Modelling of Milestones for achieving Resource Efficiency

Turning Milestones into Quantified Objectives: Food waste

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1.1 Introduction

The European Commission's Roadmap to a Resource Efficient Europe[1] provides a framework for future actions and milestones for resource efficiency to be met by 2020. Each of the milestones in the Roadmap suggests possible indicators that could be used to track progress of resource efficiency in the EU.

This document is a summary of the analysis performed in relation to potentially setting a target for food waste reduction. In the Roadmap, the milestone related to food proposes that by 2020, *"disposal of edible food waste should have been halved in the EU."* While the milestone is set on disposal of edible food waste in the EU, the food chain is global and changes in the diet and thus demands of consumers in Europe will impact production and thus resource inputs worldwide.

In the analysis document accompanying the Roadmap (Annex 6), a more specific version of the milestone was proposed for 2020:

Decrease of edible food waste in households, retailers, and catering by 50% in the EU.

This clarifies indicates that any quantified indicator used to track progress of this milestone should focus on:

- food intended for human consumption;
- of which only the edible fraction;
- the final stages of the supply chain beginning with retail.

This document sets out to define food waste, investigate how best it can be measured and provides a first assessment of the impacts of setting a food waste reduction target in the EU.

1.2 Background on food waste

A significant amount of food suitable for human consumption is unnecessarily discarded (179 kg per capita in the EU27[2], with evidence showing that over 60% of it may be avoidable[3]). Reducing food waste is a key lever for improving resource efficiency in the food system.

The definition of food waste is a topic under significant discussion this year. The Preparatory Study (2010), Parfitt *et al*. (2010)[4] and the FAO point to differing definitions currently in use, and the resulting difficulty comparing data across the EU[5].

Bio-waste is defined in the Directive 2008/98/EC as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. Food waste forms a fraction thereof, though there is not yet a

[1] European Commission (2011) Roadmap to a Resource Efficient Europe, COM (2011) 571.
[2] BIO Intelligence Service (2010) Preparatory study on food waste across EU27
[3] WRAP (2009) Household food and drink waste in the UK
[4] Parfitt, J., Barthel, M. & Macnaughton, S. (2010) Food waste within food supply chains: quantification and potential for change to 2050, Phil. Trans. R. Soc., vol. 365, pp. 3065-3081
[5] FAO(2012) Food Wastage Footprint: An environmental accounting of food loss and waste - Concept Note

legal definition of food waste. The food loss/waste distinction and edibility are key aspects to consider.

- **Food losses and waste**

Food loss, according to the final draft of the FAO definitions currently in circulation (March 2013), refers to food that during its movement along the food supply chain gets spilled, spoilt or otherwise lost or incurs reduction of quality before it reaches its final product or retail stage. Food loss is the unintended result of the process or the institutional/ legal framework. Food waste, according to the working definition to be finalised by the FUSIONS project by the end of 2013[6], refers to food intended for human consumption that is discarded, whether through negligence, choice or economic necessity. Food waste can occur at all stages of the food supply chain from farm to fork, whereas losses are mostly limited to the pre-sale phases. Given the focus of the milestone on food waste in households, retail and catering towards the consumption end of the supply chain, we will be focusing on food waste (and not food loss) in this document.

- **Edible and non-edible food waste**

Food waste (in a broad sense) can be both edible and inedible. Edible food waste refers to food that is normally eaten and can be digested by humans. Inedible food waste refers to fractions of discarded food that are not normally eaten or digested, such as bones, pineapple and banana skins, eggshells, etc. From a quantification perspective, it is very burdensome to separate the edible and inedible fractions of food waste because these occur naturally together, both in food preparation and in leftovers. Cultural and regional preferences regarding food exist and change over time, for example the consumption of offal, bread crusts and potato skins. These are nevertheless edible, and the introduction of categories such as "possibly avoidable", based on preferences, may be confusing to consumers and provide justification for unnecessary food waste.

1.3 Current targets in the EU

Besides the Resource Efficiency Roadmap, there is no specific EU policy addressing the issue of food waste. There are however waste policies in place such as the Waste Framework Directive (2008/98/EC) and the Landfill Directive (1999/31/EC). The Landfill Directive sets as a policy target the progressive reduction of biodegradable municipal waste (BMW) going to landfill. The Landfill Directive places an absolute target on the tonnage of BMW that can be land filled by 2006, 2009 and 2016 by linking the quantity permitted to the quantity produced in 1995. Thus, the Directive obliges Member States to reduce the amount of biodegradable waste in landfills by 65% by 2016 compared to 1995 levels. However, the Landfill Directive does not submit countries to binding specifications on methods for disposal of BMW not sent to landfills, a situation which has led most MS to opt for incineration rather than waste prevention, composting or anaerobic digestion.

The Waste Framework Directive forms the backbone of EU waste management legislation, provides basic definitions of key waste management terms and lays out basic waste

[6] Working documents not yet publicly available www.eu-fusions.org

management principles. In particular, it sets out a waste management hierarchy to help steer policy towards more favourable waste management principles such as prevention or re-use, and to leave disposal as a last resort. In relation to the waste management hierarchy, reducing food waste is considered a waste prevention action.

The European Parliament passed a resolution in January 2012 calling upon the European Commission and Member States to take "radical measures" to reduce waste from farm to fork by 50% by 2025.

The Waste Framework Directive requires Member States to establish National Waste Prevention Programmes and objectives by December 2013. The European Commission by the end of 2014 is also expected to set waste prevention and decoupling objectives for 2020 based on best practices. Member States have been encouraged to include food waste prevention policies and targets in their National Waste Prevention Programmes. Some Member States have already set targets, though some of these are not official. Key actions taken by some MS are listed below:

- France has already announced its 50% reduction goal of the volume of food waste by 2025, and furthermore proposes a national pact against food waste, signed by a wide range of leading stakeholders to signal their shared commitment.
- In the case of the Netherlands an intermediate target of 20% has been set for 2015.
- In the UK, the Courtauld Commitment develops voluntary, quantified targets over short time spans, working with industry and wider stakeholder partners. The current relevant target is a 4% reduction in household food and drink waste between January 2010 and December 2012, against a 2009 baseline, and a follow-up target will be announced shortly.
- In Sweden, a 20% food waste reduction target for 2020 was suggested, but this was not passed by the government. This will be proposed again as part of their National Waste Prevention Programme to be delivered later in 2013.
- In a recent press release, the Austrian Environment Ministry has proposed a 20% food waste reduction target for 2016, but no baseline year has yet been stated.7

1.4 Possible indicators

Some possible indicators for the reduction of edible food waste along the food chain:

- Amount of food waste, based on existing Eurostat waste statistics
- Amount of food waste, using Eurostat plug-in food waste statistics (currently voluntary)
- Amount of food waste and overconsumption (difference between food supply and nutritional requirement), based on FAOstat

[7] http://www.lebensministerium.at/lebensmittel/kostbare_lebensmittel/lebensmittelkostbar.html

1.4.1 *Indicator based on existing Eurostat waste statistics*

The main resource for waste statistics at European Level is Eurostat most notably through its "Data Centre on Waste". However, there is not as yet a specific food waste data category, the closest being "animal and vegetal waste", which may include by-products or tobacco in some instances, as Member States have some freedom in interpreting the scope of this category. There is a further issue that specifically edible food waste is very difficult to quantify, requiring a burdensome level of waste separation. Eurostat data is presented in tonnes of waste or kg per capita. Data can be broken down per category of waste and per sector where the wastes were generated.

