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Extent, underlying drivers and impact assessment of prevention approaches

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Food losses and food waste – Extent, underlying drivers and impact assessment of prevention approaches

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Executive Summary

The topic of food losses and food waste (FLW) has received increasing attention in recent years by policy makers, non-governmental organizations (NGOs) and scholars alike. This report provides a summary of the current knowledge on the topic by providing a structured review of available evidence on the extent of FLW, the underlying drivers and potential prevention approaches. Even though the focus is set on Denmark, the results are transferable to other industrialized countries.

The report addresses FLW from an **economic and resource-efficiency perspective** highlighting the economic mechanisms leading to FLW as well as evaluating potential prevention approaches from a cost-benefit point of view. However, given the fact that FLW is a highly complex topic linked to the functioning of the whole food system, providing clear-cut and straightforward cost-benefit assessments is not always feasible. Nevertheless, there are some major lessons one can learn from the existing knowledge.

First, defining food losses and food waste is not straightforward and there are numerous reasons why so far no generally agreed definition of food losses and waste exists.

Differences in definitions can be traced back among others to (i) the chosen perspective from which food losses and food waste can be assessed, i.e. whether it is addressed from a waste or from a food perspective, (ii) the specific research questions tackled and (iii) the available data sources. Additionally, there are cultural differences in what is considered waste with intestines of animals being considered waste in some countries but not in others.

Defining and measuring FLW at the primary production and processing stage is especially complex and no consensus has been reached how to address the issue at these particular production stages. Particularly, the differentiation between FLW and co- or by-products can be a grey area and is not always clear-cut. An example in this context are potato peels and brewing wastes that can be either considered FLW or by-products depending on whether they are traded or not. This fact of differing definitions is reflected in rather diverse estimates on the extent of FLW for the primary production stage in Denmark ranging from 110,000t up to 631,669t. Consequently, given the complexities of food supply chains it might be more realistic to work with different definitions according to the research objectives tackled.

Second, the largest share of FLW in tonnages is found for bread and bakery products and fruits and vegetables, whereas in monetary terms cold cuts, fresh meat, fresh ready meals and fresh dairy products are most important. This product hierarchy seems to be valid for the food service sector, retailers and households alike.

Third, food categories that are wasted in large quantities are not necessarily the categories with the highest environmental impact.

The empirical evidence highlights that the food categories with the largest environmental impact are beef meat, followed by bread and cereal products. Wasted meat accounts for the highest amounts of water and nitrogen resources, followed by wasted cereals. In contrast, wasted resources associated with fruit and vegetables, the two product groups with highest FLW level in mass, are relatively low compared to other food product groups. Within the fruits & vegetables category, tomatoes, peppers and bananas seem to account for a large share of the carbon footprint of wasted fruits & vegetables. In contrast, apples, carrots and potatoes, all products with rather high waste levels in mass, seem to contribute only little to the carbon footprint due to relatively low production-related emissions.

Consequently, there is no clear link between FLW quantity and the associated environmental footprint and the product hierarchy of wasted food groups depends on the chosen indicator. These results are highly relevant for deciding on which food categories to focus on while setting up strategies to reduce food losses and food waste.

Fourth, FLW is caused by a large number of different, often interrelated drivers, which means that there will be not only one approach that will lead to reduced FLW levels.

Several studies are available trying to classify the different drivers of FLW. Even though all classifications differ slightly from each other some major points can be summarized. First, it seems important to classify drivers according to the potential to intervene. For example, inherent characteristics of food such as perishability or limited predictability of supply due to climatic conditions are important drivers of FLW. Yet, they are almost unchangeable meaning that the intervention potential is low. In contrast, non-use or suboptimal-use of available technologies and organizational inefficiencies are also important drivers but with a much higher intervention potential. Second, some drivers are relevant for several or even all production stages such as aesthetic standards and consumer preferences and thus if these drivers are addressed there might be an impact on all stages simultaneously. Third, at household level, the supply chain stage that is responsible for the largest share of FLW in industrialized countries, food management skills (i.e. cooking, shopping and home-stock management skills) are a key determinant of food waste behaviour. Thus, a crucial element in reducing FLW in industrialized countries seems to target at the improvement of such food management skills.

Fifth, with respect to **potential prevention strategies** discussed in publications on FLW the following points are noteworthy:

- **Integrative supply chain management** and optimal **cold chain management** seem to be promising ways to reduce FLW levels. However, currently there is only limited cooperation among food supply chain

stakeholders at the EU level. Thus, there is a need for initiatives addressing to improve cooperation and communication across the supply chain. With respect to cold chain management the existing evidence indicates that lowering average fridge temperature plus placing more perishables in the fridge at household level would result in net benefits both financially as well as environmentally. Moreover, at the retail level a general reduction in storage temperature would reduce FLW in all product categories. Yet, for certain products, such as dairy products, this could lead to a negative net effect due to high electricity costs. Consequently, the lowering of storage temperature in the retail sector might be considered cost-efficient only for certain product categories such as meat.

- **Providing information** to consumers about the correct interpretation of **date labels** and **simplifying date labels** to avoid consumer confusion have been put forward in many publications to reduce FLW. While reducing information asymmetry and increasing consumer knowledge about date labels is definitely important, the potential of such information strategies on date labels and date labelling amendments with respect to FLW reduction should not be overestimated. First, in quantitative terms products without any date label, i.e. fruits and vegetables, bread (if bought from a bakery) are wasted the most. Date labelling amendments would not affect these product categories. Second, in many cases the real reason for discarding food is not the date label itself but the fact that consumers did not use the product on time which is again related to their food management skills.

- **Amending governmental marketing standards** has been put forward as another strategy to reduce FLW. However, as with the amendment of date labels the impact of such a strategy on FLW levels should not be overestimated**. Retailers use (aesthetic) standards as strategic tools and often actually set higher standards than legally required implying that the real reason for FLW is not the standards themselves but rather the market requirements**. This is due to the fact that over time the responsibility of establishing and monitoring food safety and quality standards has been shifted from governmental agencies to private companies such as manufacturers, retailers and third-party certifiers. Consequently, it seems much unlikely that the amendment of governmental marketing standards would lead to significantly reduced FLW levels.

- **Improved packaging** that extends the shelf-life of highly perishable products is put forward as another strategy contributing to lower FLW levels. However, it is a matter of fact that in industrialized countries including Denmark there have been substantial technological improvements to keep food lasting longer over the course of the food supply chain. Yet still a high amount of food is still lost and wasted. Thus, as in the case of date labelling amendment the same line of reasoning might apply; it is not the short shelf-life per se that leads to FLW but general food management skills and shopping and eating routines. Food management skills and routine will most likely not change by extending the shelf-life of products.

Sixth, applied economic studies analysing the impacts of potential prevention strategies quantitatively are currently almost non-existent.

The majority of available studies estimates the amount of FLW, calculates the benefits in terms of possible household monetary savings if food waste levels could be reduced and discusses possible intervention strategies to reduce FLW. Even though these studies provide valuable insights for the understanding of the extent of the problem, these studies do not model or predict impacts of reducing FLW, since costs are usually only calculated as the costs embodied in the food wasted. More specifically, supply and demand interactions, substitution effects and vertical linkages among sectors and the role of the price mechanism are usually not taken into account. However, such an approach is needed to derive meaningful policy recommendations.

Several studies argue for example that awareness and education campaigns targeting at changing consumer behaviour are usually rather inexpensive. However, in existing studies opportunity costs consumers might have to face while reducing food waste levels such as for example more time spent for grocery shopping, preparation and cooking, are usually not addressed and taken into account. **Thus, more research is needed to assess how the prevention of FLW can lead to a more resource-efficient food system, by particularly investigating how costly it might be to reduce FLW and which trade-offs might occur among different stakeholders.** From a wholesaler and retailer perspective for example there is a trade-off between ensuring product availability and customer satisfaction on the one hand and preventing FLW on the other hand. Consequently, for most stakeholders the optimal amount of FLW is not zero FLW, since there exist significant trade-offs with other objectives.

Seventh, given all the uncertainties surrounding FLW with regard to definition, extent, major drivers, and linkages between prevention strategies and reduction potentials deriving clear-cut policy recommendations is not straightforward. Nevertheless, some general policy and research recommendations are given in the following based on the existing knowledge:

- Since economic resources are limited, governmental actions might focus primarily on reducing FLW in food categories with a high environmental impact. According to the existing knowledge this would be meat (specifically beef), cereal products (specifically bread) and several selected fruits and vegetables (e.g., bananas).
- An inventory of studies for Denmark as a database on FLW as part of sustainable diets and food chains should be set up in order to foster an exchange of data and knowledge among scholars, practitioners and policymakers alike.

- Linkages between ongoing projects focusing on sustainable consumption need to be established. Especially linkages between the New Nordic Diet and FLW seem to be worth to investigate further by investigating which market interventions might be effective and cost-efficient to foster sustainable consumption patterns including reduced FLW levels.
- Furthermore, more research is needed how choice editing might help decreasing FLW at all stages of the supply chain and how food supply chain interrelations impact on food losses and waste. More specifically, sustainability assessment of different supply chains with a special focus on the role of different standards and contractual agreement under different market structures on the extent of FLW should be carried out.

Overall, the report concludes that there is a need for a more holistic approach to the food system to develop strategies for a more sustainable food system in general and reducing FLW in particular.

1 Introduction

There has been an increasing interest in the topic of food losses and food waste in recent years by different stakeholders. This is reflected in numerous funded projects focusing on the topic and a growing body of scientific literature investigating food losses and food waste from different angles (e.g.; FAO, 2011; Kummu et al., 2012; Bagherzadeh et al., 2014; HLPE, 2014; WRAP, 2015; Chen et al., 2016). It is estimated that on a global scale about one third of all food produced measured in quantitative terms is lost or wasted along the supply chain (Gustavsson et al., 2011). At the same time, the global population is rapidly growing, urbanizing and becoming wealthier with substantial consequences on dietary patterns, especially in terms of increasing consumption of livestock products such as meat and dairy (e.g., WHO, 2002; Godfray et al., 2010). This has raised major concerns about existing inefficiencies in global, regional and local food systems, especially the associated inefficient use of scarce resources such as land and water.

In this context, reducing food losses and food waste is considered an essential part of achieving a more sustainable global food system in which finite resources are used more efficiently (FAO, 2011; BIO Intelligent Service, 2012a, 2012b; Kummu et al., 2012)[1]. Besides, Monier et al. (2010) stress that reducing the amount of food waste is critical if European countries are to meet targets with respect to limiting greenhouse gas emissions as well as fulfilling obligations under the European Landfill Directive to reduce biodegradable waste going to landfill. Moreover, the EU and its Member States adopted recently the UN Sustainable Development Goals (SDG), including a target to halve per capita food waste at the retail and consumer level by 2030, and reduce food losses along the food production and supply chains (European Commission, 2016).

