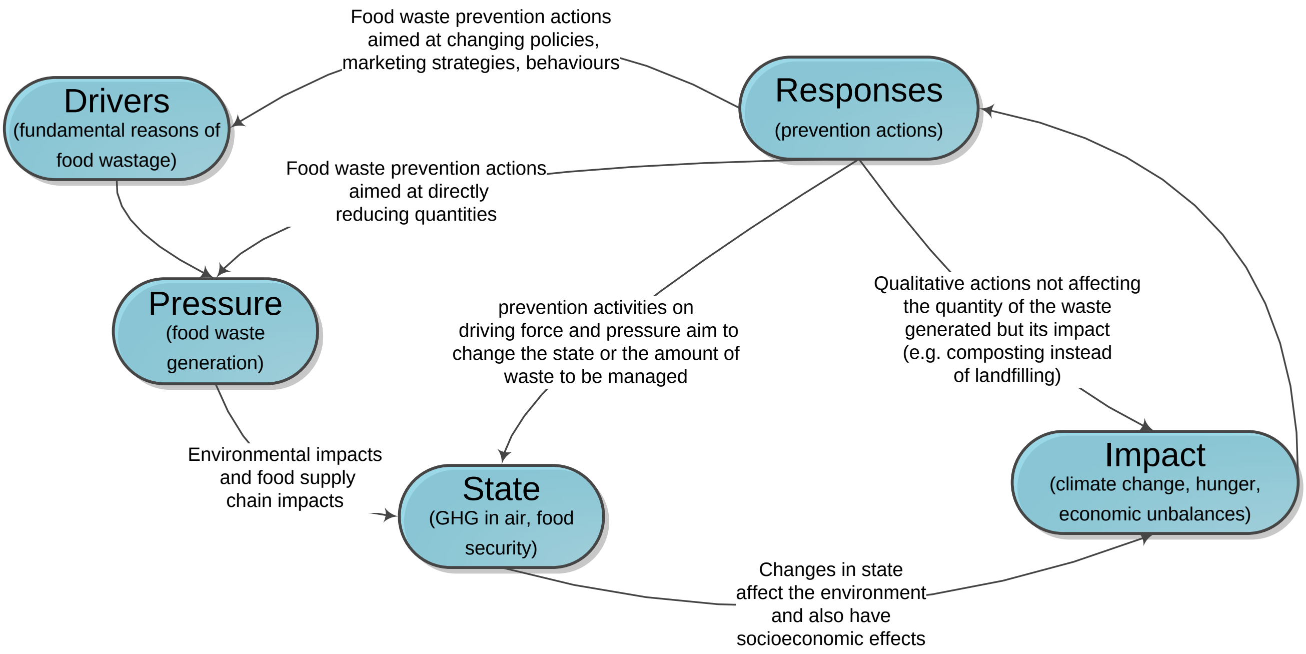


Figure 15: General representation of the DPSIR analysis on food waste

5 Food waste prevention: methodological approach for definition of targets

Chapter 4 and Annex 1 provided examples of food waste prevention targets and measures that are being applied in some member states. A key issue is that these targets (set as a reduction of quantity of food waste) are typically not correlated with the targets or improvements set at e.g. environmental or economic levels. In fact, from a conceptual point of view and towards more sustainable waste management, it seems more meaningful to first define what improvement(s) are desirable/needed as reduction in the environmental impact (e.g. to comply with current environmental legislation), and based on this improvement(s) to then derive the food waste prevention target (and the associated prevention actions) that allows to achieve the improvement(s).

This section aims at developing a generic methodological approach to identify environmentally sustainable targets for food waste prevention. A food waste prevention target (FWPT) is here defined as the ratio (as %) between the total quantity of prevented food waste (that allows achieving the environmental improvement set by the decision-maker) and the total quantity of food wasted. The other dimensions of sustainability – namely the economic and social dimensions – will be disre garded for the time being in order not to further complicate an already complex system. The goal is to show how to calculate the food waste prevention targets that lead to a desired improvement of the environmental performance along the entire food supply chain.

This analysis is not an easy task due to the complexity of the food supply chain, which depends on multiple product supply chains and multiple transformation processes.

5.1 Environmental impacts associated to food waste prevention

In order to estimate the reduction in environmental impacts associated to a given food waste prevention strategy or action, two alternative approaches could be used:

1. The first one is to evaluate the environmental impacts (using LCA) in the baseline scenario (i.e. before prevention actions are implemented) and again once the prevention action has been applied (see section 4.5). This approach requires LCA modelling expertise and the use of LCA databases and software tools.

2. The second one is to use directly data from literature. Some studies (e.g. Bernstad Saraiva Schott and Canovas, 2015), using an LCA approach, have analysed a number of food waste prevention actions, quantified their effectiveness in preventing food waste and quantified the associated reduction in environmental impacts. The main challenge is to know which assumptions, allocations, etc., have been considered when calculating each value and the applicability of these values in other case studies.

In this report, the environmental impact associated to food waste prevention will be calculated making use of data from literature (as from the above approach n.2). Data concerning quantities of food waste prevented ($\mathrm{Q}_{\mathrm{prevented}_{\mathrm{i,j,k=p}}}$) by each action and the environmental impact of the different steps of the FSC ($EI_{j,k,a}$) will be required.

In order to calculate the impact prevented by a prevention measure ($\mathrm{STEI}_{\mathrm{prevented}_{\mathrm{i,a}}}$), it is assumed that the quantity of food waste prevented by action *i* in the FSC *j* at a certain stage *k* of the FSC ($\mathrm{Q}_{\mathrm{prevented}_{\mathrm{i,j,k=p}}}$) will never be produced and so an equivalent amount of food for human consumption is reduced in the food system. Then, it can be assumed that the impact avoided by the measure will be considered equal to sum of the impact of producing this amount of food (that will no longer have to be produced) and the impact of disposing the amount of food waste prevented (end of life phase that will no longer take place). Nonetheless, the validity of the hypothesis that the implementation of the action has no environmental impact must be checked. Therefore, the environmental impact prevented by a given prevention action *i* for the impact category *a* ($\mathrm{STEI}_{\mathrm{prevented}_{i,a}}$) is calculated following the approach presented in FAO (2013) shown in Figure 16. Equations are detailed in section 5.1.2.

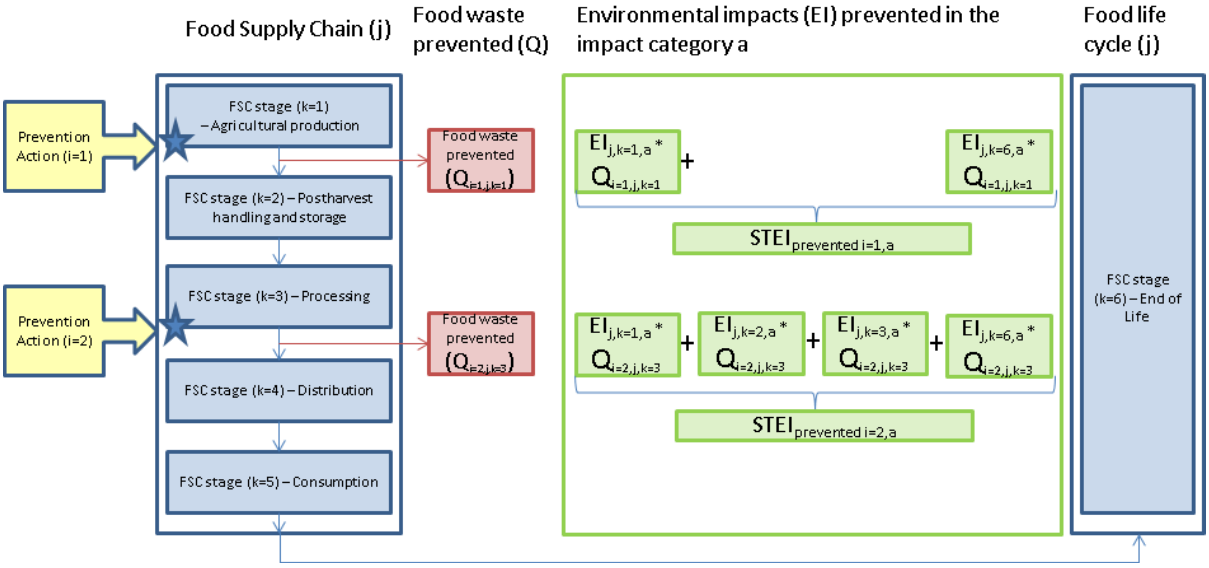


Figure 16: Framework for calculating the environmental impact prevented by a prevention action.