Waste categories in Eurostat[8] are based on the European Waste Classification for Statistics[9] (EWC-Stat). A Previous study suggested that the category "EWC_09_NOT_093: Animal and vegetal waste excluding slurry and manure" as the most pertinent proxy for food waste.[10]

Note that methodologies of data collection and calculation differ between MS. Eurostat states that *"Member States are free to decide on the data collection methods. The general options are: surveys, administrative sources, statistical estimations or some combination of methods."* Data is available for all MS in this stream, though given different MS interpretations of the data categories, green waste, tobacco and by-products may be included in this data in some instances, presenting an important limitation in data robustness.

The EWC_09_NOT_093 data are available for all MS by NACE-branch[11]. A relevant NACE branch for tracking progress of the milestone is "EP_HH – Households". However, there is no specific data for retail and catering. These two sectors are included in the broad branch "Services" covering NACE sections G to U (except G46.77).

Eurostat data includes both edible and non-edible food waste. Gustavsson et al. (2011), having used FAO statistics separated by food category, indicate a conversion factor they used to determine the part of the agricultural product that is edible. Some examples are 80% for fruits and 50% for fish and seafood. Using such factors however implies the ability to breakdown the food waste stream by commodity group (cereals, starchy roots, oil crops & pulses, etc.), which is not the case with Eurostat data.

The EWC_09_NOT_093 category in households could be used as proxy for this milestone. Major limitations are it takes into account both edible and non-edible material and, it does not breakdown food waste generated the catering and retail sectors. Data is available for years 2004, 2006, 2008 and 2010.

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[8] EUROSTAT Data Explorer: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

[9] EWC-STAT 4 - European Waste Classification for Statistics, version 4 available at: http://ec.europa.eu/eurostat/ramon/other_documents/ewc_stat_4/index.cfm?TargetUrl=DSP_EWC_STAT_4
See also: Commission Regulation (EU) No 849/2010 of 27 September 2010 amending Regulation (EC) No 2150/2002 of the European Parliament and of the Council on waste statistics.

[10] BIO Intelligence Service (2010) Preparatory study on food waste across EU27

[11] The NACE (Nomenclature des Activités Economiques des Communautés Européennes) designates the type of activity selected. Relevant NACE branches for this preparatory calculation are DA (Manufacture of food products, beverages and tobacco), HH (Households), A (Agriculture, Hunting and forestry). The "Other category" NACE branch has also been used.

1.4.2 *Indicator based on Eurostat plug-in food waste statistics*

Eurostat is presently conducting a voluntary data collection on 2012 food waste generation, in which 17 Member States are participating. This data collection is based on the NACE system, introducing a data plug-in with more detailed indicators (such as animal tissue waste, plant tissue wastes, biodegradable kitchen and canteen waste) within the existing framework. Results of this data collection exercise will be available in 2014. This new data will fill the food service and retail data gaps, and will be able to suggest where edible and inedible food waste are most likely to occur.

Through this pilot data collection exercise, a robust data collection process may emerge that would enable more clearly defined and comparable data to be submitted by Member States. The evident limitation of this indicator is that it is still in a trial stage, and that it may be some time before it is mandatory for Member States to submit this data, if there is a requirement at all.

1.4.3 *Indicator based on food supply (FAOstat)*

FAO data is available on food supply in terms of calories, while the daily food requirement per person is based on WHO recommendations. From this basis, it is possible to estimate calories "lost", either to overconsumption or to waste. The average food supply per person in the EU is just over 3400 kcal/ capita/ day. The EEA calculated average EU-27 dietary energy requirement for 2006-2008 to be 2537 kcal/capita/day[12]. Thus, it can be interpreted that there is overconsumption and/or wastage of around 860 kilocalories daily by an average EU citizen.

A potential difficulty of this indicator is edibility: it is unclear that the FAO conversion factors that derive calories from the total weight of the food supply remove inedible fractions (such as banana skins and meat bones). If the second indicator (amount of food waste, using Eurostat plug-in food waste statistics) comes into force, as more accurate data collection on food waste expands, this food supply indicator may then enable us to estimate the scale of overconsumption, through subtraction. This could be useful in developing indicators on a healthy diet.

1.4.4 *Assessment of the three indicators according to RACER criteria*

In sum, all indicators suffer from difficulty measuring edibility, as removing the inedible fraction from food waste quantities is burdensome and impractical. Eurostat suggests that it knows under which NACE codes inedible food waste is likely to occur, but has no plans to separate this data (possibly given risks to accuracy and limited usefulness).

Progress on this milestone can be evaluated using existing waste statistics, and could be done so more effectively using the second indicator if the Eurostat data plug-in on food waste becomes mandatory. The use of waste data statistics is the main way in which food waste has been quantified until now, so benefits from general acceptance among stakeholders. This is a credible approach, particularly if definitions and measurement techniques are harmonised through the work of the FUSIONS project and the Eurostat data plug-in experimentation. It is anticipated

[12] www.eea.europa.eu/data-and-maps/figures/development-in-total-calorie-intake/scp019_indicator_13.1_2012.xls

that this will be easy to monitor, as Eurostat waste data is already collected, and the additional data request builds on existing NACE codes. Further feedback on the difficulty of data collection will be available in April 2013 as Member States collecting voluntary data report back to Eurostat. Comparable with any Eurostat data collection, this is auto-declarative, and so not completely without risk of manipulation.

As regards the indicator using food supply data, it suffers from the difficulty in separating food waste from overconsumption. Thus slightly less pertinent and has been less commonly used. However, food supply statistics are already collected and widely available, and relatively robust.

It is thus suggested on balance that waste statistics offer the more suitable indicator for this milestone, with the significant provisos that the waste data plug-in be generalised, and that the condition on the edibility of food waste be either removed from the milestone or integrated into the Eurostat plug-in data collection. It is our view that data on edibility is excessively burdensome to collect and not essential to the measurement of food waste reduction progress.

Figure 1: Comparison of three indicators using RACER

Indicator	Relevant	Accepted	Credible	Easy	Robust
Amount of food waste, based on existing Eurostat waste statistics	Medium	Medium	Medium	Medium	Medium
Amount of food waste, using Eurostat plug-in food waste statistics (voluntary)	High	High	High	Medium	Medium
Amount of food waste and overconsumption (difference between food supply and nutritional requirement)	Medium	Medium	High	High	High

1.5 Recent progress in the EU

The first quantification of food waste in the EU-27 was presented in the EC preparatory study in 2010.[13] A global estimate of food losses and waste was conducted by the Swedish Institute for Food and Biotechnology (SIK) for the FAO in 2011.[14] The EU food waste research project FUSIONS is conducting a more detailed estimation of food waste arisings at European level, to be published by 2016[15]. A number of Member States have conducted or are conducting national level studies on their food waste generation, and 17 Member States are participating in the voluntary Eurostat food waste data collection.