Given this background a steadily increasing literature is available providing (i) definitions of food losses and food waste (FLW), (ii) quantitative assessments of FLW using different metrics, (iii) identification of the major drivers of FLW and (iv) possible solutions how to reduce the extent of FLW. The current report focuses on food losses and food waste in developed countries and investigates the topic from a resource efficiency perspective.

The report contributes thereby to the existing literature as follows. First, the report provides a brief overview of the current state of the art in defining and measuring FLW. Second, a review of the available literature on FLW for Denmark is conducted. This existing evidence is benchmarked with data from other industrialized countries. Third, main drivers of FLW that are discussed in the literature are presented. Fourth, the potential of these different prevention approaches to substantially reduce FLW is discussed based on existing impact assessments of FLW prevention measures and own considerations. For each proposed prevention measure

[1] It needs to be stressed that the relationship between reducing food waste and food losses on one hand and increasing food security on the other hand is not that straightforward since food insecurity is mainly caused by limited accessibility to food (purchasing power and prices of food), rather than by lack of food per se (e.g., FAO, 2011; HLPE, 2014).

the report aims at assessing the potential to reduce FLW (effectiveness) as well as economic costs and benefits (efficiency) to provide a list of recommended policy actions. However, given the lack of reliable data on costs and benefits of FLW prevention actions coupled with the complexity of drivers of FLW such an assessment might not always be fully feasible. Fifth, the aspect of valorising FLW as bio-resources is briefly addressed. In this context, the existing knowledge about preferable valorisation strategies and possible barriers to use food residues as bio-resources is reviewed and discussed in a Danish context. Finally, FLW and the prevention of it are put into the broader context of promoting sustainable food systems discussing possible synergies and trade-offs. Based on this discussion, recommendations with respect to policy actions and future research are derived.

2 Definitions of food losses and food waste

Until now, no uniform definition of food losses and food waste exists, a fact often cited as a major drawback for making comparative statements across different studies (e.g., Priefer et al., 2013; HLPE, 2014). Differences in definitions can be traced back among others to (i) the chosen perspective from which food losses and food waste can be assessed, i.e. whether it is addressed from a waste or from a food perspective, (ii) the specific research questions tackled and (iii) the available data sources. Additionally, there are cultural differences in what is considered waste with intestines of animals being considered waste in some countries but not in others (e.g., Gjerris & Gaiani, 2013; HLPE, 2014). These differences have led to different definitions of food losses and food waste used in the available literature.

The High Level Panel of Experts on Food Security and Nutrition (HLPE, 2014) defines food losses and food waste from a food and nutrition perspective as follows:

> ***"Food loss and waste (FLW)** refers to a decrease, at all stages of the food chain from harvest to consumption in mass, of food that was originally intended for human consumption, regardless of the cause."*
> ***"Food quality loss or waste (FQLW)** refers to the decrease of a quality attribute of food linked with to the degradation of the product, at all stages of the food chain from harvest to consumption."*

Furthermore, they define that food losses occur at all stages of the food chain prior to the consumer level, whereas food waste occurs at the consumer level. It is important to note that according to these definitions inedible fractions of food such as bones or shells are not considered as FWL. This is in contrast to the definition proposed within the FUSIONS[2] project. According to the FUSIONS definition,

[2] FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) is a project about working towards a more resource efficient Europe by significantly reducing food waste. The project runs for 4 years, from August 2012 to July 2016 and is funded by the European Commission Framework Programme 7. For more information please visit: http://www.eu-fusions.org/index.php

> ***"Food waste** is any food, and inedible parts of food, removed[3] from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)."*

The FUSIONS project stresses that the provided definitional framework goes further than many existing definitions by (i) including fish discarded to sea and waste of any materials that are ready for harvest, but which are not harvested, as waste, (ii) covering both food and drink waste, and hence both solid and liquid disposal routes and (iii) excluding food or inedible parts of food that are removed from the food supply chain and sent to animal feed, bio-material processing or other industrial uses from food waste (Östergren et al., 2014) . The latter aspect is called valorisation or conversion and, according to this definition, is distinct from food waste.

Thus, contrary to food waste definitions proposed by HLPE (2014) and FAO (2014), the food waste definition by FUSIONS includes "inedible parts of food", which would mean that in case banana peels are not redirected from the food industry to animal feed or biochemical applications, it counts as food waste. However, edible and inedible parts of food that are used for animal feed or bio-material processing are not defined as food waste. This definition is in line with the food waste definition used by the Waste and Resources Action Programme in the UK (WRAP, 2015):

> *"**Food waste** is any food that had the potential to be eaten, together with any unavoidable waste, which is lost from the human food supply chain, at any point along that chain".*

This definition covers solid and liquid food waste as well as avoidable and unavoidable food waste. Thereby, avoidable food waste refers to edible parts of food, whereas unavoidable food waste refers to the inedible parts (see also Monier et al., 2010; Jensen & Bonnichsen, 2015). Other studies differentiate even further between avoidable, partially avoidable and unavoidable food waste (e.g., WRAP, 2009; FAO, 2011). Partially avoidable food waste refers thereby to food wasted that is considered not edible by some consumers but edible by others such as for example apple skins or bread crusts. In this context it is important to stress that the concepts of avoidable versus unavoidable and edible versus inedible, respectively, are not straightforward and universally agreed upon since these terms might have different implications at different stages of the supply chain and in different cultural contexts (Bond et al., 2013; Segrè et al., 2014). Segrè et al. (2014) illustrate this with the example of fish bones and fish eyes that are in most cultures considered inedible. However, they are rich in micronutrients and could be used for human consumption if the appropriate technology is available.[4] Another example is chicken feet, which are not eaten in most parts of Europe, but are

[3] The term 'removed from' encompasses other terminology such as 'lost to' or 'diverted from'.
[4] This is also one argument put forward to include inedible parts of food into the definition of food waste since once the technology is available they could become edible.

considered a delicacy in many Asian countries. Thus, the categories avoidable versus unavoidable and edible versus inedible are not clear-cut but depend on food safety considerations, available technologies and cultural factors.

Moreover, there is no uniform view in the existing literature on whether food that was initially intended for human consumption but ends up as animal feed or is otherwise converted (e.g. into biogas) should be counted as food waste or not. According to the WRAP and FUSIONs definitions, food used for animal feed is not lost from the human food supply chain and therefore this food is not considered wasted. This is in contrast to definitions proposed by the HLPE (2014) and FAO (2014).

Other scholars go even a step further and define overconsumption, i.e. the difference between the energy value of consumed food per capita and the energy value of food physiologically needed per capita as a waste of food (e.g., Parfitt et al., 2010).

Regarding the different stages in the supply chain, it has been pointed out that food waste is more apparent and easier to define at the consumer level than at the agricultural producer level where the topic is more complex (e.g., House of Lords European Union Committee, 2014). For example, there is no agreement so far whether food that is not harvested because of adverse weather conditions should be defined as food lost or not. The report by the House of Lords European Union Committee (2014) thus concludes that the idea of a universal food loss and waste definition that can be applied across countries and across different stages in the food supply chain might be rather unrealistic and not in line with the complexities of the problem.

To sum up, the discussion above shows that defining food losses and food waste is not straightforward and there are numerous reasons why different definitions exist. Although a general applicable definition of food losses and food waste would be an important step towards reliable cross-country comparisons, such a uniform definition might not be feasible given the complexities of food supply chains. It might be more realistic to work with different definitions according to the research objectives tackled. This position is also taken in the first version of the Food Loss and Waste Accounting and Reporting Standard report which explicitly stresses the modular definition of FLW meaning that what is defined as FLW depends on the objective why to define and quantify FLW (WRI, 2016).

Given this background the present report does not adopt a specific definition of food losses and waste (FLW)[5]. The major objective of this report is to provide a review of the existing literature on underlying causes of and

[5] For consistency and simplification, we will use the term FLW throughout the whole report as a general term referring both to food losses and food waste.

approaches to prevent FLW and it does not aim at providing own calculations of FLW for which a clear definition would be indispensable. However, while reporting certain FLW estimates, wherever applicable, on which grounds these estimates have been derived will also be reported.

3 Extent of food losses and food waste

3.1 Overview about methodological approaches for quantifying FLW levels

Two current reports generated within the FUSIONS project address how FLW levels have been quantified so far and based on this review derive methods and indicators, which seem to be most appropriate to be used in future assessments of FLW (Møller et al. 2014a; 2014b).

Existing studies on FLW have used the following methods to assess the extent of FLW quantitatively: (i) direct measurement, (ii) scanning, (iii) waste composition analysis, (iv) food waste diaries, (v) questionnaires, (vi) calculations based on available statistics, (vii) interviews and surveys, and (viii) mass- and energy balances (Møller et al., 2014a; 2014b). Since each method has advantages and disadvantages, a combination of methods is considered a good solution to generate estimates that are more reliable by reducing sampling errors. Moreover, different methods might be more appropriate for different stages in the supply chain and for different research questions. Thus, one major conclusion derived in these reports is that there is not a single method that can be recommended for all applications. In fact, the choice of method rather depends on the scope of the study and what kind of information is already available. Table 1 presents the recommended approaches for each stage in the supply chain.

Table 1: Recommended approaches for quantifying FLW

Stage in the supply chain	Quantification of FLW
Primary production	• On-site measurements of mass or volume • FLW diary • Interviews and questionnaires
Processing industry	• On-site measurements of mass or volume
Wholesale & Retail	• Scanning/ Stock-keeping tools • On-site measurements of mass • Interviews of key personnel
Food Service Sector	• Waste composition analysis • On-site measurements of mass • Food waste diary • Interviews
Households	• Waste composition analysis • Food waste diary

Source: Møller et al. (2014b), p. 83

It is further highlighted that if the purpose of quantifying FLW is to use the derived information as a basis for implementing measures to reduce FLW, it is indispensable to collect information about the underlying causes. This might be achieved by interviews, surveys and/or food waste diaries. For example, at the household level an option to determine the proportion of food discarded is to conduct a household waste composition analysis (Lebersorger & Schneider, 2011). In comparison to consumer self-measurement methods such as food waste diaries or questionnaires, waste composition studies can be considered more objective and accurate since they are carried out by a third party. Household waste composition analyses also offer the benefit that they are often carried out routinely on a regular basis. However, key limitations of this approach are that (i) only the food that is discarded through waste collection is included (i.e. liquids poured down the sink are not taken into account), (ii) no detailed picture of specific types of food wasted is provided and (iii) no data about the underlying reasons why the food was discarded is collected (Koivupuro et al., 2012). Thus, a combination of both approaches is recommended in table 1.