When this approach is used, the following aspects should be considered:

- The prevented amount of food waste replaces the same amount of food that reaches the FSC stage to which the prevention action is applied.
- Regarding food characterisation, it is important to note that different studies (FAO, FUSIONS, BoP, etc.) use different food group categories (fruits, cereals, meat, fish, etc.)
- Some prevention actions influence several stages of the FSC, although the exact stages and/or the exact proportion among the different stages involved are not known. In all these cases, it would be necessary to discuss the best choice of calculation and the deviations in the values obtained.
- It is also possible that when combining different prevention actions additional food waste prevention is achieved (i.e. multiplier effect).

It is particularly important to have robust knowledge of the methodology used for the calculation of the environmental impact of each FSC stage *k* of a FSC *j* for the impact category *a* ($EI_{j,k,a}$), i.e. which flows have been taken into account, which functional unit has been used (see box 5.1), etc. To estimate them, it is possible to e.g. use the data published in Notarnicola et al., (2016) as mentioned in section 2.2.1.

BOX 5.1 – Different functional units used in LCA of food waste

The environmental impacts of food waste may be expressed relative to an LCA functional unit based on "mass of food waste". Such mass can include (1) both avoidable and unavoidable parts food waste; or (2) only the avoidable parts. Alternatively, the functional unit can also be defined based on the (3) calorific value of the food wasted. The functional unit chosen for the calculation of food waste environmental impacts should be the amount of food waste generated in the region under study in the reference year, which represents the sum of the amount of all the food commodities wasted in the different stages of their FSC.

1. Mass of food wasted accounting for both avoidable and unavoidable food waste: Is the functional unit recommended in this report that allows the use of the environmental impact results to calculate food waste targets. This is the functional unit that includes in the calculation all the parts of food waste considered in the food waste definition.

2. Mass of avoidable food wasted: Is the functional unit that assigns impacts only for the edible parts of food waste that could be avoided if the food supply chain was more efficient. In this case the inedible parts are free form environmental burdens. This functional unit is not recommended for the objective of the present report because according with the food waste definition here assumed the unavoidable (inedible) parts are also included in food waste and therefore these also contribute to environmental impacts. In this report unavoidable parts are, however, excluded from the prevented food waste, with the rational that the prevention of these parts is difficult to achieve with the commonly used prevention measures. However, these parts may be removed from the food supply chain to be used as animal feed or for the production of bio-products, this uses are out of scope of this report.

3. Calories of food wasted: This functional unit links the environmental impacts of food waste to the amount of food energy lost when food is wasted. This is a very important way of approaching the food waste problem since it allows assessing the environmental impacts of food waste per nutritional value of the food being wasted, which can easily be related with the actual human needs. As an example, a food commodity may have a high environmental impact per mass but if it has a high calorific value it may satisfy the human energetic needs easily than a commodity with lower impacts per mass and low calorific value. The only concern related with this approach is the uncertainty of calculating an average calorific value to the food being wasted, which adds to the overall results' uncertainty when calculating the food prevention targets.

FUSIONS project used **1 kg of food product utilized by the consumer** to analyse the avoided impacts of food that is consumed rather than wasted.

5.1.1 Preliminary remarks

In order to tackle food waste and its impact effectively, it is important to understand where the wastage hotspots are along the FSC and which food commodities wasted have the greatest impact (to be rigorous, not only in terms of GHG, also in terms of other impact categories such as natural resources depletion and other socioeconomic impacts).

There is clear need to improve the calculation of footprints related to waste of food, mostly those occurring in non-agricultural phases. According to FAO Factsheets (FAO, 2013) research needs include also full cost accounting of the global environmental and social impact of food wastage and the calculation of the opportunity cost of food wastage mitigation measures taking into consideration environmental and social costs.

It is important to note that, while some waste reduction solutions are easy to implement without any additional cost to the environment (such as better planned meals), some others can induce important environmental impacts (such as refrigeration systems impact on GHG emissions) (ReFED, 2016).

Possible food waste reduction options and their impact, therefore, should consider the following important questions:

- Would the food waste reduction strategy under consideration have its own impact on natural resources (i.e. GHG emission, water, land and biodiversity use)?

- How would this impact compare to simply letting the food get wasted and producing new food?
- Is the food waste reduction action acceptable economically and culturally?

The economic factor is often the first one to be considered, but the social/cultural factor also constitutes an obstacle when the proposed waste reduction strategy induces changes in cultural patterns.

5.1.2 Calculation of the environmental impacts of food waste prevention along the food supply chain

The following equations summarize the complexity of the problem (also schematically represented in Figure 16). Eq. 8 allows calculating the total reduction in the different environmental impacts *a* (for the whole system) arising from food waste prevention. Eq. 9 allows calculating the reduction in every environmental impact category *a* arising from every individual action *i* assuming that prevention actions themselves do not introduce additional impacts (rebound effect). In case prevention actions have a non-negligible environmental impact, Eq. 10 is used.

$$TEI_{prevented_a} = \sum_i STEI_{prevented\ i,a} \quad \forall\, a \qquad (8)$$

$$STEI_{prevented_{i,a}} = \sum_j \sum_{k=1}^{k=p} EI_{j,k,a} * Q_{prevented_{i,j,k=p}} + \sum_j EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} \quad \forall\, i,a \qquad (9)$$

$$STEI_{prevented_{i,a}} = \sum_j \sum_{k=1}^{k=p} EI_{j,k,a} * Q_{prevented_{i,j,k=p}} + \sum_j EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} + EI_{i,a} \quad \forall\, i,a \qquad (10)$$

Where,

$\boldsymbol{TEI_{prevented_a}}$ is the Total Environmental Impact prevented reduced for the different impact categories ***a***. Measured in the unit of the environmental impact (e.g. kg CO_2eq, in the case of climate change).

$\boldsymbol{STEI_{prevented_{i,a}}}$ is the Total Environmental Impact prevented by action ***i*** in the impact category ***a***. Measured in the unit of the environmental impact.

$\boldsymbol{EI_{j,k,a}}$ is the Environmental Impact in the FSC stage ***k*** in the FSC ***j*** in the impact category ***a.*** It is measured in the unit of the environmental impact per ton of food.

$\boldsymbol{Q_{prevented_{i,j,k=p}}}$ is the Quantity of food waste prevented by the action ***i*** in the FSC stage ***k=p*** of the FSC ***j***. It is measured in tons (See section 4.4.2).

k=1 is the first stage of the FSC and ***k=p*** is the FSC stage in which action ***i*** takes place. ***k=EoL*** is the End of Life FSC stage.