The EU generates an estimated 89 million tonnes of food waste annually, or 179 kg per capita, based on food waste generated across the supply chain. Total and per capita food waste arisings by Member State are presented in Figure 2 below, using the best available data in 2010, collected

[13] BIO Intelligence Service (2010) Preparatory study on food waste across EU27. Study conducted for the European Commission (DG ENV) Available at: http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf

[14] http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

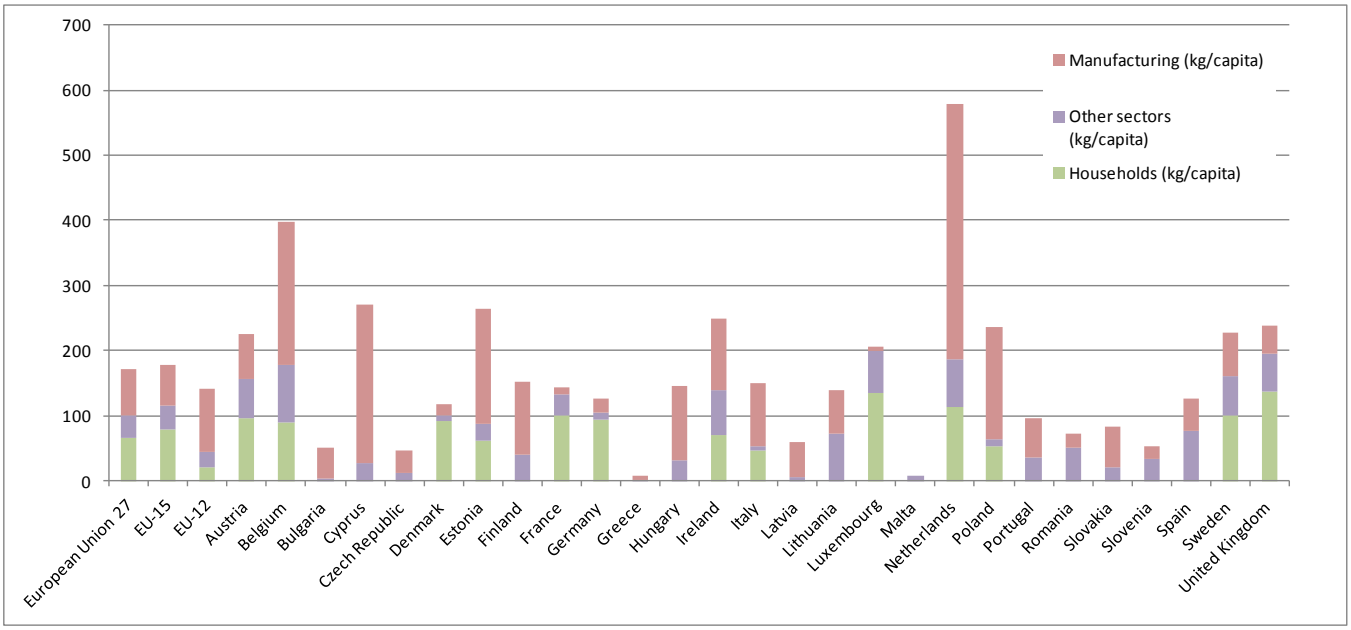
[15] www.eu-fusions.org

in the EC Preparatory Study. The publication of this study stimulated some Member States to undertake a more detailed national data collection; the Netherlands notably have a lower estimate based on new research.

From the 2006 baseline estimate of 89 million tonnes of food waste in the EU, the Preparatory Study[17] forecasted a roughly 40% rise in food waste generation based on anticipated EU population growth and increasing affluence only, to about 126 Mt in 2020. An assumption made here is that, with an increase in disposable income, an increase in food waste generation can be expected.

It was not possible to take into account the impact of waste prevention activities, given that at the time of the writing of the EC Preparatory Study, there were no national policies or target on food waste prevention, and very few even local level initiatives had quantified their results.

Figure 2: Estimated food waste in the EU27 by Member State and by sector, 2006 baseline, (kg per capita per year), (Source: EC Preparatory Study on Food Waste)



1.6 Ambition level for targets?

It is difficult to set a food waste reduction target given the current lack of robust food waste data in most Member States. Nevertheless, some Member State targets as well as the EU milestone have been set regardless, demonstrating strong political will to move forward on this issue. Only France has thus far mirrored the EU's ambition with its 50% target, with the small number of other MS setting targets in the 20-25% range, to 2015 or 2020, and even then, many of these have not been able to pass national legislatures.

It would be helpful to consider the minimum quantity of food waste possible, but as the 2011 EC study on the Evolution of Bio-Waste Generation/Prevention and Indicators points out, it has not been possible to identify this minimum, because the estimated quantities currently generated

vary so widely across MS and sectors.[16] The following targets are thus proposed based on current Member State ambitions.

Table 1: Proposed targets for food waste

Level of ambition	Target	Comment
Low	*By 2020, edible food waste in households, retailers and catering is reduced by 10% (compared with 2010) in the EU*	This target is likely to be achievable across the EU, even in new MS where food waste generation is generally lower. It addresses households, for which a wide range of prevention strategies are available and where edible food waste is likely to be concentrated.
Medium	*By 2020, edible food waste in households, retailers and catering is reduced by 20% (compared with 2010) in the EU*	The Netherlands have set a 20% target for 2015, so this target is not inconceivable. Fair period in which to implement prevention policies, though possibly more challenging in new MS where food waste levels are already lower.
High	*By 2020, edible food waste in households, retailers and catering is reduced by 50% (compared with 2010) in the EU*	This target would require systemic change across the supply chain in all MS over a relatively short period, and there is no precedent of 50% reductions being achieved.

1.7 Possible policy measures and relative costs

To reach these prevention targets, concerted action would be needed. Awareness-raising, voluntary agreements, economic instruments, reduction of barriers such as aesthetic standards and health-based restrictions on redistribution, and innovation can all play a role in achieving significant food waste reduction.

Research to understand national food consumption and wastage behaviours and a nationwide campaign adapted to this context would be suitable in addressing consumers in the household, retail and food service settings. The UK campaign Love Food Hate Waste is a good example here. NGOs can also support these activities. Voluntary agreements engaging and supporting industry actors in reaching prevention targets can also be helpful[17].

Economic instruments to catalyse change would be most effective: separate collection of food waste and pay as you throw schemes for households, bans or significant taxes on the landfilling of food waste for business (as in the Republic of Ireland). Further options aimed at the catering and retail sectors include incentives for redistribution (e.g. tax credits for food donations) and reducing barriers to redistribution (e.g. protecting food donors and foodbanks from civil and criminal liability for food donated in good faith).

[16] UBA, BIO (2011) Evolution of (Bio-)Waste Generation/Prevention and Indicators http://ec.europa.eu/environment/waste/prevention/pdf/SR1008_FinalReport.pdf

[17] The Courtauld Commitment for example: www.wrap.org.uk/content/courtauld-commitment-3

Policymakers can also provide guidance or regulation on contractual clauses that impact food waste in the supply chain, principally quality standards and contractual issues. Quality standards on size, shape, colour etc. imposed by retailers on suppliers can lead to important tonnages of edible produce being discarded. Awareness raising towards consumers on this issue and the provision of evidence that consumers are willing to purchase imperfect products can support this.

As regards supply contracts, retailers have large freedoms in refusing stock due to changes in their supply needs, due to quality standards, and in imposing penalties on suppliers for failure to deliver agreed quantities of fresh fruit and vegetables. This results in a strong impetus for an overproduction buffer[18], a food waste driver that would benefit from additional government oversight and regulation. Policymakers can also facilitate the transfer of otherwise wasted food to livestock feed, reducing legal barriers or providing incentives depending on the national context.

Innovation in finding commercial uses for foodstuffs that would otherwise become waste is an important lever for retailers (bruised apples for apple juice for example). Retailers can also stimulate packaging innovation by demanding resealable packaging, packs that easy to empty completely, a variety of portion sizes, smart packaging such as ethylene absorbers, which absorb the gas released from produce that stimulates the ageing process. Retailers can also contribute by removing 'sell-by' dates from products, replacing these with codes that are unidentifiable to consumers. Confusion between 'best before' and 'use by' dates continues and can be addressed with a coherent policy approach, which is likely to be product specific. The avoidance of "buy one get one free" schemes, that can encourage customers to buy more than they need, is also helpful. Alternatives include for example Tesco's "Buy One Get One Free LATER" initiative.