Besides, recommendations with respect to which indicators should be used for reporting FLW levels at each stage in the food supply chain and the needed data for calculating these indicators are provided. These recommendations are presented in table 2.

As is the case for all fields of research the quality of estimates crucially depends on the quality of the underlying data. Put in other words, estimates can never be better than the underlying data and thus great attention should be placed on data collection in order to be able to generate consistent and reliable indicators of FLW (Møller et al., 2014b).[6]

[6] Everybody would agree to this statement. However, the crucial point is that data collection is costly and thus recommendations should be based on at least preliminary cost-benefit analyses. Unfortunately, we are not aware of any study addressing this aspect in terms of recommended data collection methods.

Table 2: Recommended indicators for reporting food losses and waste and required data

Stage	Data needed	Recommended indicators
Primary production	• Production volume; • Sold or donated amount; • Proportion of the product which is edible in the stage of disposal; • Plant products: production area; • Animal products: total number of animals born and slaughtered • Amount of food waste in product group • The final fate of the waste	• Food waste per produced unit; • Food waste per sold unit
Processing & Manufacturing	Micro-level approach: • Total food waste (tons), primary data collected by weighing the amount of wasted food in the process where is occurs; • Total manufactured food sold (tons), data collected from manufacturers Macro-level approach: • Total manufactured food sold (tons), available from national statistics; • Waste percentages (%) derived from detailed and representative "micro level" case studies	• Total food waste (in tons)/ total manufactured food sold (in tons)
Wholesale & Retail	• Total food waste generated per year; • Rejected amounts of food during commission activities per year; • Conversion factor to calculate mass out of economic value; • Food amounts donated to redistribution per year; • Conversion factor for inedible parts; • Turnover in economic value; • Total input of food products in mass	• Total food waste(tons) / year • Total food waste (tons)/ turnover (in monetary terms) • Total food waste (tons) / total input of food products (tons)
Food service sector	• Amount of food waste per product category (split in storage, preparation, and plate leftovers) per outlet subsector such as hotels, restaurants, canteens, etc. • Amount of food produced per product category per outlet sub sector • Number of food service outlets per sub sector in the country (for upscaling)	• Amount of total food waste in food service storage per produced amount food • Amount of total food waste in food service preparation per produced amount food; • Amount of total food waste due to serving (plate leftover and display waste) per produced amount food
Households	• Amount of food waste per household; • Number of household members; • Amount of food purchased	• Amount of total food waste per capita; • Amount of edible food waste per capita; • Amount of total food waste per purchased amount of food

Source: Own presentation based on Møller et al., 2014b

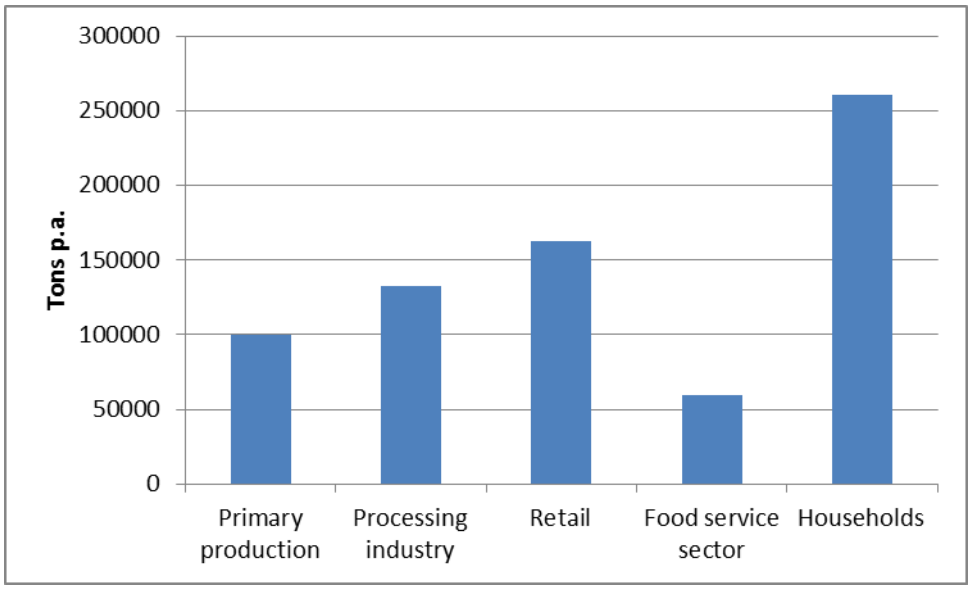
3.2 Extent of food losses and food waste in Denmark

In the following section we will provide an overview of existing estimates of the extent of FLW for Denmark and if available provide a comparison with results from other industrialized countries. First, we will focus on existing estimates in terms of physical quantities. Second, existing and own estimates with respect to the economic value of FLW in Denmark are presented. Third, a brief overview about existing studies analysing the environmental costs of FLW, that is the natural resource use related to FLW, is given.

3.2.1 Existing estimates in terms of physical quantities

A recent report by the Danish Agriculture & Food Council (2015) stated that the annual avoidable FLW, i.e. edible food lost or wasted, in Denmark is estimated to be around 716,000 tons. The contribution by each stage in the supply chain is estimated as follows: households (36 %), retail industry (23 %), food industry (19 %), primary production (14 %), and the food service sector (8 %). These numbers are illustrated in figure 1.

Figure 1 Annual avoidable FLW generated at each stage of the supply chain, data for 2012



Source: based on Danish Agriculture & Food Council (2015), p. 6

Besides, table 3 displays all studies conducted so far for Denmark on the topic of FLW reporting the used data sources, methodology, and the estimated extent of FLW. Whenever sufficient information was available, avoidable (edible) and unavoidable (inedible) FLW levels are reported separately.

Table 3: Existing estimates of FLW for Denmark, physical quantities

Study	Year of estimates	Data & Methodology	Stage & Amount	Total
Overview studies				
Danish Agriculture & Food Council (2015)	2012		**Households:** 260,942t, 76 kg/per capita,	716,000t
Marthinsen et al. (2012)	Not clear	Existing data	**Food Service**: Estimated interval: 46,000t – 148 000t; Best estimate: 140,000t; 94,000t	
Mogensen et al. (2011)	2001		**Food Service:** 46,000t, **Households**: 473,000t, 237,000t	303,000t
Kjær & Werge (2010)	2010	National statistics	**Retail:** 45,676t; **Households:** 494,914t	
CONCITO (2011)		Several sources: Mogensen et al. (2011), Ministry of Fisheries and Food	**Primary production**: 50,000-60,000t of discarded fish; 541,000t	
Empirical studies				
Franke et al. (2016)		Questionnaires, interviews & direct-in field measurements	**Primary production**: 350,000t (side flow definition); 110,000t (FUSION definition of FLW)	
Danish Environmental Protection Agency (Miljøstyrelsen, 2014a)	2013	Survey of cantinas, restaurants, hotels and retailers (N=53)	**Food Service:** 115,700t, 59,700t **Retail:** 172,300t, 167,560t	
Danish Environmental Protection Agency (Miljøstyrelsen, 2014b)		Survey and waste analysis of households in blocks of flats	**Households:** 102 kg/ per capita/year; 59.2 kg, 43.2 kg Avoidable food waste disposed down the sink: 1.6 kg per HH/week	
Kjær & Kiørboe (2012)	2011	Danish Environmental Protection Agency (Miljøstyrelsen, 2012) data plus own calculations	**Households:** Share of FW in % of purchased quantities: 11% fruits & vegetables; 17.4 % bread; 14.4 % meat, fish, eggs; 2% dairy[a]	
Danish Environmental Protection Agency (Miljøstyrelsen, 2012)	2011	Survey of single-family homes : waste analysis and interviews	**Households:** 76 kg/ per capita & year: 42kg, 34kg	
Priefer et al. (2013)	2006	FAO Food Balance Sheets	**Primary production:** 631,669t, **Processing:** 269,973t; **Retail:** 95,183t, **Households:** 683,587t	1,730,600t
Jensen (2011)	2001	Based on Mogensen et al. (2011) and own calculations	**Primary production:** 620,000t; 105,000t; **Processing:** 166,000t; **Food Service:** 37,000t; **Retail**: 46,000t; **Households**: 480,000t	
Monier et al. (2010)	2006	Eurostat, national statistics, extrapolations	**Processing**: 101,046t; **Food service:** 148,266t; **Retail:** 45,676t; **Households:** 494,914t	642,000t
Ettrup & Bauer (2002)	2001	Survey of 24 retail stores	**Retail**: 165 – 562 kg/mill DKK turnover	

Notes: black printed numbers refer to total food waste, i.e. avoidable and unavoidable food waste; red printed numbers refer to avoidable food waste; blue printed numbers refer to unavoidable food waste; [a] This share is considered to be highly underestimated given the fact that this estimate only included dairy products discarded into the bin whereas most dairy products are usually discarded via the sink.

Primary production

The primary production stage comprises plant production (horticulture, arable crops), livestock production and fisheries. According to Figure 1, in 2012 100,000t of avoidable FLW occurred at the primary production stage which represents 14% of total avoidable FLW in Denmark. However, from table 2 it can also be seen that other studies report much higher FLW levels for the primary production stage due to the fact that not only avoidable FLW is reported.

According to Jensen (2011), FLW in primary production is estimated to be around 620,000 tons, from which 515,000t are either hidden FLW or unused by-products and only 105,000 t is avoidable.[7] Also Halloran et al. (2014) state that a significant amount of potentially edible products are lost in the primary sector, including dead or discarded animals and wasted grain in the field amounting to 541,000 t of food lost in this sector per year. They conclude further that this total amount surpasses that of household food waste and that a large percentage of FLW in this sector is due to standardization in terms of sizing, quality and varieties demanded by stakeholders in later parts of the chain, for example wholesalers, large kitchens, and retailers.

With respect to estimates available for other European countries a report by OVAM (2013) provides evidence for Flanders in Belgium. They estimated that in 2009/2010 food losses due to livestock mortality ranged between 2-7% in the case of cattle, 3-17 % in the case of pigs and 4-7% in the case of chicken. In both years, less than 0.3% of pigs and cattle and less than 2% of poultry were rejected in Flemish abattoirs. Losses of milk and eggs were both estimated to be less than one percent. Furthermore, Peter et al. (2013) conducted a study on FLW in primary crop production in Germany and the results indicate that storage losses range between 3 - 10% of total production across different crops. Peter et al. (2013) also elaborate on the problem of defining FLW in primary production in comparison to other stages in the supply chain. They decided to define FLW as food that is totally lost for any purpose whereas all products that could potentially be eaten by humans but end up as feed or are used in another way are not considered to be lost. This means that for example wheat and potatoes used for energy use are not considered as FLW in this study. Due to this approach the study concludes that FLW at the primary production stage are rather small.