$\boldsymbol{EI_{i,a}}$ is the Environmental Impact in the impact category ***a*** of implementing action ***i***. It is measured in the unit of the environmental impact.

5.1.3 Simplified calculation

In order to simplify the process of calculating the environmental impact of food waste prevention the decision maker may use data from studies that calculate the environmental impacts of the EU food system as a whole.

As mentioned before, some reports disaggregate environmental impact data on the individual FSC stages *k* of the FSC *j* ($EI_{j,k,a}$) but also indicate the average environmental impact in absolute or per tonne of average food wasted per FSC stage *k* in the impact categorie *a* ($\overline{EI}_{k,a}$). The projects FUSIONS and the Basket of products are good examples of such studies calculating the impacts of food products consumed within the (average) EU diet.

In this case, Eq. 9 turns out to be simpler (Eq. 12), as follows:

$$STEI_{prevented_{i,a}} = \sum_{k=1}^{k=p} \overline{EI}_{k,a} * \sum_j Q_{prevented_{i,j,k=p}} + \overline{EI}_{k=EoL,a} * \sum_j Q_{prevented_{i,j,k=p}} \quad \forall\, i, a \qquad (12)$$

This represents a simplification that assumes that the products wasted within the scope of the decision-maker are similar to the EU average, as well as the food waste composition.

5.2 Calculation of the food waste prevention targets

In the context of this report, a Food Waste Prevention Target (**FWPT**) is the ratio (as %) between the total quantity of prevented food waste ($TQ_{prevented}$) that allows to achieve the environmental improvement in the impact category *a* (Im_a) set by the decision-maker and the total quantity of food wasted in the reference year ($TQ_{generated}$) (see Eq. 13). The total prevented food waste $TQ_{prevented}$ (Eq. 14) is the sum of all quantities prevented ($Q_{prevented_{i,j,k=p}}$) by all prevention measures *i* and in all the FSC *j*. $TQ_{generated}$ (Eq. 15) is the sum of all quantities ($Q_{generated_{j,k}}$) of food waste generated in all FSC *j* in all FSC stages *k*.

$$FWPT = \frac{TQ_{prevented}}{TQ_{generated}} \qquad (13)$$

$$TQ_{prevented} = \sum_i \sum_j Q_{prevented_{i,j,k=p}} \qquad (14)$$

$$TQ_{generated} = \sum_j \sum_k Q_{generated_{j,k}} \qquad (15)$$

This prevented target is calculated under the assumption that the efficiency of the food supply chains should remain the same before and after the prevention, e.g. same food consumption (nutritional) needs must be satisfied. Otherwise, the functions of the food supply chains are not comparable.

A description of different prevention measures to be applied is given in Chapter 4. The choice of the best combination of prevention measure(s) should take into consideration their efficiency in achieving the desired food waste targets, mostly based on the scope and participation factors (S and P) and the environmental impacts arising from their implementation.

5.2.1 Generic formulation of the problem

Given:

- a set I of prevention measures
- a set J of FSC or food commodities (divided in a set K of FSC stages)
- a set A of impact categories
- the quantity of food waste generated in the FSC stage *k* of the FSC *j* ($Q_{generated_{j,k}}$) and the environmental impact of each FSC stage k of the FSC *j* in the impact category *a* ($EI_{j,k,a}$),
- the quantity of food waste prevented by action *i* in the FSC stage *k=p* of the FSC *j* ($Q_{prevented_{i,j,k=p}}$).
- the environmental improvement *Im* in the impact category *a* (Im_a) as the percentage of reduction desired by the decision-maker.

The goal is to calculate the total quantity of prevented food waste ($\boldsymbol{TQ_{prevented}}$) and the group of measures to be implemented in order to set a food waste prevention target (FWPT) that allows to achieve the desired environmental improvement ***Im*** replaced

This can be calculated by solving the following system of equations:

$$\max TQ_{prevented} \quad \forall\, a$$

Subject to:

$$TEI_{prevented_a} \leq TEI_{generated_a} * Im_a$$

Where:

$$TQ_{prevented} = \sum_i \sum_j Q_{prevented_{i,j,k=p}} * x_i$$

$$TEI_{prevented_a} = \sum_i \sum_j \sum_{k=1}^{k=p} EI_{j,k,a} * Q_{prevented_{i,j,k=p}} * x_i + \sum_i \sum_j EI_{j,k=EoL,a} * Q_{prevented_{i,j,k=p}} * x_i \quad \forall\, i, a$$

$$TEI_{generated_a} = \sum_j \sum_k EI_{j,k,a} * Q_{generated_{j,k}}$$

Where x_i is a binary variable that takes the value of 1 in case the prevention measure is implemented and 0 otherwise. With this $\max TQ_{prevented}$, FWTP (Eq. 13) is calculated and allows achieving the desired environmental improvement $\boldsymbol{Im_a}$. Due to the nature of the problem formulation, since the prevention measures have to be either implemented or not (i.e. they cannot be implemented partially), it could happen that the exact number $\boldsymbol{Im_a}$ is infeasible. In that case the solution would be the closest $\boldsymbol{Im_a}$ that fulfils the constraints.

5.2.2 Possible shortcuts: the "polluter pays" perspective

The complexity of food waste targets definition may be diminished by focusing the calculations on the FSC stages and food commodities that lead to the highest environmental impacts.

The FSC stages that typically lead to higher impacts are the ones further down the food supply chain, because as explained before the impact of the food waste generated in this stages include the impacts of all the previous food production stages and the treatment stage (according with the "polluter pays principle").

This perspective is highlighted by the EU FUSIONS, which included an interesting double representation of the environmental impacts along the FSC. When displaying the results for the climate change impact category based on the origin of the emissions (Figure 17), it turns out that most of the GHG emissions (72.4%) derive from the production stage, since this stage is very resource and energy intensive. The end of life (EoL) stage of the food supply chain, which is where all wasted food from households ends up to, accounts for just 7.1% of the total GWP of food waste. But if we look at the same data from the perspective of the polluter (Figure 18), as the consumption stage produces most of the food waste, most of the environmental impacts (68%) are accounted to that stage. With this "polluter pays" perspective, food wastage at a given FSC phase accumulates the impacts of the phase itself, the previous phases (if any), and the impacts associates at the End of Life of the food waste.