Retailers also have an important potential role in customer education and awareness raising. Such actions may focus on storage guidance, how to use leftovers from given products or ingredients, or how produce, like people, are not identical and thus encouraging the acceptance of natural variation.

In the food service sector, the provision of flexible portion sizes is a major driver for waste prevention, be it by offering two serving sizes as does TGI Friday's or by providing self-service or family-style serving options where customers can adjust their portion to their appetite. Research by the Nordic Choice hotel chain, furthermore, found that smaller plates reduced food waste at buffets by 20 percent.[19]

In order to meet the high milestone target, regulatory action along with strong use of economic instruments would likely be needed, in order to effect such a significant reduction in a short time. Bans or taxes on the landfilling and incineration without energy recovery of food waste might begin to make food waste prevention a more economically viable option. A legal requirement for companies to publicly disclose food waste data would also provide an incentive for businesses to bring attention to the issue and to improve their performance in relation to customer communication. These regulatory approaches should be accompanied by the range of softer instruments outlined above. Targets should be applied to Member States within which there

[18] IME (2013) *Global food: Waste not, want not.*

[19] http://www.nytimes.com/interactive/2013/01/27/magazine/one-page-magazine.html?_r=0

should be flexibility to assess where food waste can be reduced most effectively given national circumstances and wastage patterns.

The table below gives a first estimation of the level of costs associated with the various policy measures, based on estimates made in the EC Preparatory Study, stakeholder interviews, additional research and internal expertise. The table provides an idea of the types of measures that could be considered and what their relative costs would be. The policy measures listed do not take into account the benefits can would be achieved. This is examined in the next section.

Table 2: Estimated level of costs of policy measures

Measure	Estimated cost	Who bears cost	Sector targeted					Further information on costs	Source
			Households	Retail	Food Service	Manufacturing	Agriculture		
Reducing barriers to redistribution	+	National governments		x	x	x	x	Legislation such as the Good Samaritan Law is thought to have a negligeable cost. A new study has been commissioned by the European Economic and Social Committee on MS practices and legislation regarding food donation, which should bring further clarification on this in early 2014.	
Retail watchdog	+	National governments		x		x	x	The administrative cost of creating a retail watchdog position is expected to be limited to the salary of one senior level civil servant, at the relevant wage rate in each MS, and one assistant.	http://www.guardian.co.uk/business/2013/mar/31/supermarkets-watchdog-ready-sort-out-bullies; https://www.gov.uk/government/news/groceries-code-adjudicator-formally-established
Packaging innovation	++	Manufacturers		x		x		Costs highly variable depending on the technology involved. A comparative assessment of packaging technologies, their potential to reduce food waste, their relative costs and any barriers to implementation, would support advancement here, on a topic much discussed but significantly lacking comparative data.	
Flexible portion sizes in food service	+	Food Service businesses			x			Sodexo have undertaken several activities testing alternative portion sizes in 2013, and may be able to provide information on the costs of these activities later in the year. Their Better Tomorrow Plan provides guidance for cafeterias on controlling portion size.	http://blog.sodexoprestige.co.uk/2011/10/28/food-waste-high-on-the-sodexo-sustainability-agenda/
Targets	+	National governments	x	x	x	x	x	Costs will be mainly linked to measuring baseline and subsequent quantification activities. The Courtauld Commitment, a UK voluntary agreement, saved businesses £1.8bn in 2005-2009 through food waste and packaging reduction.	http://ec.europa.eu/environment/eussd/pdf/bio_food waste_report.pdf ; http://www.wrap.org.uk/node/14507
Public disclosure of food waste volumes	+	Retailers		x				NorgesGruppen, Norway's largest food retailer, publicly discloses its food waste data. It was the first and is so far the only Norwegian retailer to do so. The group does not nevertheless imagine that Norwegian consumers would penalise a supermarket for disclosing comparatively high food waste data. It estimates the cost of its first food waste quantification, based on desktop analysis and external support, to have cost around 50K€. It has since increased its accuracy via a system in which all food waste is scanned, which supports inventory control and automatic ordering.	http://ostfoldforskning.no/uploads/dokumenter/Food%20Waste%20juni%202012/Active%20work%20on%20food%20loss%20prevention%20v2-Halvard%20Hauer%20NorgesGruppen%20ASA.pdf and via stakeholder interview

Measure	Estimated cost	Who bears cost	Sector targeted					Further information on costs	Source
			Households	Retail	Food Service	Manufacturing	Agriculture		
Awareness raising	++	National governments	x		x			WRAP's Love Food Hate Waste campaign in the UK involved a 700K€ initial research investment and annual running costs of 2,4M€, covering advertising, PR, events and web materials (2010 estimate). WRAP may be able to support other countries in setting up similar awareness campaigns for a to be defined fee. WRAP currently estimates that an effective food waste prevention programme in another MS could be implemented for less than 6M€ annually, making use of existing WRAP resources. WRAP notes that every £ they have spent on reducing household food waste has prevented more than £100 of food being wasted.	http://ec.europa.eu/environment/eussd/pdf/bio_food waste_report.pdf
Retail communication towards consumers	+	Retailers		x				Estimates on costs of supermarket communication towards consumers on food waste were not available, but several effective examples of supermarket campaigns have been identified.	http://www.sainsburys-live-well-for-less.co.uk/meal-planning/makeyourroastgofurther/ ; http://www.morrisons.co.uk/food-and-drink/GreatTasteLessWaste/ ; the Co-operative "Food Lover" messages on till screens in the UK
Sustainable food education in schools	+	National governments	x		x			A programme of food waste measurement, implementation of prevention and awareness measures and follow-up in a group of four schools, led by a third party association over a period of six months, costs in the range of 50-60K€ in France, as proposed by the food sustainability focused non-profit De mon assiette à notre planète.	http://www.assiette-planete.fr
Separate collection of FW	++ / +++	Local governments	x	x	x	x	x	Costs highly variable based on system used, but can often be a profitable waste management venture. However, the cost of separate collection of bio-waste followed by anaerobic digestion is estimated at 80 to 125 €/tonne, compared to 55 €/tonne for the landfill of mixed waste.	http://ec.europa.eu/environment/eussd/pdf/bio_food waste_report.pdf
Pay as you throw	++ / +++	Local governments	x	x	x			Costs of implementing PAYT systems are quite variable by MS; some examples given here.	http://www.payt.gr/images/stories/pdf/3.1.1%20TUDD_Methodologies%20&%20Secure%20funding%20methodology.pdf ; http://www20.gencat.cat/docs/arc/Home/LAgencia/Publicacions/Centre%20catala%20del%20reciclatge%20%28CCR%29/Guia%20PXG_EN.pdf
Landfill bans	++	All sectors	x	x	x	x		According to a 2010 WRAP study, the economic effect of a ban on food waste would depend largely on whether resultant biogas was used for electricity generation or not. Depending on this factor a landfill restriction could mean savings of up to £92 million, or a cost of £290 million, whereas a ban on unsorted food waste could mean savings of £340 million, or a cost of £1.3 billion.	http://www2.wrap.org.uk/downloads/FINAL_Landfill_Bans_Feasibility_Research.71d5b7d6.8796.pdf
Incentives for redistribution	+ / ++	National governments		x	x	x	x	The cost to governments of providing tax incentives for food donation, specifically reducing or removing tax liability for donated food, is thought to be limited, but no data on this has been identified.	