[7] Jensen (2011), and Jensen and Bonnichsen (2015) define hidden food waste and unused by-products as products that could have been used for human consumption had they been treated or utilized optimally through the supply chain. Hidden food waste comprises for example fruits and vegetables that have been left in the field but would have been edible. Unused by-products comprise for example slaughterhouse waste such as bones and blood, i.e. products that are not intended for human consumption. Thus, depending on the chosen definition unused by-products belong either to the category of unavoidable food waste or are not considered food waste at all since they are not primarily intended for human consumption. According to the Communication from the Commission to the Council and the European Parliament on the Interpretative Communication on waste and by-products, by-products from the food and drink industry used for animal feed are not considered waste (COM/2007/0059 final). This is in line with the definitions of food waste proposed by WRAP and FUSIONS as discussed in section 2.

In contrast, Priefer et al. (2013) as well as Gustavsson et al. (2011) define food losses and waste as all food items that were originally dedicated to human consumption, but are removed from the supply chain due to different reasons, even if they are brought to a non-food use such as animal feed. Thus these latter authors derive higher loss rates than Peter et al. (2013). Priefer et al. (2013) for example estimate that the primary production stage is on average responsible for around one third of total FLW in the EU meaning that primary production is ranking second behind the household level. For Denmark, they estimate that the primary production stage accounts for 36.5% of total FLW, a number much higher than the number presented in figure 1. However, Priefer et al. (2013) do not provide separate estimates with respect to avoidable versus unavoidable FLW.

A very recent study in this context is the one by Franke et al. (2016) focusing specifically on the issue how to measure food losses and waste in primary production which comprises according to their definition also animal rearing. They introduce a new term called "side flow" which refers to food waste and production losses in primary production that were meant to be eaten by humans but never entered the food chain. More specifically, side flow comprises primary products that are intended to be consumed by humans and thus planned feed production for animals as well as peels and bones are excluded. In table 2 two different estimates provided by this study are presented; one using the proposed side flow definition and one based on the FUSION definition of FLW. The estimated amount of annual side flow in Denmark is 330,000t, whereas the estimated amount of FLW based on the FUSIONs definition is only 110,000t. This difference is mainly due to the fact that food that was planned for food, but ends up as feed is included in the side flow estimate but not in the FLW estimate based on the FUSIONs definition. For example, in case of carrots, the results indicate an average side flow of 20%, whereby around half of this side flow is used for animal feed meaning that it is not considered FLW according to the FUSIONs definition. These differences in extent of FLW in primary production illustrate the above-mentioned problem of defining and measuring FLW in primary production and comparing estimates across studies if no uniform definition of FLW is applied.

With respect to discarded fish, Kelleher (2005) estimated that the global discard ratio is 8%. However, a more recent report by Storr-Paulsen et al. (2012) estimated that in 2010 the total discard observed in Danish waters amounted to 21,500 t, which corresponds to 26% of the total catch from these fleets. As part of the reformed Common fisheries policy (CFP) which aims at ensuring that fishing and aquaculture are environmentally, economically and socially sustainable, the European Commission has already adopted several discard bans meaning that EU fishermen will gradually be required to land all fish they catch (Larsen et al., 2013).

To sum up, defining and measuring FLW at the primary production stage is especially complex and until so far no consensus has been reached how to address the issue at this particular production stage. This fact

is reflected in rather diverse estimates on the extent of FLW at this supply chain stage ranging from 110,000t to 631,669 t.

Processing & manufacturing sector

According to figure 1, the Danish processing & manufacturing industry generated 133,000 t of avoidable FLW in 2012. This number is very close to the numbers reported by Jensen (2011) and Monier et al. (2010) displayed in table 2. Jensen (2011) reports 166,000 t for 2001 and Monier et al. (2010) report 101,046 t for 2006, respectively. Mogensen et al. (2011) estimate that avoidable FLW makes up between one to two per cent of total production and thus this stage contributes only little to total avoidable FLW in the supply chain.

With respect to studies for other EU countries, Kranert et al. (2012) report estimates for Germany. Their estimates, which are based on a non-representative survey of food processing companies (N=44)[8], range between zero and seven per cent of total production volume thus confirming the results presented by Mogensen et al. (2011). Similar conclusions are drawn by Beretta et al. (2013) for Switzerland. They estimated the extent of FLW at the processing stage based on data from eight firms engaged in the fields of vegetable and fruit processing, pasta and sugar manufacturing, baking, and dairy processing. According to these results, FLW at the processing stage are substantial but mainly unavoidable (e.g. bones, carcasses) and mostly used for feeding. In case losses are used for animal feed these products are called "former foodstuffs". According to the EU Catalogue of Feed Materials (Regulation (EC) No 68/2013) former foodstuffs are "foodstuffs, other than catering reflux, which were manufactured for human consumption in full compliance with the EU food law but which are no longer intended for human consumption for practical or logistical reasons or due to problems of manufacturing or packaging defects or other defects and which do not present any health risks when used as feed" (http://www.effpa.eu/what-are-former-foodstuffs/). Katajajuuri et al. (2014) estimated that on average 3% of the total production volume of the Finnish food industry is lost.

To sum up, the existing evidence indicates that in industrialized countries FLW at the processing stage is to a large extent unavoidable such as for example bones in meat processing. However, at the same time, available data for this stage is rather scarce and thus estimates might be biased and not very reliable. Moreover, as several studies pointed out processors and manufacturers themselves struggle with defining FLW (e.g., Gregersen & Andersen, 2015; zu Ermgassen et al., 2016). Especially the differentiation between FLW and co- or by-products can be a grey area and is not always clear-cut (zu Ermgassen et al., 2016). An example in this context are potato peels and brewing wastes that can be either considered FLW or by-

[8] Due to non-availability of data on food waste for the processing stage Kranert et al. (2012) decided to carry out a survey. They contacted around 1150 food-processing companies in Germany from which only 50 responded and only 44 filled questionnaires could be used for the analysis (response rate under 5%).

products depending on whether they are traded or not. This is in line with results from in-depth interviews with Danish processors and manufactures presented by Gregersen and Andersen (2015) indicating that there is no clear consent about what should be included in the term FLW. These uncertainties regarding what to consider as FLW are very similar to the problems discussed for the primary production stage.

Wholesale & Retail

According to figure 1, in 2012 the wholesale & retail stage generated 163,000 t of avoidable FLW. Thus, this stage ranks second in terms of generated avoidable FLW extent after households. These data are based on a recent survey carried out by the Danish Environmental Protection Agency (Miljøstyrelsen, 2014a) which covered specialized as well as non-specialized retail stores and wholesalers. Non-specialized retail stores comprise supermarkets, discounters and department stores, whereas specialized retail stores refer among others to butchers, bakeries and greengrocers. Data was collected via interviews and food waste analyses in 2013. In total, 53 businesses operating either in the food service or retail sector were surveyed and visited. At an aggregate level this results in 153,000 tons of FLW per year generated by non-specialized retailers, with 151,000 t being avoidable FLW and only 2,000t being unavoidable FLW. Specialized retail stores are assumed to produce an estimated total amount of 14,100 t per year. Wholesale traders are assumed to produce 5,200t of FLW per year. All estimates are reported with an uncertainty interval of 25% reflecting a rather large heterogeneity across respondents. Another but rather old study was carried out by Ettrup and Bjørn (2002) in 2001 with 24 retail stores. According to their results, the amount of FLW per shop ranged between 165 – 562 kg/mill DKK turnover depending on shop -size and -type.

For comparison, results for Germany show that on average 1.1 % of food products ordered by retailers do not reach the consumer summing up to 310,000 t of FLW per year at the retail level (Kranert et al., 2012)[9]. In monetary terms this means that 0.5 to 10 % of economic turnover is lost due to FLW at the retail level in Germany. With regard to the type of retailer it is assumed that FLW are less pronounced in discounters than in super- and hypermarkets due to a limited assortment and a shorter storage period. Beretta et al. (2013) report for Switzerland the extent of FLW in terms of calorie content. The rate of un-sold food products, which they use as an indicator of FLW, varies between one and five percent between the retailers analysed[10], with an average of 2.2%. However, for individual food categories such as bakery products the range is larger (between 0% and 12%). Results based on retailer interviews presented in Miljøstyrelsen (2014c) indicate that between 1 to 2% of turnover (in monetary values) is discarded with higher rates for fruits and vegetables (4-8%) and meat (3-6%). Similar numbers are presented by Lebersorger and Schneider (2014) for Austria. Based

[9] Food donations were subtracted.
[10] Their results are based data from two supermarket chains and one discounter.

on a sample of 612 retail outlets they estimate the loss rate for fruits & vegetables, dairy products and bread & pastry to be 2.8 % by mass and 2.6 % in monetary terms. At the same time, their findings indicate a large heterogeneity in FLW across retail stores.

Eriksson et al. (2012) report based on an analysis of six Swedish retail stores that 4.3% of delivered quantities of fresh fruits and vegetables were discarded. The largest category was pre-store waste (goods rejected at delivery; 3.01%), followed by recorded in-store waste (0.99%) and unrecorded in-store waste (0.3%)[11]. Pre-store FLW, i.e. products rejected at distribution centres was also named an important contributor to FLW for retailers by Regnell and Stendys (2016). However, it needs to be stressed that this FLW is not recorded at the retail level since the products at this stage are still the property of the supplier.

With respect to product categories, the largest share of FLW in tonnages is found for bread and bakery products and fruits and vegetables, whereas in monetary terms cold cuts, fresh meat, fresh ready meals and fresh dairy products are most important. The same products dominate both in quantitative as well as economic terms in all European countries (Stenmarck et al., 2011; Kranert et al., 2012; Katajajuuri et al., 2014; Regnell & Stendys, 2016).