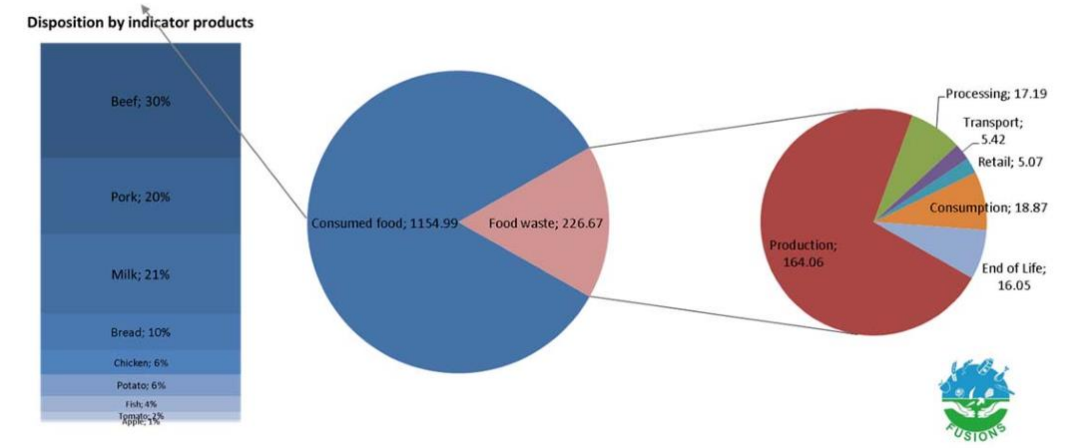


Figure 17: Estimation of GWP of consumed and wasted food in EU in Mt CO_2 eq. with food waste related GWP on the view of the emission origin (source: FUSIONS)

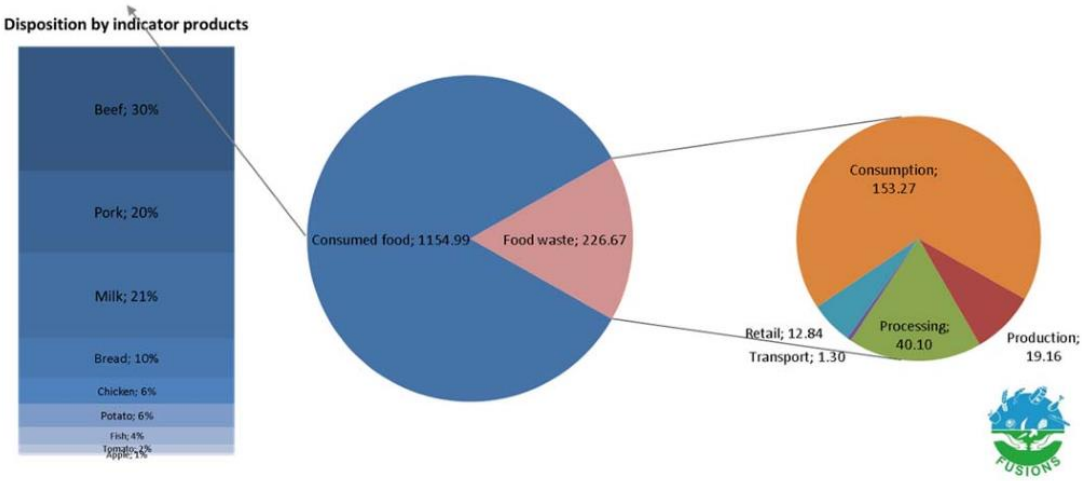


Figure 18 - Estimation of GWP of consumed and wasted food in EU in Mt CO2 eq with food waste related GWP on the view of the polluter-pays principle (source: FUSIONS)

Therefore, in the EU, consumption is usually the stage that presents higher environmental impacts, and is typically the one associated with the highest amounts of food wasted. This explains the fact that many food waste studies and prevention measures are directed to consumption.

Fruits, vegetables and cereals are the groups of food products with higher waste rates. On the other hand, meat, fish and dairy products represent the smaller fraction of wasted products (Bernstad Saraiva Schott and Cánovas, 2015). However, even in small amounts, typically meat and fish products present the highest contribution to the climate change impacts of food waste generation, because the production of animal and fish based commodities requires more resources and produces more emissions than other types of food commodities (Priefer et al., 2016).

Therefore, one way to achieve higher environmental efficiency is to focus food waste prevention targets and measures on the consumption stage and on meat and fish commodities.

5.3 Economics of food waste reduction: a brief overview

When looking at the overall viability of implementing prevention actions, in many cases environmental benefits do not play the major role. Stakeholders and decision makers' concern is sometimes more on the economics side, and even worse they focus only on a limited part of that, e.g. the cost for implementing an action.

Many basic notions have to be reinforced when talking about this aspect such as the nonlinearity of the implementation costs with respect to the target and the length of time of the action. The initial costs in this field will be probably far higher than the maintenance operational costs, as target groups must undergo quite a radical change of habits/equipment that requires some effort.

Another important fact to be considered is that the economic benefits must be taken into account: when avoiding food waste, the value of the same product at retail or wholesale market must be accounted as a saving.

ReFED, a collaboration of business, nonprofit, foundation and government leaders committed to reducing food waste in the United States, published a dataset[21] evaluating in detail the possible impact, and economic value as the difference of benefits and costs (see Figure 19), of 27 actions focusing on prevention and reuse, plus 4 about recycling. The interesting thing is that none of the actions shows a negative balance: in other words, the savings from substituting food market value always exceeds the cost for implementing the action.

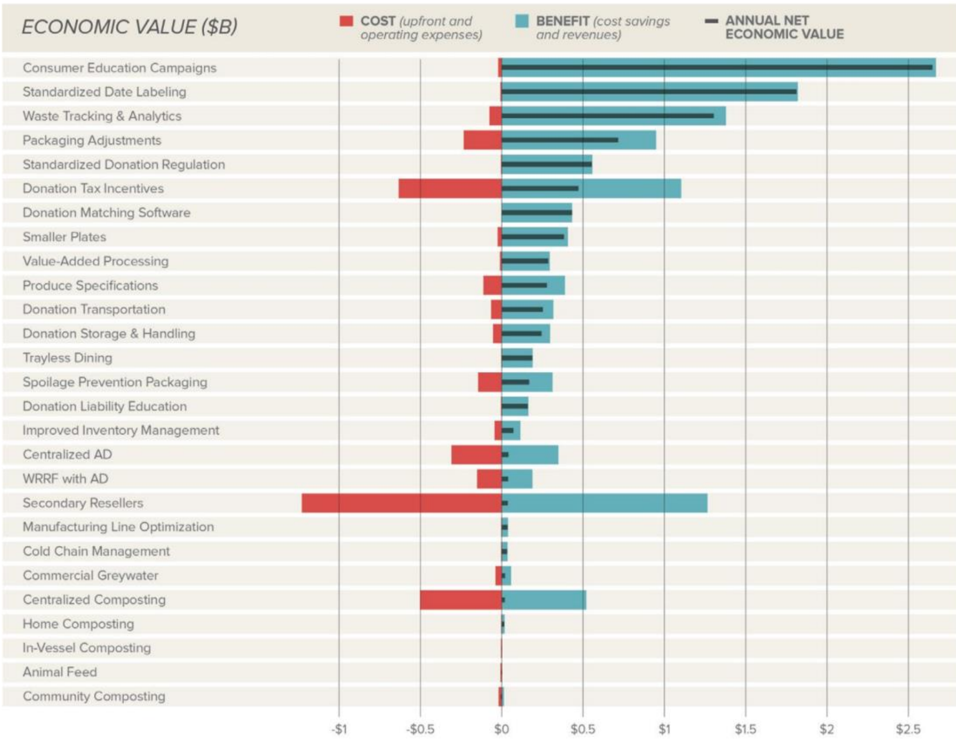


Figure 19: Cost/benefit balance of a set of food waste prevention actions for the US. Source ReFED

[21] http://www.refed.com/?sort=economic-value-per-ton

BOX 5.2 – How significant food waste prevention costs / benefits are?

Food and drink is the largest manufacturing sector in the EU, with a turnover of € 1244 billion (Fooddrink Europe, 2014), and a R&D expenditure of 0.23% (€ 2.8 billion). To see the order of magnitude of implementing food waste prevention actions in the EU, we could take data from ReFED, averaging the pure cost of all the actions which results in about €550/t per year. Taking the EU data of 116 Mt total food waste produced (Manfredi et al., 2016), and assuming a target of 20% reduction, it would need almost € 13 billion, around 1% of the EU turnover, to implement them.