Legend:
+ : moderate cost
++ : significant cost
+++ : very high costs

The cost of taking no action should also be considered. Families in the UK are estimated to spend 800€ per year on food that they do not eat[20], avoidable food and drink waste costing UK households a total of 14 billion euros per year. Furthermore, WRAP estimates that avoidable food waste in UK hotels, pubs, restaurants and quick service restaurants has a value of 850 million euros[21]. The cost estimate of food waste including packaging is at 8.1 billion euros annually in the UK. Similar cost estimates have not been identified in other Member States, but this gives a first idea of the cost that inaction presents. Costs are also incurred at farm level, where produce harvested but unsold presents an economic loss, and produce unharvested continues to generate costs, using land, fertiliser, and other resources during its growing cycle. The FAO launched a consultation for a Full Cost Accounting of Food Wastage in October 2013, to validate a framework for monetization of global food wastage.[22]

1.8 Expected risks and consequences of setting a target

This milestone and its high level of ambition sends a strong message to Member States and the food supply chain that food waste is a critical issue for resource efficiency in Europe.

1.8.1 *Key actors affected*

Food waste is generated across the entire supply chain. The annex of the Roadmap nevertheless specifies that the 50% target on edible food waste is applicable only to households, retailers and catering, thus limiting its impact potential. Retailers and the food service sector have numerous options to reduce food waste, and if the milestone target became mandatory, they may be affected by regulatory measures, such as landfill bans and waste data disclosure requirements. Retailers also influence food waste at farm level, via stringent quality standards or lack of certainty in supplier contracts, leading farmers to overproduce food to ensure they can always fulfil a last minute order. Tesco for example is demonstrating its understanding of its impact on food waste across the supply chain in its new food waste reduction programme.[23] If it is not possible to include all actors in the supply chain in the milestone, the impacts of those covered by it on other actors should also be taken into account, otherwise the milestone would create a precarious incentive for retailers to shift their waste to other actors.

[20] WRAP Household Food Waste: http://www.wrap.org.uk/content/solutions-around-household-food-waste

[21] WRAP Handy Facts & Figures UK Retail & Hospitality/Food Service: http://www.wrap.org.uk/sites/files/wrap/RSC%20Facts%20%20Figures,%207%20October%202013.pdf

[22] E-Forum on Full Cost Accounting of Food Wastage:

http://www.fao.org/nr/sustainability/food-loss-and-waste/food-wastage-forum/en/

[23] Tesco Reducing Food Waste: http://www.tescoplc.com/index.asp?pageid=590

Assuming that consumers eat the same quantities and types of food, a reduction of household food waste will lead to a reduction in household expenditure of food and thereby savings. This in the short term will lead to a reduction in demand for food, which will affect retailers and food producers negatively. The savings generated by reducing food waste would in the long-term likely be spent on other products and services. Some consumers might choose to 'trade up' and buy more expensive types of food, e.g. red meat instead of white meat[24], or organic food instead of conventionally produced food. Other consumers might choose to spend their savings on eating out or on non-food consumption areas. The change in demand will determine how retailers and producers are affected, but the long-term effect will also depend on the ability of retailers and producers to adapt to the change in demand.

A reduction of food waste in retail and in the food service sector will also lead to a reduction in their purchase costs. This in turn will lead to a reduction in demand for food, which in the short term will affect food producers negatively. The cost savings from reduced food waste in retail and food service sector would probably not be spent on other products or services.

Although in both cases food producers seem to be negatively impacted by a potential reduction in demand as a result of reductions in food waste, this would probably be more than compensated by the general overall trend of increasing food demand due to growing global populations and income.

1.8.2 *Contribution to reduced environmental impacts*

The food we consume has embedded environmental impacts because of the energy, natural resources used and associated emissions generated throughout their life cycle.[25,26] When food is discarded, all of the embodied energy and resources, as well as related environmental impacts such as GHG emissions, are effectively wasted. When food wastage occurs at a given phase of the food supply chain, three types of impacts must be considered:

- Impacts associated with the end-of-life of the waste;
- Impacts of the given phase;
- Impacts of the previous phases.

Each phase of the life cycle adds its own environmental impacts. Therefore, the impact of food wastage accumulates along the food chain. In other words, the later a product is lost along the chain, the higher is the 'environmental cost': food processed, transported and cooked that is then wasted at home has a higher impact per kg than low processed food products lost at the farm. This phenomenon was taken into account for the carbon impact calculations only.

[24]Omann, I., Friedl, B., Hammer, M. and Pack, A. (2007) The environmental effects of food consumption for different household categories in Austria. Sustainable Europe Research Institute (SERI), Department of Economics and Wegener Center for Climate and Global Change (University of Graz, Austria)

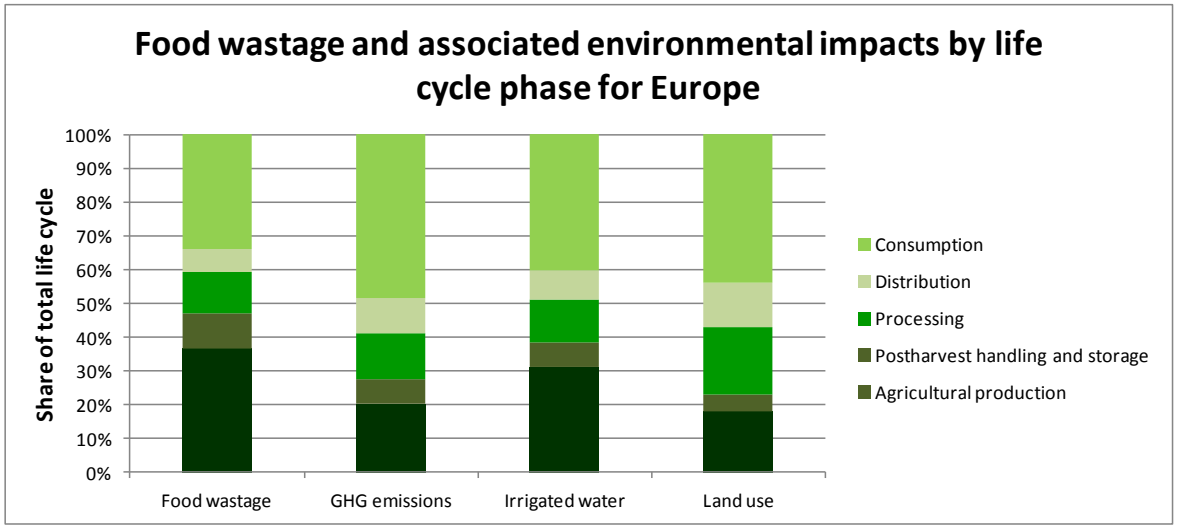
[25] European Commission (2006) Environmental Impact of Products (EIPRO): Analysis of the life cycle environmental impacts related to the final consumption of the EU-25.

[26] UNEP (2010) Assessing the environmental impacts of consumption and production: priority products and materials. A Report of the Working Group on the Environmental Impacts of Products and Materials to the International Panel for Sustainable Resource Management.

The environmental impacts of food wastage in the EU27 have been estimated in Table 3 below using BIO's internal model. The baseline food waste generation data from the 2010 Preparatory Study have been used, as well as impact factors for carbon, water and land emanating from the FAO Global Food Wastage Footprint study[27]. Please note these impact factors cover the Europe region used in the FAO study, which covers all European countries as well as all of Russia. Environmental impacts calculations should always be set in context, and an outline of the methodological decisions made in this estimate are presented in Annex I.

The estimate provides a first indication of where in the life cycle reductions of food wastage would have greatest effect. The consumption phase causes the greatest cumulative carbon impacts compared to other life cycle phases, though impacts of agricultural production are also high (as demonstrated in Figure 3 below). Given that the impact factors for carbon, water and land cover wider Europe as well Russia, further analysis would be needed to verify whether the distribution of life cycle impacts is accurate for the EU27.