In contrast to the number presented in figure 1, Priefer et al. (2013) estimated that in Denmark the retail level accounts only for 5.5 % of all FLW generated along the supply chain indicating a rather low importance of the retail stage in terms of total FLW amounts. A similar result is reported by Kranert et al. (2012) for Germany (5%). This large difference between relative shares is most likely due to the consideration of total FLW, i.e. the inclusion of both edible and inedible fractions of food by the latter mentioned studies. However, at the same time the authors themselves point out that these numbers might be misleading in terms of the importance of the retail level with respect to FLW prevention. First, the retail level can usually send return shipments (e.g. damaged food) back to the processors without additional costs and thus even though the FLW might be caused at the retail level it is not reported at this stage (Stenmarck et al., 2011). Second, retailers might use marketing strategies that lead to more FLW at the household level and implement strict aesthetic standards for fruits and vegetables leading to FLW in the previous supply chain stages (e.g., Priefer et al., 2013; HLPE, 2014). The report by the House of Lords European Union Committee (2014) even states that retailers are central to prevent FLW due to their influence on agricultural producers, manufacturers and consumers alike. This statement is closely related to the literature on potential market power exercised by

[11] The authors define pre-store waste as items rejected by the store at delivery due to non-compliance with quality requirements. This waste belongs to the supplier in accounting terms, but usually becomes physical waste at the store (Eriksson et al., 2012). Unrecorded in-store waste was defined in this study as waste that was not recoded either due to underestimated mass when recording unpackaged waste or unrecorded wasted items. The latter can occur in error or as a deliberate act for example when it is not cost-effective to record small amounts of waste (Eriksson et al., 2012).

retailers towards processors and producers (oligopsony) and consumers (oligopoly). These factors and linkages are discussed in more depth in section four and five of this report.

Food service sector

According to figure 1, in 2012 the Danish food service sector generated 60,000 t of avoidable FLW. Looking at the results presented in table 3, the most recent estimates for the food service sector in Denmark are based on the same report as for the retail level (Miljøstyrelsen, 2014a). This report estimated the amount of total FLW generated by the food service sector to be 115,700 t per year, with the highest share coming from restaurants (52.5%), followed by institutions such as schools, hospitals and nursing homes (22.6%), canteens (14.7%) and hotels (10.2%). However, two important points need to be stressed. First, the sample size is very small and thus the uncertainty interval of the estimates is rather large (25% for hotels and restaurants and 50% for institutions, respectively). Second, the share of avoidable FLW differs substantially across actors. Even though restaurants are estimated to be responsible for the largest amount of FLW, the share of avoidable FLW is estimated to account for only 33%. In contrast, the share of avoidable FLW in total FLW is estimated to be 80% for institutions and 60% for canteens, respectively. Thus, these recent estimates indicate a large heterogeneity across different actors in the food service sector as for restaurants the unavoidable share seems to dominate, whereas in institutions and canteens the reverse seems to apply.

With respect to other countries, Kranert et al. (2012) estimate that the food service sector is responsible for around 17% of all generated FLW in Germany. Based on previous studies conducted in Germany they assume that per meal (500g) 175g of FLW is generated whereby the share of avoidable FLW is assumed to range between 48 - 56%. Marthinsen et al. (2012) report a similar range derived from previous studies conducted in Nordic countries. They report that in case of adult servings 115 to 243 g of food is wasted per meal and between 64 to 95 g per serving in school kitchens. Beretta et al. (2013) cite several studies that conducted an analysis of FLW levels for the food service sector in Switzerland. These results indicate that per meal on average 115g of FLW is generated. Another study by Betz et al. (2015) found that between 7 to 11% of the mass of all food delivered to the Swiss food service sector was wasted during the process chain, from which 75% was classified as avoidable FLW. Parry et al. (2015) report for the UK that overall 18% of total food purchased by weight is estimated to be lost or wasted, of which again the largest share (75%) is considered avoidable. For Finland it has been estimated that about 20% of all produced and handled food in the food service sector is wasted (Katajajuuri et al., 2014)

Overall, the available evidence shows that plate waste and serving losses which is food remaining from the buffet and serving bowls at the counter make up the largest part of generated avoidable FLW in this sector

(e.g., Engström & Carlsson-Kanyama, 2004; Betz et al., 2015). With respect to avoidable FLW, starch components (i.e., potatoes, rice, pasta) and vegetables are the most frequently wasted items. Regarding unavoidable FLW fruit and vegetables peelings seem to make up the largest share in this category (Parry et al., 2015).

Households

According to figure 1, in 2012 Danish households generated 260,942 t of avoidable FLW meaning households are responsible for the largest share of avoidable FLW in the supply chain (36%). In contrast to the other stages of the supply chain, where results regarding the relative importance of the stage differ quite tremendously across studies, this result is stable across all studies. Priefer et al. (2013) estimate for example that the Danish households' share in total FLW is 39.5%.[12]

Looking at the presented results in table 3, two recent reports addressing FLW by Danish households are available from the Danish Environmental Protection Agency (DEPA) (Miljøstyrelsen, 2012; 2014b). Both reports are part of the waste prevention efforts of the DEPA and provide estimates of FLW at the household level based on interviews with a subsequent waste analysis. Miljøstyrelsen (2012) provides estimates for single-family homes, whereas Miljøstyrelsen (2014b) focuses on households living in blocks of flats.

Miljøstyrelsen (2012) analysed waste from approximately 800 households living in one of the following municipalities: Gladsaxe, Helsingør, Kolding and Viborg. Thus, both large and small towns in both Jutland and Zealand are represented in the sample. The waste was divided into 19 different waste types, including six types of FLW. In addition, the households were also interviewed to get to know their views on the waste disposal system. According to these results, each Dane generates on average 76 kg of FLW per year, whereby 42 kg (55%) are considered avoidable and 36 kg (45%) unavoidable FLW such as bones and shells. The largest share of avoidable FLW is non-processed vegetable FLW (55%), followed by processed vegetable FLW (17%). Non-processed and processed animal FLW accounts for 14% each. **It is especially vegetables and leftovers that are reported to be thrown away, followed by cold cuts and bread. Fruit and milk products come thereafter, whereas raw meat is barely thrown away. Thus, the hierarchy of products discarded is very similar to the one being present at the food service and retail level.**

According to the results by DEPA (Miljøstyrelsen, 2014b), households living in blocks of flats produce on average 102.4 kg of FLW per capita and year, whereby the avoidable share accounts for 59.2 kg (58%) and the

[12] However, there are also studies reporting much higher relative shares for the household level. Kranert et al. (2012) and Downing et al. (2015) estimated that households in Germany and the UK, respectively, are responsible for around 61% of all generated FLW.

unavoidable share for 43.2 kg (42%). Respondents also reported avoidable FLW disposed down the sink with an average of 1.6 kg per dwelling and week. For comparison, the weekly amount of avoidable FLW in the domestic refuse from these households amounts to 1.95 kg per dwelling. Thus, adding the avoidable FLW disposed down the sink to the one found in the domestic refuse generated almost doubles the avoidable FLW per household. With respect to food categories it is reported that mainly milk, dairies, coffee and tea are discarded down the sink, whereas in the domestic refuse fruits and vegetables make up the largest share.

These findings with respect to extent and importance of different food groups are in line with study results for other European countries (e.g., Williams et al., 2012; Priefer et al., 2013; Katajajuuri et al., 2014). By weight, fresh fruits and vegetables represent the largest group in household FLW, followed by meal leftovers and bakery products. The picture changes slightly if FLW is expressed in monetary terms. By cost, meat and fish as well as leftovers seem to be the most important food groups wasted in the UK (Parry et al., 2015).

3.2.2. Economic value of food losses and food waste in Denmark

Besides estimating the quantitative amount of FLW, several studies calculated the economic value of food that is lost or wasted. For Denmark, Kjær and Kiørboe (2012) estimated that the share of food bought ending up as waste ranges between 11 % (fruits % vegetables) and 17 % (bread) amounting to a monetary annual value of FLW of 3,200 Danish kroners per household. These numbers are in line with results from the UK where it has been estimated that in 2011 an average British household purchased around 27 kg of food and drink per week, from which 19% was not consumed. Expressed in monetary terms this means that avoidable food and drink waste accounted for approximately 14% of the shopping budget (WRAP, 2013b). In contrast, Katajajuuri et al. (2014) report that for their Finnish sample food wasted account only for around 5% of the food budget.

Jensen (2011) provided estimates on the economic value of FLW along four Danish food supply chains (grains, fruits/vegetables, meat and dairy). These estimates were based on physical amounts reported in various Danish sources (especially Kjær & Werge, 2010) and international publications. Since then new data have been collected (see the previous section), especially for the household, retail and food service sectors (Miljøstyrelsen, 2012; 2014a; 2014b). Based on these newer data updated estimates of the economic value of Danish FLW at different stages of the food supply chain are provided in the following. In addition to the four food categories assessed in 2011, the present study also includes seafood.

FLW in primary production and manufacturing are estimated using loss rates based on considerations from Mogensen et al. (2011) and are identical to the rates used in the 2011-analysis for grains, fruits/vegetables, meat and dairy. However, in the current study, the rates have been applied to updated quantities of the

respective product categories. For primary fishery, a loss rate of 26% has been used, based on findings from Storr-Paulsen et al. (2012).

For the wholesale & retail, food service and household stage, the estimation of FLW is based on DEPA's reports for the respective sectors. In these reports, FLW were categorized into foods of crop or animal origin, edible versus non-edible, and processed or unprocessed. Based on this information, the amounts of FLW have been distributed on the five food categories. Results of these estimations are shown in Table 4.

Table 4: Estimated quantities of FLW based on existing studies for Denmark, 2012

1000 tons	Primary sector	Manufacturing	Wholesale & Retail	Food service	Households
Grains, flour, bread, pasta					
Total FLW	293	13	13	23	71
Avoidable FLW			13	23	71
Fruits, vegetables and potatoes					
Total FLW	193	30	19	48	240
Avoidable FLW			19	26	108
Dairy products and eggs					
Total FLW	48	79	5	13	24
Avoidable FLW			5	13	17
Meat					
Total FLW	86	46	4	20	60
Avoidable FLW			4	9	46
Seafood					
Total FLW	160	10	3	10	8
Avoidable FLW			3	4	8
Other					60
Total, 1000 tons					**463**
Total, kg per capita					**86**

Sources: Own calculations based on Mogensen (2011), Miljøstyrelsen (2012; 2014a; 2014b), Storr-Paulsen et al. (2012), Statistics Denmark

Note: Due to the difficulty in defining FLW at the primary and manufacturing stage, especially the challenge with respect to differentiate FLW from by-products (see the discussion in section 2 and above) only total FLW levels are reported for these two stages, while for the other three stages the amount of avoidable FLW is reported separately.

Compared with previous estimates from 2011 reported in Jensen (2011), the total physical amount of FLW for the first four categories considered is around 4 per cent lower in the present study. However, since seafood and other foods are included in the current calculations, the total estimated FLW amount is larger than that estimated in 2011. Furthermore, the distribution across foods categories is also different than previously

estimated. This difference might be due to changes in the actual composition of FLW in the retail, food service and household sectors, but might be also explained by better and more detailed data for these sectors.