But this is indeed a biased point of view, as taking into account the benefits (for the consumers / final resellers) of reducing purchases of unnecessary food, the global figure turns out to be positive, with a global economic value of around €3200/t.

So this is really a matter of reallocation of assets rather than a simple cost-effect calculation.

5.3.1 A case study of food waste prevention economics

ReFED data could be used as a good case study with detailed and validated data including potential and actual prevention figures of the whole set of actions, an estimation of the environmental benefit in terms of GHG reduction and the economic balance of the implementation of those actions.

The data presented in Figure 19 for the list of actions is summarized in Table 5, grouping them for stage of the supply chain or group of actions, with a specific focus on food donations.

Table 5: Summary of data from ReFED database, grouped and adapted.

	Addressable waste	**Diversion Potential (K tons / year)**	**Diversion potential (kg/capita)**	**Economic Value ($M / year)**	**Benefit ($M / year)**	**Cost ($M / year)**	**Economic value ($/t)**	**GHGs (K tons / year)**	**GHG (kg CO2eq / t)**	**Reduction of baseline GHG**
Processing	9.850	890	2,9	1.538	1.765	227	1.727	3.398	3.817	-3,0%
Consumer	36.018	1.244	4,1	5.029	5.086	58	4.043	4.972	3.998	-4,4%
Donation	13.280	3.210	10,5	2.395	3.166	771	746	11.250	3.504	-10,0%
Retail/ Restaurant	7.317	701	2,3	1.099	2.717	1.618	1.569	1.944	2.774	-1,7%
TOTAL	**66.465**	**6.045**	19,7	**10.060**	**12.735**	**2.674**	1.664	**21.564**	3.567	**-19,1%**

Every actions has an implicit estimation of its participation rate and scope factor, calculated by ReFED advisory group, that leads to an estimation of the diversion potential (19.7 kg/capita) and a reduction of the baseline GHG (-19.1%)[22]. The net GHG reductions along with the calculated cost and economic benefit (calculated and shown in Table 5) can be displayed in a Pareto-front chart (Figure 20 and Figure 21). The results shown in Figure 20, that displays the cost-efficiency of the set of actions reducing GHG emissions, are somehow reverted and changed in Figure 21, which represents the economic value including the benefits (the value is negative when benefits are higher than the costs).

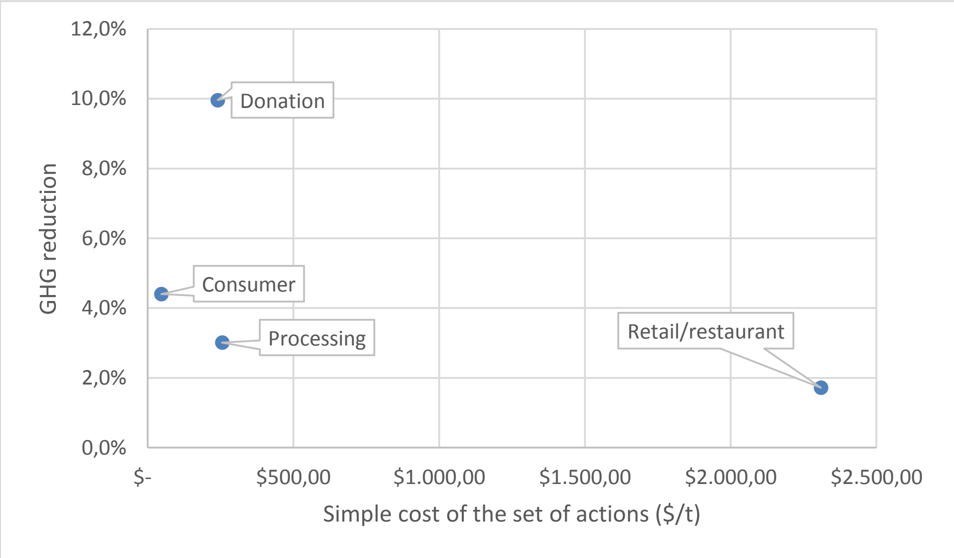


Figure 20: Scatterplot with the cost of a set of actions and its effect in terms of GHG reduction. Source: processing on ReFED data.

22 Baseline food waste emissions in the US: source http://www.cleanmetrics.com/pages/ClimateChangeImpactofUSFoodWaste.pdf

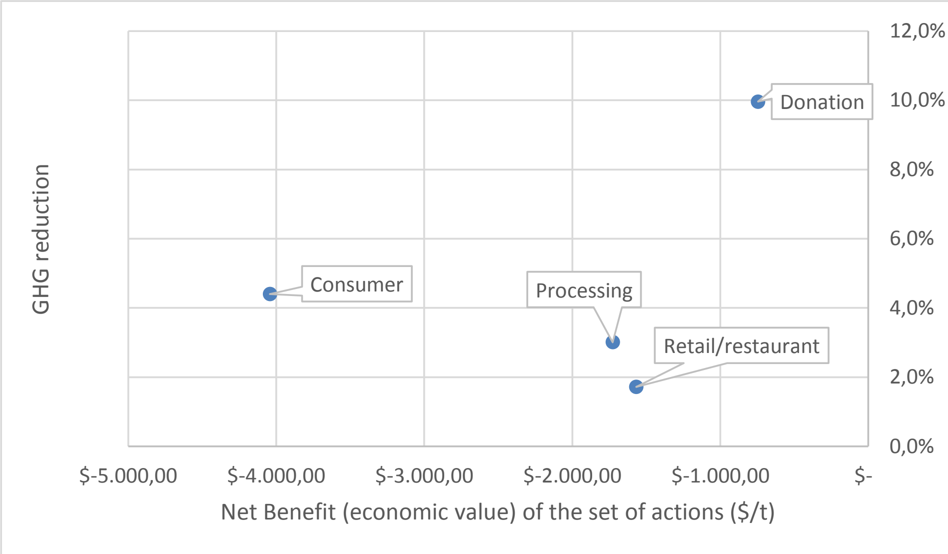


Figure 21: Scatterplot with the net economic value of a set of actions and its effect in terms of GHG reduction. Source: processing on ReFED data.

ReFED data represent a theoretical situation with an average "standard" participation rate, variable for the specific actions. In Annex 2, detailed data with the estimation of the maximum participation for each action, according to the assumptions of ReFED technical Annex, is presented.

With this improved scenario it's not actually possible to estimate the change in the specific cost or benefit for each action, as for many of them the total investment is not linear (i.e. there is a fixed part and a variable one proportional to the scope of the action). Therefore, in Figure 22 we only highlight the fact that the effect of increasing participation up to a maximum can significantly improve the quantitative and environmental effects, in a different way for each set. For instance, actions on consumers (such as sensitization campaigns) in some cases may reach very high participation rates, like in the specific trials performed in WRAP's campaign Love Food Hate Waste. The increased economic benefit is not shown here, as it is most probably not linear. Higher participation will significantly reduce initial investment costs per tonne, increasing even more the overall viability.