Figure 3: Food wastage and associated environmental impacts by life cycle phase for Europe[28]



[27] BIO(2013) FAO Global Food Wastage Footprint: http://www.fao.org/docrep/018/i3347e/i3347e.pdf

[28] Based on quantities of food waste in the EU27 and impact factors with geographic representativeness for the Europe area including Russia

Table 3: Environmental impacts of food waste in Europe calculated using the BIO IS model[29]

Sector	Food waste volumes estimates [30] (Mt)	Carbon			Water			Land		
		Average impact factor (t CO_2 eq. / t)	Phase of the food life cycle covered	Results (Mt CO_2 eq.)	Average impact factor (m^3 / t)	Phase of the food life cycle covered	Results (km^3)	Average impact factor (ha / t)	Phase of the food life cycle covered	Results (1000 ha)
Manufacturing	34.8	2.20	Production + Postharvest handling & Processing	76.3	78.6	Production	2.73	0.44	Production	15,428
Retail/Wholesale	4.4	2.74	Production + Postharvest handling & Processing + Distribution	12.1	78.6	Production	0.35	0.44	Production	1,968
Households	37.7	3.56	Production + Postharvest handling & Processing + Distribution + Consumption	134.2	78.6	Production	2.96	0.44	Production	16,736
Food Service/Catering	12.3	3.56	Production + Postharvest handling & Processing + Distribution + Consumption	43.7	78.6	Production	0.96	0.44	Production	5,444
Total	**89.2**			**266**			**7.01**			**39,575**
- 10% reduction	***8.9***			***26.7***			***0.7***			***3.9***
- 20% reduction	***17.8***			***53.3***			***1.4***			***7.8***
- 50% reduction	***44.6***			***133.3***			***3.5***			***19.6***

[29] Based on quantities of food waste in the EU27 and impact factors with geographic representativeness for the Europe area including Russia

[30] BIO Intelligence Service (2010) Preparatory study on food waste across EU27

A 50% reduction of food waste in the consumption phases would correspond to about 45 million tonnes of food in the EU27.[31] This amount is more than the total food supply of Spain[32]. The corresponding reduction in GHG emissions is equivalent to over 55% of total GHG emissions from agriculture in the EU27 in 2011 (461 Mt of CO_2 eq.)[33]. Halving food waste in households, retailers, and catering in the EU, would free up to almost 200,000 km^3 of agricultural land, or the total amount of agricultural land in Poland.[34] The reduction in water abstraction corresponding to the 50% target is estimated to be about 3,500 million m^3, or more than the total water abstraction in Sweden.[35]

It must be stressed that the calculated impacts (in terms of GHG emissions, blue water consumption and land use) are actually the impacts attributable to a portion of food production/consumption that is equivalent to the volumes of wastes estimated to occur in the EU-27. Thus, impacts quantified here cannot be directly seen as the impacts that would be avoided, if food waste in Europe were to be reduced. An accurate estimation of the avoided impacts would require a consequential analysis taking into account the impacts of a reduction in food waste on food prices and the resultant changes in the quantity and geographic location of food production and consumption, and in the subsequent changes in agricultural practices.

1.8.3 *Contribution to economic growth or well-being*

Waste reductions in the retail and catering sectors could generate cost savings for these actors of the chain (although measures for food waste limitation may also have a cost), leading potentially to increased profitability for retailers/caterers or lower prices for consumers. A low food price relative to disposable income is however one of the drivers of the rise of food waste at consumption level in the past decades Parfitt *et al.* (2010)[4]. As regards waste at consumer level, a WRAP study[36] has shown that cutting all avoidable food waste from households could save £480 per household per year. Consumer savings through reduced food wastage may trigger consumers to purchase higher quality (higher priced) food products.

A modelling exercise conducted by LEI[37] as part of this study compared the relative economic impacts of food waste reductions. The modelling assumed that reduced food waste would lead to reduced demand for food, which in turn would affect agricultural production and food prices. Based on economic theory, the model assumed that any saved expenditures due to a specific type of food waste would be instead used on other (food and non-food) products and services

[31] As this estimate uses food waste data collected in the 2010 Preparatory Study, it covers the EU-27 and not the EU-28

[32] FAOstat. Food supply for Spain in 2009 – Total Crops Primary Equivalent is 29 Mt + Total Livestock and Fish Primary Equivalent is 14 Mt. In total food supply: 42 Mt

[33] Eurostat: Greenhouse gas emissions by sector [tsdcc210]

[34] EEA: CORINE Land Cover. Agricultural area in Poland in 2006: 196,372 km^2

[35] Eurostat: Annual water abstraction by source and by sector [env_watq2] – Sweden in 2007: 2630 million m^3

[36] WRAP (2009) Household Food and Drink Waste in the UK. Report prepared by WRAP. Banbury.

[37] Rutten, M., P. Nowicki, M.-J. Bogaardt and L. Aramyan (2013) Reducing food waste by households and in retail in the EU; A prioritisation using economic, land use and food security impacts. LEI report 2013-035 commissioned by BIO Intelligence Service for the European Commission as part of the project 'Modelling Milestones for achieving Resource Efficiency' (a project under framework contract Env.G.4/FRA/2008/0112 for DG Environment).

equi-proportionally (see Figure 4 and Figure 5). If incomes were to remain the same, this suggests reduced overall spending on food.

Figure 4: How the economic impacts of food waste are modelled *(NB! Costs to biowaste treatment and (policy implementation) costs to reduce food waste were not modelled)*