In order to assess the economic costs of FLW there is a need for price estimates. Such price estimates were obtained from national food production and consumption data, measured in economic value as well as in physical quantities. In particular, for each of the five product categories, total economic value and total physical value were determined based on published data from Statistics Denmark, and the relevant price variables were estimated as the ratio between the two, in the respective stages of the five supply chains. For manufacturing, the price estimates were obtained by augmenting the price estimate from the corresponding primary production by the gross average margin rate for the considered food processing industry – and similarly for the wholesale price. For the food service, retail and household sectors, the price variable was estimated as the ratio between households' expenditure for the considered commodity group and the consumed quantity of this commodity group. Resulting price assumptions are reported in Table 5.

Table 5: Market price assumptions (DKK/kg), 2012

	Primary sector	Manu-facturing	Food service	Retail	House-holds
Grain-based products	1.39	2.16	22.20	22.20	22.20
Fruits, vegetables, potatoes	3.31	4.46	12.60	12.60	12.60
Dairy products and eggs	2.74	3.20	15.00	15.00	15.00
Meat	12.51	14.60	39.46	39.46	39.46
Seafood	9.18	11.08	61.02	61.02	61.02

Source: Own calculations based on data from Statistics Denmark.

The price per kg product increases along the supply chain, because more and more resources are devoted to the product down the chain, in terms of raw materials, labour, equipment, energy and services. The price estimates are used directly to calculate the economic value of the FLW figures from table 4. For unavoidable FLW the value is assumed to be lower than – but still correlated with - the product price. In particular, it is assumed that the value of both unavoidable, i.e. inedible food waste is 50 per cent of the value of the edible food product, and by-products is 25 per cent of the value of edible food in all sectors. Multiplying the quantities of FLW with the price assumptions yields the economic costs of FLW presented in Table 6. The economic value of food lost or wasted along the supply chain in Denmark is estimated to amount to around 12 billion Danish kroner (1.66 billion Euros). Expressed in per-capita terms this equals 2,217 DKK (per year)[13].

[13] Kjær and Kiørboe (2012) stress that their estimates should be considered lower level estimates of the economic costs of FLW. Differences among their estimates and our ones might stem from the fact that we include more product categories and also unavoidable food waste.

Even though these estimates provide an indication for the extent of the economic value of food lost and wasted along the value chain, they should only be considered as indications due to the challenges in defining FLW discussed above. Moreover, a lack of data for certain stages, a large variation of quantity estimates within a certain stage and the problem of how to price unavoidable FLW (if to assign a price at all – if unavoidable food loss and by-products are all valued at zero price, the total economic value of FLW would be 9,615 mill. DKK) are other serious challenges in deriving reliable and meaningful estimates of the economic costs of FLW. Besides, as will be elaborated later on in the report such an approach only quantifies the static costs of wasted food and does not take into account dynamics arising from price adjustments once certain prevention approaches have been implemented. These points should be kept in mind while interpreting the results.

Table 6: Estimated economic value of FLW in Denmark, 2012

Million DKK	Primary sector	Manu-factur-ing	Wholesale & Retail	Food service	House-holds	**Total**
Grains, flour, bread, pasta						
Total FLW	169	15	282	517	1586	**2569**
Avoidable FLW			282	517	1586	**2385**
Fruits, vegetables & potatoes						
Total FLW	493	134	227	398	1780	**3032**
Avoidable FLW			227	327	1365	**1919**
Dairy products & eggs						
Total FLW	66	240	57	191	280	**835**
Avoidable FLW			57	191	255	**403**
Meat						
Total FLW	536	545	151	449	1950	**3632**
Avoidable FLW			151	336	1816	**2303**
Seafood						
Total FLW	999	150	90	149	320	**1708**
Avoidable FLW			90	149	320	**559**
Other					597	**597**
Total FLW	**2264**	**1085**	**807**	**1702**	**6513**	**12,372**
DKK per capita						**2,217**
DKK per household						**4,718**

Source: Own calculations

3.2.3 Environmental resource use related to FLW

Besides quantifying FLW levels in physical weight and economic value, several studies are available quantifying the environmental resource use related to FLW by means of environmental footprint indicators. Bernstad Saraiva Schott and Cánovas (2015) provide a recent review on the topic and point out that one of the major

conclusions of the existing literature on FLW is that environmental benefits related to prevention stem primarily from the avoided production and handling of food rather than from avoided waste management. This means that the calculated environmental benefits from FLW prevention largely depend on the assumptions made about which food and related services are not produced. This might explain the rather large heterogeneity in existing estimates of avoided greenhouse gas emissions ranging from 0.8 to 4.4 kg CO_2 per kg of prevented food waste (for details see Bernstad Saraiva Schott & Cánovas, 2015).

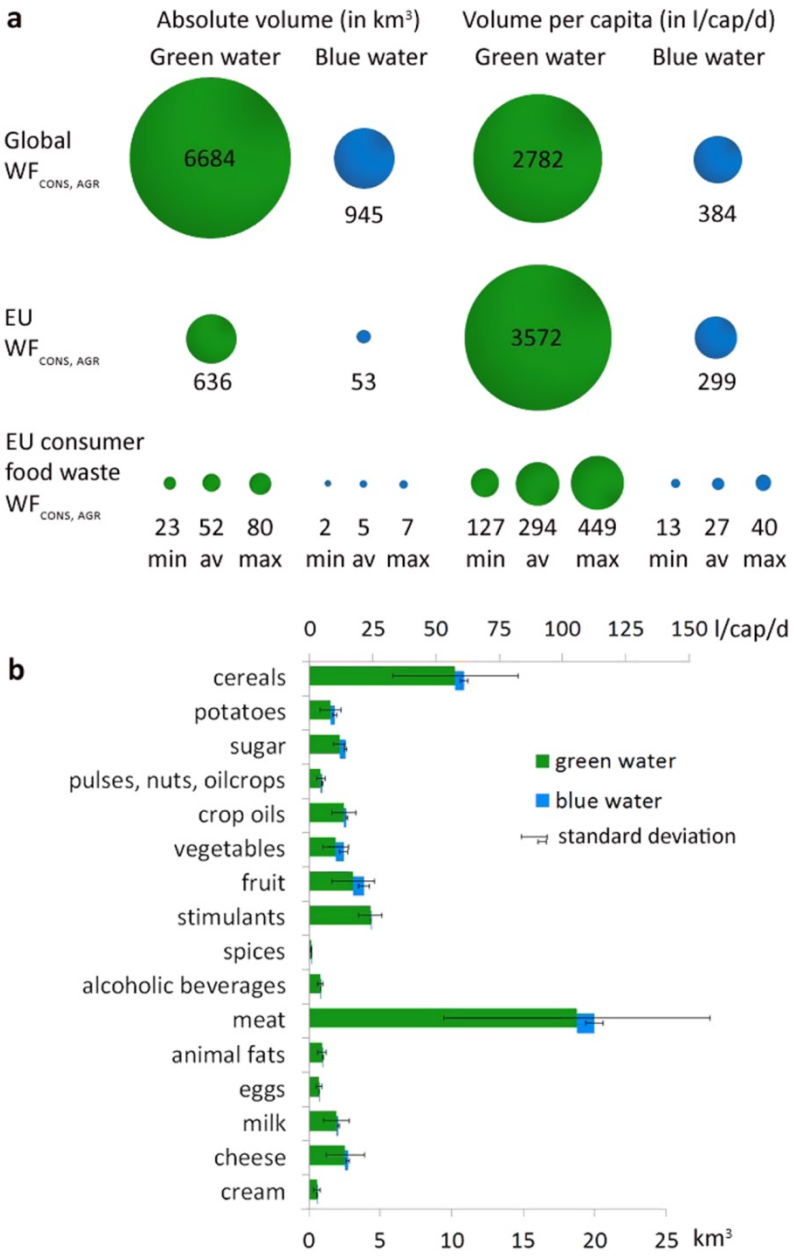
For Denmark, Mogensen et al. (2011), and Kjær and Kiørboe (2012) provide estimates of the environmental resource use related to avoidable food waste by households. Mogensen et al. (2011) estimated that the CO_2 emissions related to avoidable food waste amount to around 155 kg per capita and year. Kjær and Kiørboe (2012) estimated that for each household the annual food waste is connected with around 230 kg CO_2 emissions. Moreover, with respect to differences across different food product categories the results highlight that the food categories with the largest environmental impact are beef meat, followed by bread and cereal products.

These results are in line with results presented by Katajajuuri et al. (2014) for the Finnish food supply chain. They conclude that even though pork and beef products amounted to only 4% of all discarded food at household level, their climate impacts were among the highest, compared with other food waste categories. Moreover, even though the amount of discarded cheese was less than 2% of total household food waste, its climate impact was even higher than that of discarded vegetables.

A similar picture is drawn by Vanham et al. (2015) who quantified consumer food waste and the associated natural resources required for its production at the EU level. These authors specifically focused on the water and nitrogen footprint[14] of avoidable food waste. The results in terms of water use are illustrated in figure 2.

[14] Nitrogen is an essential factor for the production of food. The development of synthetic fertilizer based on the Haber–Bosch process has led to increased crop production and to the intensification of agriculture. While the use of nitrogen as a fertilizer and chemical product has brought enormous benefits, it also has many negative side effects on human health, ecosystem health, biodiversity and climate (Erisman et al., 2011).

Figure 2: Estimated natural resource use associated with food losses and waste at global and EU level



Source: Vanham et al., (2015)

Notes: $WF_{cons,\ agr}$ refers to the use of domestic and foreign water resources for all agricultural goods that are consumed domestically. The green $WF_{cons,agr}$ represents the consumptive rainwater use for the production of crops and animal products which citizens consume. Similarly, the blue $WF_{cons,agr}$ represents the consumptive use of water from rivers, lakes and groundwater for this production.

According to these estimates, total EU consumer food waste averages 123 kg per capita annually with an uncertainty interval ranging from 55 to 190 kg per capita and year. Thus, FLW represents around 16% of all food reaching consumers. The largest share in total FLW is avoidable consumer food waste averaging 97 kg

per capita and year or in total 47Mt per year. This represents 12% of all food reaching consumers. The associated blue water footprint (i.e., the consumption of surface and groundwater resources) associated with this amount of edible food not eaten but wasted averages 27 litres per capita per day (see part a, figure 2). The associated average green water footprint (consumptive rainwater use) is 294 litres per capita and day and the nitrogen (N) contained in avoidable food waste averages 0.68 kg per capita and year (see Annex 1 for the results on nitrogen).