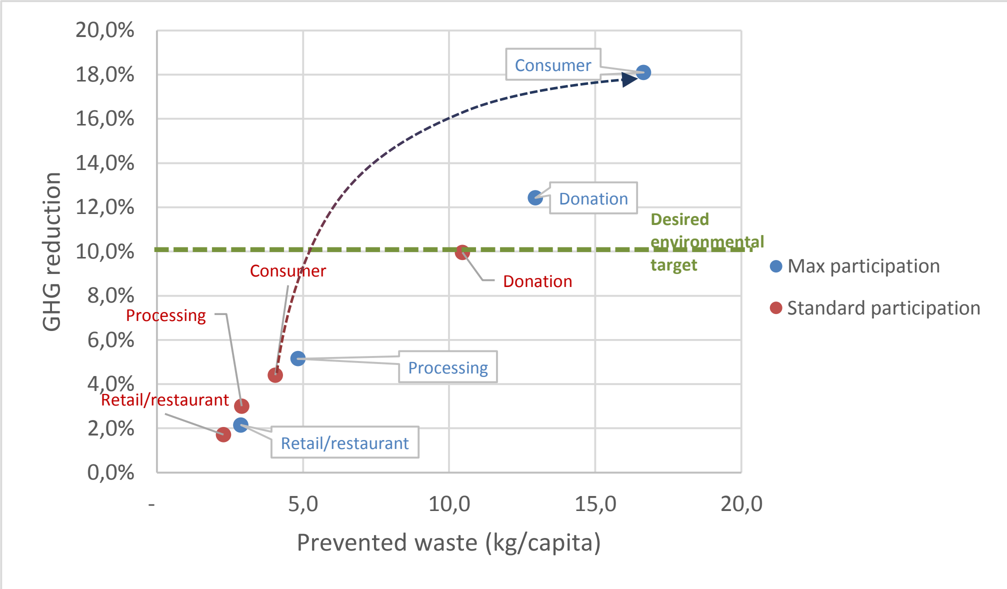


Figure 22: ReFED data - simulation of the effect of increased participation from a standard level to a theoretical maximum.

The considerations expressed above act as a hint for policy makers to focus not only on mere economics, but also on the other parameters encompassed by the complex equation that leads towards the expected emission reduction target. Focusing on the actions that may encounter a high participation if well implemented may be the key.

6 Conclusions and recommendations

Among other municipal waste streams, food waste gained prominence in the political debate in light of the recent Circular Economy (CE) package (EC, 2015a). In fact, the CE Action Plan (EC, 2015b) included food waste within the so-called "priority areas", i.e. areas that should be carefully considered to strengthen the circularity of the European economy.

Against this background, this report provided insight and analysis on the sustainability of food waste prevention. In particular, it aimed at analysing and evaluating the efficacy of some selected strategies for food waste prevention implemented at Member States' and regional levels.

Moreover, the report aimed at advancing a novel, straightforward, life cycle based methodology to identify sustainable targets for food waste. A key issue here is that food waste prevention targets are typically not correlated with the targets or improvements set at e.g. environmental or economic levels. Towards more sustainable waste management, it seems more meaningful to first define what improvement(s) are desirable/needed, for a reduction in the environmental impact(s) (e.g. to comply with current environmental legislation), and based on these improvement(s), to then derive the food waste prevention target (and the associated prevention actions) that allow the improvement(s) to be achieved. This has been the guiding principle of the novel methodology presented in this report.

An analysis of the stakeholders involved in the food supply chain, categorized by level of power and of interest, is presented in chapter 3. One key finding is that groups generating a high amount of food waste such as final consumers have a low level of power in decision making processes, and additionally, their interest is very variable according to how much they have been sensitized. As consumers increase their level of awareness they will be able to influence and to give positive feedbacks on the key decisions to be taken by the more influential stakeholders such as policy makers or food processing enterprises. The other key note is that stakeholders with a high level of power, such as policy makers, typically present the food waste issue with a high resonance in the media, but often do not focus on a strict monitoring and follow up; this, along with the difficulties in waste prevention monitoring, hampers the spread of an effective positive feedback. Looking at this from another perspective, it can be discerned that the stakeholder analysis highlights behaviours that imply incentives or barriers with respect to food waste prevention. For instance, in the actions based on sensitization or training directed at consumers, the final level of prevented food waste is directly related to the strength of the action and to the arguments used.

Quantifying food waste generation and assessing the sustainability profile of food waste management along the food supply chain is one step towards designing and prioritising strategies for food waste prevention. As presented in Chapter 4 and Annex 1, several new policies and measures to reduce food waste generation have been recently implemented at local/regional levels. At the same time, increasing effort are also observed at European level to design and implement an efficient, overarching food waste prevention strategy. The starting point for this is to set a clear definition of what food waste is and include, which definition is currently still missing in European legislation.

The analysis of food waste prevention measures/strategies implemented at Member State or regional levels (Chapter 4) revealed that a better understanding of their sustainability impacts is needed to take more informed and science based decisions. It was found that often an evaluation of their results (in terms of prevented amount of food waste) is missing or weak from a methodological point of view. And even when a monitoring mechanism is in place, consistency and transparency of the monitoring approach are often low, which makes it very difficult to make broad comparisons. So it is crucial that reporting of food waste quantities and evaluation of their impacts is conducted by following widely recognised guidelines, such as those included in the EU FUSIONS project. It was also noticed that it is key that rules and obligations are enforced for all stakeholders along the food supply chain. Towards increasing data quality and comparability, these rules and obligations should set requirements on how report the amount of food being wasted, as well as the monitoring methodology in order to increase transparency.

From the analysis presented in Chapter 4 it can be concluded that it is essential to differentiate between food waste generated (both avoidable and unavoidable), potentially prevented, and actually prevented when an action is implemented, as well as the key factors that affect these results such as the consumers' participation. Looking at data listed in Annex 1, it can be seen that both the potentially and actually prevented quantities are usually highly uncertain parameters. Food donation and consumer awareness results can also vary considerably, because their degree of implementation can vary significantly, but also because there are different success factors that affect their effectiveness.

While the key focus of this report is the environmental sustainability of food waste prevention, economic aspects should not be ignored. More and better data on the economics of food waste prevention measures (Chapter 5.5) are essential. A robust economic analysis would also help designing incentives to support food waste prevention and achieve the desired environmental improvement. Win-win economic strategies could also be developed. For instance, waste laws should address tax measures targeting the optimal food use management, establishing clear incentives and dissuasive sanctions for those who do not meet food waste reduction targets. Economical instruments should be aimed at the entire food supply chain, from the production to food waste management.

Overall, the analysis conducted in this report of food waste prevention strategies being implemented by some Member States seems to indicate that reducing food waste generation is a very complex to achieve in practice. The overarching reason is on one side the complexity of the food supply chain and, on the other side, the fact that a variety of integrated and well-coordinated measures need to be simultaneously adopted to effectively tackle the problem. Moreover, sometimes the lack of reliable and coherent data is posing a threat to the successful implementation of the most appropriate measures.

Nonetheless, it is important to consider that a given food wastage prevention measure, or combination of measures, is never a silver-bullet solution, and should be considered in the broader context that involves the overall municipal waste management system, and beyond. Nonetheless, the domino-effect related to all the small actions is really important in order to sensitize more and more people also on aspects and issues entailing, e.g. the social and socio-economic dimensions of sustainability.

The methodology presented in this report tries to identify environmentally sustainable targets for food waste prevention that allows to achieve a given reduction of the environmental impacts along the food supply chain. In this way, the linkage between quantitative prevention targets and environmental impact reduction targets is addressed in a meaningful way. From this methodology, the quantity of food waste that should be be reduced (in weight) and the prevention actions to be implemented to achieve the environmental desired improvement can be derived. Due to the nature of the problem, since the prevention measures have to be either fully implemented or not implemented at all (i.e. they cannot be implemented partially), it could happen that the desired environmental improvement cannot exactly be achieved. In this case, the best solution is the one that leads to the closest environmental improvement (fulfilling all other constraints) to the desired one.