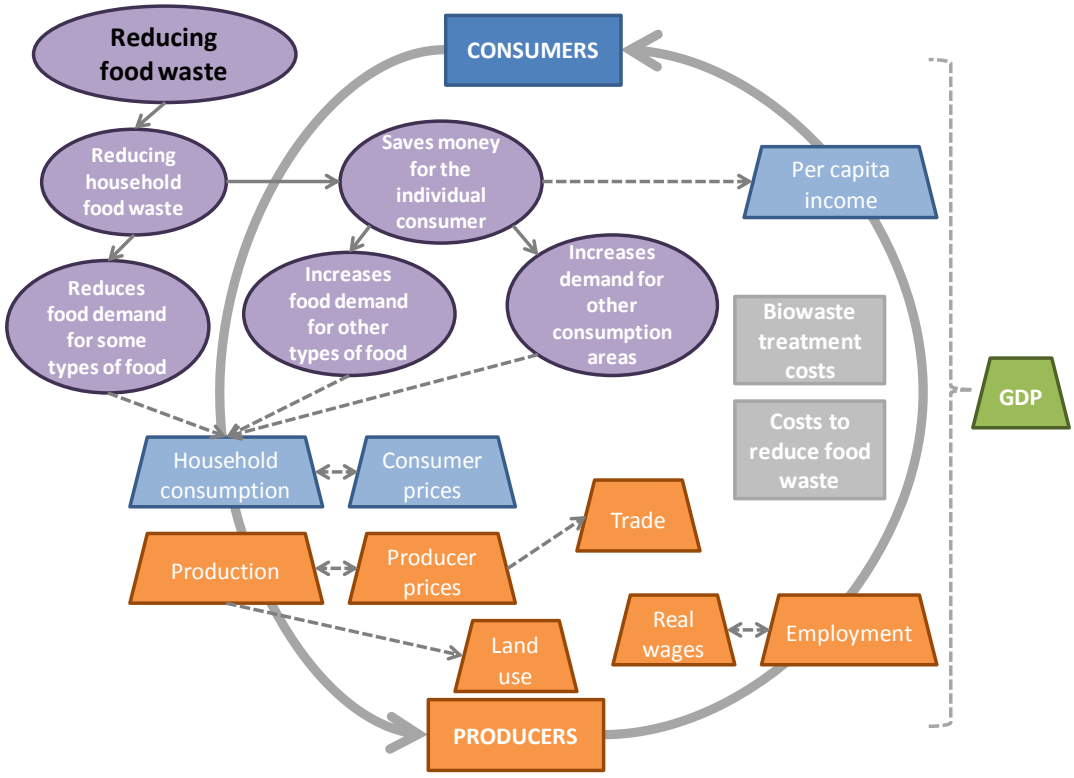
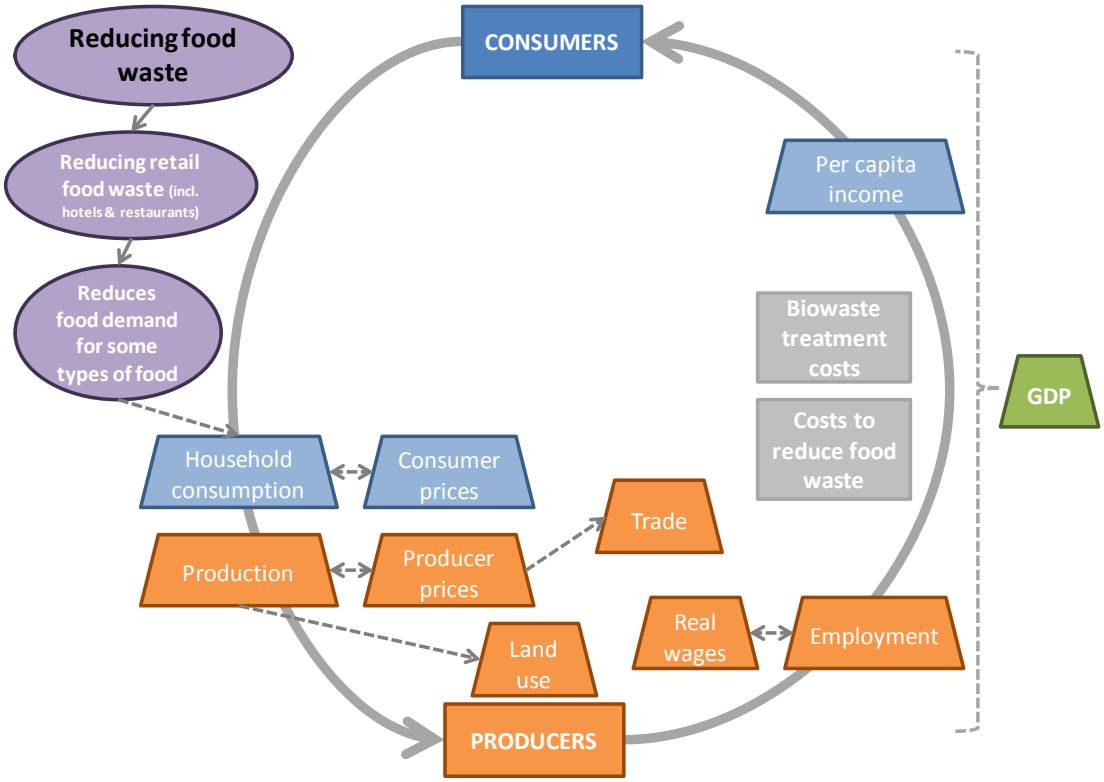


Figure 5: How the economic impacts of food losses are modelled *(NB! Costs to biowaste treatment and (policy implementation) costs to reduce food loss were not modelled)*



Three levels of ambition were modelled to 2020: 30%, 40% and 50% reduction of food waste (NB! these are different from the targets suggested in Table 1). The results show that the economic, land use and food security consequences of food waste reduction vary depending on the type of food waste reduced. In all cases, the impacts were very small in relation to the baseline (business as usual) scenario in 2020. Using the 40% reduction as point of departure:

- Food prices would generally fall (very slightly), but food security would improve in the EU and the rest of the world.
- If food waste was reduced in households as well as in the wholesale, retail and food service sectors, this would lead to a slight overall reduction in GDP (-0.09% compared to a baseline (business-as-usual) scenario for 2020). Intuitively, lower food waste entails lower demand for some food commodities to the benefit of other commodities and overall leads to a slight contraction of the economy, in line with expectations of a more resource-efficient economy.
- Reducing food waste in wholesale, retail and food service sectors only, but not in households, will lead to a slight increase in GDP (+0.006% compared to the baseline GDP in 2020. This is because it decreases costs and increases sales of the aforementioned sectors.
- The economic impacts of food waste depend on which types of food waste are avoided:
    - Reducing household waste of fruits and vegetables also benefits the EU economy slightly in terms of GDP up to

2020. This is because a decrease in spending of fruit and vegetables will lead to an increase in spending on other products and services that generate a high value added;

- Reducing household waste of vegetable oils and fats, and fish minimises GDP losses in the EU as these sectors are relatively less important in size compared to other sectors in the EU economy;
- Reducing household food waste of animal-based products (meat and dairy) will lead to the greatest decrease in GDP compared to other commodities, due to relatively strong links with other, e.g. livestock and feed, sectors in the economy.

- Reducing food waste will reduce land demand marginally (approximately 1.6% of EU agricultural lands in 2020). Reducing household waste of dairy products and red and white meat sectors, as well as fruits and vegetables (where household waste volumes are high) provide the greatest potential for reducing land demand in the EU.

While the modelling only looked to 2020, in the longer term (e.g. 2050 and beyond), GDP will always benefit through reduced food waste and thus increased efficiency in the supply chain.

A comparison of the impacts of reducing food waste with those of shifting to a healthier diet with lower consumption of animal-based products was also considered. While both will lead to a reduction in GDP, a healthier diet has a less negative impact on GDP, and will save more land (impacts on land use being likely to be predominantly outside of the EU). These findings therefore suggest that waste reductions in EU should be accompanied with a sustained long-term behavioural change towards a healthy diet, as this has a lower cost in terms of GDP while offering greater land use-related improvements.

A study similar to the LEI modelling investigated the agricultural and economic effects of adoption of healthy diet recommendations in the UK , using 2004 data, also finding that reductions in the consumption of food from animal sources (in line with WHO guidelines) resulted in minor changes to GDP (up to -0.04% loss). [38] The study mentioned that if diets matched nutritional guidelines, 70,000 premature deaths would be prevented each year in the UK, representing a saving of £20 billion (€23 billion) to the health services[39]. The socio-economic benefits of a healthy diet could even be greater, if the indirect costs of lost

[38] Lock, K., R.D. Smith, A.D. Dangour, M. Keogh-Brown, G. Pigatto, C. Hawkes, R.M. Fisberg and Z. Chalabi (2010) Health, agricultural, and economic effects of adoption of healthy diet recommendations. The Lancet, Volume 376, Issue 9753, pp 1699 - 1709.

[39] HM Government (2008) Food matters: towards a strategy for the 21st century. London: Cabinet Office.

productivity through absenteeism from work due to diseases related to unhealthy diets are considered[40].

In another study[41] on adopting a healthy diet in Canada, the macro-economic modelling again showed that negative losses to GDP would occur if meat consumption was reduced. Only in the case of reducing meat consumption and simultaneously increasing the consumption of vegetables, fruits, dairy products and grains would there be a minor positive benefit to the economy (0.09% increase of GDP).

A study[42] yet to be published by WRAP came to a different result regarding the impacts of reducing food waste. The study suggests that consumers may find ways to waste less food without changing either their overall expenditure on food or the quantity eaten. Although the amount of food purchased is reduced because less food is wasted, consumers 'trade up' towards higher price foods to the extent that they maintain their current spending on food. In this scenario, the effects on the economy might be even less notable.