Besides these overall numbers, the study provides some very important findings with respect to the environmental impacts of different food categories as presented in the lower part b of figure 2**. These results indicate that among all the food product groups wasted, meat accounts for the highest amounts of water and nitrogen resources, followed by wasted cereals. In contrast, wasted resources associated with fruit and vegetables, the two product groups with highest FLW level in mass, are relatively low compared to other food product groups. Thus, there seems to be a clear discrepancy between FLW quantity and the associated environmental footprint.**

This discrepancy has also been highlighted by Scholz et al. (2015) in their study on the carbon footprint of supermarket FLW. Their results indicate that even though fruits & vegetables waste was most important in terms of mass, the carbon food print was rather low in comparison to meat and dairy products. **Moreover, within the meat category beef products, even if not wasted in large quantities, had the highest carbon footprint, while poultry, which had rather high waste levels, had a rather low carbon footprint. Within the fruits & vegetables category, tomatoes, peppers and bananas accounted for almost half of the carbon footprint of wasted fruits & vegetables. In contrast, apples, carrots and potatoes, all products with rather high waste levels in mass, contributed only little to the carbon footprint due to relatively low production-related emissions (Scholz et al., 2015).**

To sum up, the product hierarchy of wasted food groups is not uniform but depends on the chosen indicator. In terms of mass, fruits & vegetables are clearly the most important product category. However, expressed in monetary value or environmental resource use meat, especially beef, and cereal products (incl. bread) are most relevant.

4 Main drivers of food losses and food waste – Existing knowledge

4.1 Overview

Several studies are available investigating the underlying causes and drivers of FLW (e.g., Parfitt et al., 2010; Priefer et al., 2013; HLPE, 2014; Segrè et al., 2014). A recent report published within the FUSIONS project stated that based on the existing literature and expert views 271 drivers of FLW were identified (Canali et al.,

2014). Even though one might question whether this number is correct or useful in itself, it clearly shows that FLW and the prevention of it is a wide and multifaceted problem that needs to be addressed and tackled from different angles and different disciplines. This number also makes clear that there will be no easy or one size fits all solution to reduce FLW levels.

All these reports have proposed (slightly) different ways how to classify this large number of drivers and causes of FLW. The report by the HLPE (2014) classifies the underlying FLW causes into micro-, meso-, and macro-level causes. Micro-level causes refer to stage-specific causes that result from actions or non-actions of individual actors of the stage, while meso-level causes include secondary or structural causes and macro-level causes refer to systemic issues such as a malfunctioning food system or the lack of an institutional environment to foster coordination of actors. A similar approach is chosen by Segrè et al. (2014) who distinguish between microeconomic, macroeconomic and noneconomic conditions driving FLW.

Canali et al. (2014) classify FLW drivers into technological, institutional and social drivers. With respect to institutional drivers the authors differentiate further between drivers related to business management & economy and drivers related to legislation & policies. The following matrix illustrates the different categories and groups of drivers identified by Canali et al. (2014) whereby the drivers are listed according to the potential to intervene with increasing intervention potential from left to right. For example, inherent characteristics of food such as perishability or limited predictability of supply due to climatic conditions are important technological drivers of FLW. Yet, they are considered almost unchangeable meaning that the intervention potential is low. In contrast, non-use or suboptimal-use of available technologies and organizational inefficiencies are also important technological drivers but with a much higher intervention potential.

Table 7: Classification of drivers of FLW according to FUSIONs

Context categories	Grouping of identified drivers of current food waste causes		
Technological	Drivers inherent to characteristics of food and its production and consumption which cannot be changed via technologies	Drivers related to collateral effects of modern technologies	Drivers related to suboptimal use of food processing technologies and supply chain management
Institutional (business management)	Drivers not easily addressable by management solutions	Drivers addressable at macro level	Drivers addressable within the business unit
Institutional (legislation and policy)	Agricultural policy and quality standards	Food safety, consumer health and animal welfare policies	Waste policy, tax and other legislations
Social	Drivers related to social dynamics which are not readily changeable (e.g. aging population, single-HH)	Drivers related to individual behaviour which are not easily changeable	Drivers related to individual behaviours modifiable through information and increased awareness

Source: Canali et al. (2014), p. 9

Koester et al. (2013) provide a similar but still different systematization of the drivers of FLW. They group the main drivers of FLW into: inadequate technologies (e.g., poor cooling facilities), consumer preferences (e.g., variety seeking), high opportunity costs (e.g., accepting a certain amount of FLW is cheaper than more frequent delivery), high transaction costs, education (e.g., limited food preparation skills), and worldwide trends (e.g. urbanization, nutrition transition).

Another relevant study is the one by Garnett (2014) who elaborates on approaches to achieve a sustainable food system, which also includes a reduction in FLW levels. Similar to the classifications presented above she argues that the approaches can be broadly classified into technological improvements, behavioural changes, and food system changes. However, she adds to the discussion that each approach also represents different ideologies, values and vision of a sustainable food system[15]. The first approach, the technologically-driven efficiency approach, basically rests on the assumption that a sustainable food system can be achieved by technological innovations and managerial improvements. Thus, the boundaries of our environmental limits can be extended so that more consumers can enjoy an affluent life with less environmental impact. The major focus of attention is set on technological improvements along the supply chain. In contrast, the behavioural change or demand restraint perspective focuses on the consumption side and especially on excessive consumption as a major cause of a currently unstainable food system. Solutions for a more sustainable food system are related to changing consumption patterns and diets that reduce environmental pressures while at the same time contributing to public health by lowering the risk of non-communicable diseases. The third perspective focuses both on production and consumption and considers the currently prevailing unsustainable food system including FLW as a problem of imbalanced relationships among actors in the food supply chain. The central argument that distinguishes this perspective from the other two is that unsustainable food systems are a result of social structures rather than solely caused by technical imperfections or individual consumption decisions.

It seems to make sense to keep these underlying motives and the vision one has about future food systems in mind while speaking about FLW and possible prevention approaches. In the following the identified drivers of FLW for each stage in the supply chain will be discussed in more detail.

[15] According to Garnett (2014), these three different approaches should be considered as ideological tendencies rather than standalone ideologies and individuals or institutions may adopt any one, or all three of these approaches at different times and to different degrees.

4.2 Primary production

Segrè et al. (2014) classify contributing factors to FLW in primary production into four major categories: i) losses linked to pests, disease, and weather; ii) losses linked to economics causes such as low market prices at the time of harvest; iii) losses linked to aesthetic imperfection of the goods such not in line with minimum quality standards in terms of shape, size, colour, and time to ripeness; and iv) losses linked to farmers' decision to overplanting to guarantee supply. These causes are also discussed in other studies (e.g., Gustavsson et al., 2011; Waarts et al., 2011; Priefer et al., 2013; HLPE, 2014).

Waarts et al. (2011) focus in their study especially on legal and regulatory causes of FLW using the Dutch food supply chain as a case study. Their study highlights that at the primary production stage especially strict norms for contaminants and Maximum Residue Levels (MRL) for pesticides and veterinarian medicines in foods are significant drivers of FLW. Over time lower and lower limits of pesticide residues in fruits and vegetables have been implemented resulting in reduced use of plant protection products on the one hand and increases in FLW on the other hand. It is discussed further that following the precaution principle some norms are stricter than necessary to exclude risk for public health since norms are based on what is technically feasible minimum. This means that food that fails to comply with the feasibility norm but meets the public health norm is destroyed.

Besides these food standards, quality requirements by processors and retailers with respect to size and shape are named as major drivers of FLW. The report by CONCITO (2011) states that there are examples where up to 90% of harvest is discarded due to not fulfilling size requirements.

The report by OVAM (2013) concludes that the major aspects in primary livestock production affecting FLW concern livestock mortality, disapproved carcasses in slaughterhouses, and losses of milk and eggs. Losses in arable agriculture are mainly harvest and storage losses and in horticulture process losses at both production and auction levels are most important.

Segrè et al. (2014) elaborate further on the underlying microeconomic causes for FLW in primary production. They point out that farmers are usually price-takers meaning that they cannot influence the market price. In combination with information asymmetry or imperfect information this may lead to the situation that a producer does not harvest a certain crop in order to minimize economic losses. Put it differently, since imperfect information did not allow predicting the exact harvest time, total production volume and the market price at time of harvest might be too low to cover the harvesting costs. Harvesting costs are usually the main costs of production (CONCITO, 2011). Other underlying reasons leading a farmer to decide not to harvest all crops might stem from imperfect competition meaning that retailers might exercise a certain degree of market power towards farmers. Bond et al. (2013) report for example that in the UK main retailers have a large

impact on UK farming practices by providing contractual agreements such as “on time- in full” which means that farmers have to deliver a predefined amount of crops at a specific time. This leads to overstocking by farmers to ensure the agreement is met and excess goods are usually not sold due to a lack of alternative markets.

With respect to the fishing and aquaculture industry FLW in these sectors seems mainly caused by political and economic reasons such as the existence of political quotas and low market prices for specific fish species (by-catch) (Storr-Paulsen et al., 2012; OVAM, 2013).

4.3 Processing & Manufacturing

As main causes of FLW generation in this sector are named: surplus production (e.g. due to short-term cancellations and returns by retailers, production for specific brands), aesthetic standards, failure to comply with food safety and hygiene rules, damaged packaging or incorrect labelling, seasonality of products, and high storage costs (e.g., Priefer et al., 2013, HLPE, 2014).

Thus, using the classification proposed by Canali et al. (2014) FLW at this stage is driven by technical errors and management inefficiencies (technological drivers), contracts/agreements, customer expectations and demand (business drivers), tax and hygiene policies (legislation and policies) and consumer preferences (social drivers). Furthermore, Göbel et al. (2015) report that specifically in the meat processing industry the major factors driving production processes are time and cost pressure. Thus, currently it is not economically beneficial for processors to increase work levels or time to reduce losses and waste during meat processing as illustrated by the following statement by a manager from a slaughter and butcher house in Germany: “There is always still meat on the bone which has to be thrown away because of the time factor. It is too expensive to pay someone to remove the flesh from the bone or the pig’s head, so it is thrown away.” Moreover, the interviews highlighted that food safety aspects play an especially important role in meat processing since not keeping close to product specifications leads to FLW to avoid any health risks for consumers and in turn reputation damage for the processor/manufacturer (Göbel et al., 2015).