Furthermore, the key figures presented encourage the further analysis of the effectiveness of policies aimed at quantitative prevention or at environmental improvement and the climate change fight, such as just changing our diet. Starting from the fact that food waste is globally responsible for the third largest contribution to GHG emissions, ranked directly behind China and the USA. The set of actions investigated by ReFED highlights a potential 19.9% reduction of this impact, which is a good signal at first viewing; however, it is necessary to go deeper into these numbers, and to let every country or region choose its own most appropriate combination of policies and actions.

BOX 6.1 – Policy recommendations for effective food waste prevention

The following points are an attempt to summarise some of the key findings from the analyses conducted in this report. They intend to provide relevant insight to policy and decision makers at local/regional/country levels who are involved in designing and/or implementing efficient food waste prevention measures and strategies:

- Monitoring and transparency: it is crucial that higher degree of harmonisation in reporting of food waste quantities is achieved. For instance, the reporting guidelines developed by the EC FUSIONS project could be followed. Governments should establish obligations for all stakeholders in the food system to report the amount of food being wasted and, at the same time, to explain how data are obtained.
- Setting prevention targets: targets should be implemented by decision and policy makers in quantitative, measurable terms. Such targets should be derived based on the improvement of the sustainability performance along the FSC that is aimed at. In this report, the methodology presented helps deriving food waste prevention targets based on the 'targeted' environmental improvements.
- Green taxation on food waste: The principle of re-using food that is still edible should prevail over the free market patterns that often result in wastage of edible food. Taxing food waste and using this revenue to tackle food waste is a win-win approach. Waste laws should address tax measures targeting the optimal food use management, establishing clear incentives and dissuasive sanctions for those who do not meet the standard of food waste avoidance. Economical instruments should be aimed at both the food supply chain and the management of food waste.
- Food labelling: Rationalization of food expiry labelling in order to improve the clarity of expiry dates and differentiating the labels depending on whether the date given refers to a real health risk, or "best before" dates that only refer to organoleptic characteristics.
- Food Aid: Donations are one of several strategies that have demonstrated a high potential for food waste prevention. New forms of managing this surplus can be found by allocating more resources, and with wider objectives, rather than simply delivering food to vulnerable individuals and families. These resources can also be used to improve the nutritional balance and self-esteem of the beneficiaries, and to strengthen both the economic and social environments in which there are more people in need.
- Good Samaritan laws: For donors, one of the barriers to the donation of food is the fear of being sued, due to the possible food intoxication of the final beneficiaries. These laws, which remove responsibility from donors, could promote the quality and quantity of food donations.
- Raising awareness and consumer empowerment: Consumer habits are key to reducing some practices that generate high quantities of edible food waste.
- Gleaning regulation: Gleaning activities aim at using the surplus left in the fields after harvesting for animal feed. A good way to promote this could be by giving the authorization to do gleaning for social economy organizations, in order to ensure that the collected product will be delivered to people with fewer resources, and by employing vulnerable people as labour. On the other hand, actions aimed at using this surplus by the farmers themselves are both an economical

alternative and a prevention strategy.

- Public procurement: Include public procurement technical specifications, requirements and clauses that favour the reduction of food waste.
- Food System waste prevention board. Organizational and knowledge sharing instruments, including all of the actors involved in the food supply chain, including politicians, aid organizations, etc. to set out agreements, joint actions, spread best practices, and promote campaigns to raise awareness and educate on the prevention of food waste.

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List of abbreviations

BoP	Basket of Products
CE	Circular Economy
DEA	Data Envelopment Analysis
EEA	European Environmental Agency
EF	Environmental Footprint
FLW	Food Loss & Waste
FSC	Food Supply Chain
FU	Functional Unit
FWF	Food Waste Footprint
FWPT	Food Waste Prevention Target
GHG	Greenhouse Gas
GWP	Global Warming Potential
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCT	Life Cycle Thinking
MS	Member States
MSW	Municipal Solid Waste
OEF	Organisation Environmental Footprint
PEF	Product Environmental Footprint
PEFCRs	Product Environmental Footprint Category Rules
RT	Round Table
SCP	Sustainable Consumption and Production
S-LCA	Social Life Cycle Assessment
UNEP	UN Environment Programme
WFD	Waste Framework Directive

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Annex 1: List of prevention actions and associated data[23]

Table A. 1

		FOOD WASTE: $Q_{generated}$ (1) (kg/inh)	TYPE OF ACTION	FOOD WASTE: $Q_{generated}$ (SPECIFIC SOURCE)	POTENTIALLY PREVENTED ($Q_{potential}$ or $q_{potential}$)	ACTUALLY PREVENTED (max $Q_{prevented}$ or $Q_{prevented}$)	Source	
Primary production		**18±3**	Better storage, handling.(developing countries)			60%	Lipinski, 2013	Average
			Gleaning			227 kg/volunteer * y	St Andrews society, Virginia (USA)	Average
Processing & Manufacturing		**33±25**	Packaging Adjustments			0,651 kg/inhab*y	ReFED	2016
			Manufacturing Line Optimization			0,0627 kg/inhab*y		
Wholesale& Retailing	**Supermarkets**	**9±2**	Retail discount supermarkets&bakeries			3,3 kg/inhab*y	Salhofer et al. "Potentials for prevention of MSW". Austria	2007
			Last minute market&other packagingawareness strategies			20 t/shop center*y	Sainsbury 's supermarkets. ACR+, Quantitative benchmarks for waste prevention	2009
					5,6 kg/inhab*y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
					226 t/ 800m2 or 350 employees		Ademe, Les Dechets alimentaires-premiers pas vers la réduction...	2011
	Local fresh markets				0,35 kg/inhab*y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
	Small-medium retail				3,15 kg/inhab*y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
	Wholesale markets							
	Retailing in general		Improved Inventory Management			0,1857 kg/inhab*y	ReFED	2016
					9,1 kg/inhab*y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
			Promote and support local charity food supply nets			92,23 g/inhab*y		2010

[23] As stated in the report, these data should not be taken to be directly used in a methodology for calculating environmental impact, but as a reference when designing food waste prevention actions.

		FOOD WASTE: $Q_{generated}$ (1) (kg/inh)	TYPE OF ACTION	FOOD WASTE: $Q_{generated}$ (SPECIFIC SOURCE)	POTENTIALLY PREVENTED ($Q_{potential}$ or $q_{potential}$)	ACTUALLY PREVENTED (max $Q_{prevented}$ or $Q_{prevented}$)	Source	
			Food donation		14-36 kg/cap*y	Around 10% (Qpr*P)	Beretta et al, 2013 Market Study. Estimation	2001
					21- 19,4 kg/inhab*y		Bereta et Al. Canton of Aargau-Bern, Switzerland	2013
			Food donation			1,033 kg/inhab*y	Switzerland. Beretta et al, 2013	2009
			Food donation to Social Supermarkets			14,4t/bussiness*y	Austria. ACR+ Quantitative benchmarks for waste prevention	2009
					40 kg/inhab*y		Brussels Region. ACR+ presentation (Biowaste, need for EU legislation?)	2009
	Other		Best management and coordination with supplier	1,43 g/sandwich on-the-go produced	1,43 g/sandwich	0,2568 g/sandwich	Mark&Spencer & Unic, UK	2010
			Secondary Resellers			0,5581 kg/hab*y		
Food preparation & consumption	Households	92±9	Consumer education campaigns			1,8326 kg/inhab*y	ReFED	2016
			Standardized Date Labeling			1,2495 kg/inhab*y	ReFED	2016
			Granel shoping, buy what you need		60%	almost 60%	FAO	2013
			"Coaching" against foodwastage campaign		20 kg/inhab*y	14 kg/inhab*y	Gaspillage alimentaire. NGO France Nature Environment	2012
			Love Food Champions-Training		130 kg/household/y	Around 50%	WRAP, UK	2015
			Love Food Hate Waste		45,76 kg/inhab*y (46,8%)	21% or 9,55 kg/inhab*y (Qpr*P)	WRAP, UK	2012
			Awareness and training campaign			14,7% or 6,68 kg/inhab*y (Qpr*P)	Worcestershire County Council, UK	2011
				92 kg/inhb/y	20,3 kg/inhab*y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
			Actions on better conservation of food			50% of food wastage	Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
			Actions on better adjustment of food quantities			25% of Fwastage	Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
			Smart food consumption			10-16 kg/inhab*y	Brussels Region. ACR+ presentation (Biowaste, need	2009