1.8.4 *Links with other milestones*

- Sustainable production because environmental impacts of food waste could be limited if consumer have access to more sustainable food products;
- Turning waste into a resource because environmental impacts of food waste could be limited if food waste streams are dealt with more sustainable practices. This milestone calls for absolute reductions in waste generation per capita, in which food waste reduction can play a role. The separate collection of food waste furthermore enables composting and anaerobic digestion, among options for valorisation that are environmentally preferable to landfilling.

1.8.5 *Risk of the milestone being counter-productive*

A major risk of this milestone, regardless of the level of ambition set, is its focus on only the downstream phase of the food supply chain. Waste (not loss) is generated at every phase from farm to fork, not only at the point of consumption. It is estimated that in the UK for example, 30% of vegetable crops are never harvested[43], because it is not sufficiently profitable to do so or because they do not meet buyer-imposed aesthetic standards. Comparatively little is known about food waste at the agricultural phase of the food supply chain and its exclusion from the milestone misses an opportunity to support greater understanding and reduction of food waste overall.

Furthermore, the food supply chain functions as an interactive ecosystem. Food waste is already shifted significantly between sectors, in the distribution chain through refusals to

[40] Dube,L, J. Beauvais,P.J. Thomassin, D. Sparkling (2009) Building Convergence: Toward an Integrated Health and Agri-Food Strategy for Canada. The Canadian Agri-food Policy Institute.

[41] Mukhopadhyay, K. and Thomassin, P.J. (2012) Economic impact of adopting a healthy diet in Canada. Journal of Public Health, Volume 20, Issue 6, pp 639-652.

[42] WRAP (forthcoming) The economics of food waste. Prepared by Fathom Financial Consulting.

accept stock too close to its use by date and by encouraging consumers to buy more than they need through two for one offers. The focus of the milestone on retail, catering and households presents a significant risk that food waste generated in these sectors will be shifted upstream, to distributors, processors, manufacturers and to farmers, threatening its overall objective of halving the disposal of edible food waste in the EU.

Annex I: Quantitative assessment of environmental impact of food waste

The calculation model used here for quantifying the environmental impacts of food waste in the EU27 is based on several equations, which are multiplications of activity data (i.e. food waste volumes) and specific factors (i.e. carbon, water and land impact factors). The model covers distinct types of food products representing most of the food consumed globally. For each type of food product, specific factors were used to characterise their impacts in each life cycle phase.

The estimates used for food waste arisings in Europe and the key methodological choices for the calculation of the impact factors are presented below.

- **Food waste volumes**

The Preparatory Study on food waste[44] estimated, based on 2006 EUROSTAT data and other available data, that overall 89 Mt of food waste are generated every year in the EU[45]. In its scenario 2, the preparatory study further disaggregated this figure between:

  - Manufacturing 34.8 Mt
  - Retail/Wholesale 4.4 Mt
  - Households 37.7 Mt
  - Food Service/Catering 12.3 Mt

- **Carbon footprint**

Presentation of the indicator

The carbon footprint of a food product is the total amount of greenhouse gases (GHG) emitted throughout the life cycle of that product, expressed in kg or tonnes CO_2 eq. This encompasses all GHG emissions of the agricultural phase – including the emissions related to the production and transport of all inputs, as well as the emissions due to on-farm energy use and non-energy related emissions (such as CH_4 and N_2O) from soils and livestock. The carbon footprint also includes the GHG emissions related to the processing of food, delivery to a point of sale or use location and to the consumption as well as emissions from waste disposal.

As mentioned previously, the later a product is lost or wasted along the supply chain, the higher the 'environmental cost'. This is taken into account in the calculation model for the quantification of climate impacts.

[44] BIO Intelligence Service (2010) Preparatory study on food waste across EU27. Available at: http://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf

[45] Agricultural food waste is not included in the scope of this estimate

Methodological choices in BIO IS model

Production phase – Impact factors of the production phase are adapted from published LCAs and life cycle inventory (LCI) databases covering major food commodities (crop, livestock, fish & seafood). Emissions due to land use change are not accounted for in the model since this issue is tackled only in a fraction of the currently available LCA data sources.

Postharvest handling & Processing – Regarding postharvest handling, the model focuses on emissions due to the transport between the farm and the processing/storage facilities. Concerning processing, energy use is often one of the major sources of environmental impacts. The modelling therefore focuses on energy consumptions issues.

Distribution – Food retailing encompasses a large diversity of systems characterised by low or high degree of complexity. In the BIO IS model, a simplified description of the food retail sector is proposed. It makes a distinction between:

- the 'modern' retailing sector (hypermarkets, supermarkets, convenient store chains, etc.). This is the main retailing type in Europe. The modelling includes the energy consumed in the stores for lighting, heating and cooling systems, the energy consumed (electricity) by freezers and refrigeration appliances, refrigerants consumed – including refrigerant leakage, and transportation of the products from warehouses to the stores.
- the 'traditional' retailing sector (e.g. local markets, short distribution channels, etc.). In this case, the main impacts are related to transportation.

Consumption – It is considered in the model that the GHG emissions are related to energy used to cook and/or store the food in a fridge or a freezer.

End of life – The model is based on municipal solid waste disposal routes – i.e. landfill, compost and incineration. It must be underlined that waste management systems can provide indirect GHG savings due to energy generation (for instance, landfill gas or combustion energy can be used to produce electricity and/or steam). Such potential credits are not accounted in for in the present modelling.

- **Blue water footprint**

Presentation of the indicator

The concept of water footprint developed by the Water Footprint Network (WFN) addresses the issue of water consumption. It defines the water footprint of a product as the total volume of fresh water that is used directly or indirectly to produce the product. Under the WFN definition, a water footprint consists of three indicators that measure different sorts of water appropriation: 'blue' (surface or ground) water, 'green' (rain) water and 'grey' (waste) water.

Methodological choices in BIO IS model

Recent work on the global water footprint of human activities or specific country studies demonstrates the major role played by agriculture. It indicates that consumption of agricultural

products is responsible for 92% of global fresh water consumption[46]. Therefore, the model focuses on the agricultural production phase.

Blue water in agriculture corresponds to irrigation water taken from ground or surface water. The blue water footprint is used in the model as a proxy for the fresh water depletion impacts of food waste. In addition, it should be mentioned that the water footprint for fish and seafood is not taken into account in the model.

- **Land use**

Presentation of the indicator

Land occupation describes the surface of land necessary to produce foodstuffs, i.e. cropland and grassland. The BIO IS model calculates the amount of land used to produce uneaten food because of waste. Land (and particularly agricultural land) can be seen as a limited natural resource with a number of competing uses (e.g. agriculture, buildings, roads).[47] The land occupation indicator is expressed in hectares (ha).

Methodological choices in BIO IS model

It should be noted that the land use factor for wild fish catches is not accounted for as such products do not require agricultural land. In some aquaculture productions systems, fish can be fed with feeds made from agricultural products. However, the land occupation factor related to aquaculture is also not accounted for in the model due to lack of data.

The estimate of the environmental impacts of food wastage in the EU27 is presented on p19 of this document.

[46] Hoekstra, A.Y. & Mekonnen, M.M. (2012) The water footprint of humanity. Proceedings of the National Academy of Sciences of the United States of America, 109(9), pp.3232–7.

[47] Mattila, T., Helin, T. & Antikainen, R. (2011) Land use indicators in life cycle assessment. The International Journal of Life Cycle Assessment, 17(3), pp.277–286.

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