		FOOD WASTE: $Q_{generated}$ (1) (kg/inh)	TYPE OF ACTION	FOOD WASTE: $Q_{generated}$ (SPECIFIC SOURCE)	POTENTIALLY PREVENTED ($Q_{potential}$ or $q_{potential}$)	ACTUALLY PREVENTED (max $Q_{prevented}$ or $Q_{prevented}$)	Source	
							for EU legislation?)	
					30 kg/HH * y		Brussels Region. ACR+ presentation (Biowaste, need for EU legislation?)	2009
					45%		Save the Food Project. Spain	2011
	Restaurants	21±3	Smaller Plates			0,5581 kg/hab*y	ReFED	2016
			Restaurants training&change of menus			48,5 kg/customer*y or 20-25 kg/restaurant/d	LIPOR, Menu Dose Certa Project (Portugal)	2012
			Tray-less buffet			25-30% // 25 kg/student*y	Grand Valley State University (GVSU),USA (Lipinski et al. 2013)	2013
			Trayless Dining			0,2609 kg/hab*y	ReFED	2016
					12 kg/inhab*y		Brussels Region. ACR+ presentation (Biowaste, need for EU legislation?)	2009
			Awareness campaign customers & kitchen management	154 g/meal		51%	IBGE, Infos fiches-dechets	2009
						2 kg/hab/y	La politique de prevention du gaspillage alimentaire. IBGE	2009
			Internal audit	120-250 g/meal		20-41%	PREWASTE	2012
			Awareness campaign	100-140 g/meal		23%	EUREST, Sweden	2010
				115 g/meal	44.3 g/meal		Bereta et al, 2013	2011
	Schools, canteens		Awareness campaign	7,73 kg /y . Student		1,003 kg/y*student	Prewaste, 2012 (Halmstad, UK, Contest between schools with monitoring)	2010
			Awareness+Monitoring		80%	47%	Lean Path (USA)	2012
						11%	Kalskrona municipality, Sweden. Maping report on waste prevention practices	2009
				8,3-14,2 kg/student*y	77%		Food Waste in Schools. WRAP,	2011
					6 kg/student*y		Brussels Region. ACR+ presentation (Biowaste, need for EU legislation?)&IGBE	2009
	Hospitals		Menú for patients,		273	196	Hvidovre Hospital.	2005

		FOOD WASTE: $Q_{generated}$ (1) (kg/inh)	TYPE OF ACTION	FOOD WASTE: $Q_{generated}$ (SPECIFIC SOURCE)	POTENTIALLY PREVENTED ($Q_{potential}$ or $q_{potential}$)	ACTUALLY PREVENTED (max $Q_{prevented}$ or $Q_{prevented}$)	Source	
			quantity adequation...		g/patient and meal	g/patient/meal (72%)	Reorganization of a hospital system...	
	Food services in general		Waste tracking-analytics			1,79 kg/hab/year	ReFED	2016
					5,6 kg/inhab/y		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
			Actions to reduce food coocked and not served		87%		Diagnosi malbaratament Alimentari, CAT, Spain. Estimation.	2011
					11 kg/hab*y		Brussels Region. ACR+ presentation (Biowaste, need for EU legislation?)	2009
Transversal			Produce Specifications			0,835 kg/inhab*y	ReFED	2016
			Donations (tax incentive, matching software, transportation...)			2,5157 kg/inhab*y	ReFED	2016
			Cold Chain management			0,0551 kg/hab*y	ReFED	2016
			Value-Added Processing			0,3209 kg/hab*y	ReFED	2016
			General awareness campaign across UK			1,300 kg/y*inhab	Love Food Hate Waste , UK	2000-2008 average
			Food donation to proximity charity nets		95%		UK. ACR+ Quantitative benchmarks for waste prevention	2009
TOTAL		173±27						

Annex 2: Detailed data from ReFED

Table A. 2:

Type	Type	Solution	Addressable waste (waste that occurs in the scope of the action)	Diversion Potential (K tons / year)	Participation factor	Participation / adoption in maximum scenario (estimated according to the assumptions of ReFED)	Economic Value per ton diverted	Economic Value ($M / year)	Benefit ($M / year)	Cost ($M / year)
Consumer	**Prevent**	Consumer Education Campaigns	**26500**	584	15%	100%	$4.531	$2.648	$2.669	($22)
Processing	**Prevent**	Waste Tracking & Analytics	**1905**	571	75%	100%	$2.282	$1.303	$1.378	($75)
Consumer	**Prevent**	Standardized Date Labeling	**8000**	398	5%	10%	$4.547	$1.812	$1.820	($8)
Donation	**Recover**	Donation Tax Incentives	**5100**	383	100%	100%	$1.230	$470	$1.103	($633)
Retail/restaurant	**Prevent**	Produce Specifications	**3600**	266	7%	10%	$1.039	$277	$389	($112)
Retail/restaurant	**Prevent**	Packaging Adjustments	**2750**	208	76%	100%	$3.443	$715	$949	($234)
Donation	**Recover**	Standardized Donation Regulation	**427**	193	82%	100%	$2.863	$553	$557	($4)
Consumer	**Prevent**	Smaller Plates	**1185**	178	75%	100%	$2.147	$382	$407	($25)
Retail/restaurant	**Prevent**	Secondary Resellers	**167**	167	100%	100%	$218	$37	$1.265	($1.229)
Donation	**Recover**	Donation Matching Software	**300**	150	100%	100%	$2.879	$432	$433	($1)
Donation	**Recover**	Donation Transportation	**445**	110	62%	100%	$2.294	$252	$317	($65)
Donation	**Recover**	Donation Storage & Handling	**445**	103	58%	100%	$2.366	$244	$297	($53)
Donation	**Recover**	Value-Added Processing	**1135**	102	60%	100%	$2.783	$285	$295	($10)
Consumer	**Prevent**	Trayless Dining	**333**	83	83%	100%	$2.253	$187	$190	($3)
Processing	**Preve**	Spoilage Prevention	**5300**	72	3%	15%	$2.326	$167	$312	($145)

	nt	Packaging								
Retail/restaurant	**Prevent**	Improved Inventory Management	**800**	59	74%	100%	$1.194	$71	$114	($44)
Donation	**Recover**	Donation Liability Education	**755**	57	50%	100%	$2.810	$159	$164	($4)
Processing	**Prevent**	Manufacturing Line Optimization	**30**	20	67%	100%	$1.770	$35	$39	($3)
Processing	**Prevent**	Cold Chain Management	**2300**	18	8%	15%	$1.816	$32	$35	($4)

Source: ReFED (2016), adapted.

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