4.4 Retail sector

For the UK, a report prepared for DEFRA (2008) analysing the root causes of FLW generated by manufacturers and retailers found that the majority of products with high and very-high waste are products with short shelf-lives (less than two weeks) such as meat, fruits and vegetables. Especially high waste rates were found for fresh red meat and processed fresh products such as bagged salads and sandwiches. The majority of products

with long shelf-lives (i.e., more than two months) tend to have very low levels of waste. However, the report also points out that not all products with short shelf-lives have high levels of waste. For example, milk and cooked poultry were found to have rather low waste levels. This is explained with a stable demand not substantially affected by seasonality, weather and promotions. Thus, the report points out that it is neither the short shelf-life of a product nor the demand variability by itself that causes high FLW levels but rather the combination of these two factors.

This is in line with results presented by Eriksson et al. (2014) showing that longer shelf-life was associated with decreased waste, but only for products with low turnover. Their study results show that organic products had higher percentage waste levels than their conventional counterparts mainly due to low turnover rates.[16] This study proposes further an indicator combining the variables shelf life (SL), turnover (T) and wholesale pack size (WPS) in order to explain or predict FLW percentage rates. The indicator, called β-indicator, can be calculated as follows: $\beta=T*SL/WSP$. Thereby, wholesale package size refers to the minimum order size and shelf-life refers to the time period from packing to the best-before data. The empirical results show that the percentage of FLW increases with a decreasing β-indicator meaning that FLW rates are positively correlated with wholesale pack size and negatively with the average weekly turnover and shelf-life. The results highlight further that the single most important factor in explaining variance in FLW levels across different products was turnover.

Thus, a major challenge from the retailer perspective is to order the right amounts of fresh products since consumer demand varies according to weather, season and many other factors (e.g., Mena et al., 2011). Since retailers operate under the assumption that consumers expect bread, fruits and vegetables to be very fresh and available in great variety at all times they typically overstock to meet these consumer demands and avoid any running out of stock (e.g., Monier et al., 2010; Stenmarck et al., 2011; Priefer et al., 2013; Canali et al., 2014). Promotional campaigns were mentioned as another factor sometimes creating rather large amounts of food waste especially if the campaign is related to short-shelf life products and simply not as successful as expected (e.g., Miljøstyrelsen, 2014c; Regnell & Stendys, 2016).

From a technological perspective inappropriate packaging as well as poor handling and storage are considered important drivers of FLW at the retail level (e.g., Mena et al., 2011; Canali et al., 2014; Miljøstyrelsen, 2014c). This is again especially relevant for fruits & vegetables since they are usually very fragile. If they are not stored at the right temperature, close to other products that foster ripening, or as a towering pile following the assumption that "products sell products" which leads to damaged items at the bottom, they become "unsellable".

[16] Turnover in this study refers to sold items per time and is thus not equal to economic turnover (Eriksson et al., 2014).

Marketing standards or also called aesthetic standard are discussed as another reason for FLW at the retail level (e.g., Priefer et al., 2013; Canali et al., 2014).[17] Retailers assume that consumers infer freshness from aesthetic perfection and will not buy oddly shaped food and also chose the supermarket based on the offered perfection of fresh fruits and vegetables.

Date labelling is discussed as another challenge since even though in most EU countries it is legal to sell products after the "best-before-date", there are no clear rules how to handle such products. Thus, most retailers decide to not sell these products because of product liability and reputation reasons even though the product might still be totally safe to eat (e.g., Canali et al., 2014).

All drivers discussed so far (permanent availability, full shelves, aesthetic standards) are related to a more overarching driver of FLW discussed in the literature, namely competitive pressure among retailers resulting in a "fight for the consumer" (Miljøstyrelsen, 2014c; WRAP, 2015). At the same time some general trends in food demand such as an increasing demand for healthy foods (e.g., fresh fruits and vegetables), healthy convenience food (e.g., bagged salads) and natural food (e.g. food without preservatives, low fat, low salt) are assumed to contribute to higher FLW levels due to short shelf-lives of these products (e.g. Mena et al., 2011; Canali et al., 2014).

Supply chain inefficiencies, i.e. problems in the coordination between retailers, wholesalers and processors, also contribute to FLW. One example is the aspect of producers and wholesalers taking back unsold products without charging for it. Thus, there seems to be no incentive at the retail level for higher accuracy in stock management in order to reduce the return flow (e.g., Stenmarck et al., 2011; Canali et al., 2014; HLPE, 2014). Eriksson et al. (2012) draw a similar conclusion in their study on Swedish retailers. Their results indicate that allowing large amounts of reclamations of delivered goods is one major reason for waste, since pre-store waste made up the largest amount of food waste generated. However, from our point of view it needs to be stressed that not the possibility of reclamations itself leads to FLW but the expectations about product quality which are not fulfilled resulting in rejections of the products.

Lastly, information deficiencies in terms of wholesalers and retailers being simply not fully aware of the financial and environmental costs of FLW and missing knowledge about different disposal alternatives might contribute to FLW (WRAP, 2015). Eriksson et al. (2012) found for example in their study a positive correlation between unrecorded in-store waste and total waste[18]. Thus, they conclude that a thorough recording of

[17] Even though it must be stressed that marketing and aesthetic standards actually have possibly a stronger impact on previous stages in the supply chain (especially primary production) since fruits and vegetables not fulfilling these standards even do not reach the retail level.

[18] Unrecorded in-store waste was defined in this study as waste that was not recoded either due to underestimated mass when recording unpackaged waste or unrecorded wasted items. The latter can occur in error or as a deliberate act for example when it is not cost-effective to record small amounts of waste (Eriksson et al., 2012).

waste could be an effective way to reduce retail waste. In this context, Lebersorger and Schneider (2014) investigated whether significant correlations between FLW rates, sales area, total sales, market type and location of the retail outlet could be detected. The results indicate a rather low influence of these factors leading to the conclusion that other factors such as work routines, staff skills and appropriate demand forecasting are more important factors with respect to FLW. This was confirmed by Regnell and Stendys (2016) stating that adequate demand forecasting, product ordering and product handling are the major determinants of FLW. Thus, there is an incentive to take the human factor out of these processes and create systems that do the forecasting based on historic performance.

To sum up, all empirical evidence available stresses that from a wholesaler and retailer perspective there is a trade-off between ensuring product availability and customer satisfaction on the one hand and preventing FLW on the other hand. Thus, the optimal FLW level from a retailer perspective is determined by maximizing sales, which in turn means ensuring full shelves during the whole opening hours. Consequently, the optimal FLW level from a retailer perspective is not zero FLW since this would imply that stores run the risk of running out of stock, the worst-case scenario for retailers. Moreover, staff skills in terms of adequate demand forecasting, product ordering and product handling are the major determinants of FLW and thus improving these skills or taking the human factor out of these processes by implementing automatic systems are strategies by retailers to reduce FLW levels.

4.5 Food service sector

Previous studies identified portion sizes (one size fits all), consumer preferences, difficulty in anticipating demand and low problem awareness as major drivers of FLW in food service institutions (e.g., Monier et al., 2010; Marthinsen et al., 2012; Priefer et al., 2013; Betz et al., 2015). Canali et al. (2014) mention further inadequate storage and equipment as well as lack of good practice (i.e. poor ordering systems, service losses) as the major technology-related drivers of food waste.

Moreover, food safety regulations are considered important drivers of FLW in the food service sector (e.g., Marthinsen et al., 2012; Priefer et al., 2013). Examples of relevant legislations are the EU wide ban on use of animal by-products and catering waste for feeding animals. Thus, there seems to a clear trade-off between food safety standards and FLW levels. Even though this is true for all stages of the supply chain it seems particularly relevant for food service institutions. Results from a survey of 289 stakeholders in the hospitality sector in the four Nordic countries stress this point further (Marthinsen et al., 2012). The results show that awareness of FLW is high but the overall challenge is to find a balance between reducing the amount of food wasted while at the same time keeping the high food safety standards. Several stakeholders expressed fear that there is a risk that actions to reduce avoidable FLW might violate strict food safety regulations, which

would damage their reputation. This is in line with results reported by Waarts et al. (2011) that some actors in the food service sector create even stricter norms for themselves than required by the legislation in order to avoid damage to their reputation resulting from potential food safety problems. Thus, food is often discarded for reasons of product liability.

Further important points presented by Marthinsen et al. (2012) are that stakeholders see a need for more dialogue with inspectors from the Food Administration to have a fruitful discussion on actions and best practice solutions related to FLW prevention. Some stakeholders expressed the wish for stricter rules on waste collection since they are frustrated about the lack of local food waste collection.

To sum up, in the food service sector finding a balance between keeping high food safety standards on one hand and minimizing FLW on the other hand is a major challenge. Moreover, staff skills in terms of menu planning, anticipating demand and handling of food are important drivers of FLW levels.

4.6 Households

There is a growing literature investigating food waste at the household level from different angles (see for a recent review Aschemann-Witzel et al., 2015).

The Danish Agriculture & Food Council (2015) carried out focus group interviews with 38 Danish consumers to get a more in-depth understanding of food waste behaviour. **A major result from these discussions is that even though all consumers consider reducing food waste of importance, other aspects such as variety seeking, health considerations and impulsive eating are of greater importance in daily food handling practices.** Especially the points of variety seeking and impulsive eating are usually leading to higher food waste levels. Moreover, too large product packages, misinterpretation of date labelling and children not finishing their meal were mentioned as further determinants of food waste at the household level. Some consumers also mentioned to lack knowledge about the proper storage of certain food items and inspiration how to use leftovers.

Similar results are reported by Williams et al. (2012) investigating reasons for food waste in Swedish households and especially how and to what extent packaging influences the amount of food waste. For this purpose sixty-one Swedish families measured their amount of avoidable food waste[19] during seven days and noted in a food waste diary why each item was wasted. The results show that about 20-25% of the households' food

[19] Households were specifically asked to report avoidable food waste, i.e. bones, peels and other unavoidable food wastage should not be reported.

waste can be related to packaging with three packaging aspects dominating: (i) too large packages, (ii) packages that are difficult to empty, and (iii) date labelling[20]. As in the Danish study other reasons for discarding food were "prepared too much food" and "children did not finish their meal". Moreover, the collected data was analysed for significant correlations between purchase frequency, packaging size, household price awareness and food waste amounts. The results indicate that on average households who consider price as very important in their food purchase decisions wasted less than households that noted price to be less important. A similar result is reported by Koivupuro et al. (2012) for their sample of Finnish households.

With respect to the role of date labels as drivers of food waste at the household level an in-depth study conducted by WRAP (2011a) provides further insights. Regarding the correct understanding of date labels, results from an online survey with 2000 consumers in the UK indicate that both the "Best before" and "use by" date are usually well understood and familiar. At least 70% of participants were able to give the correct interpretation. However, additional information or dates such as "display until" reduced the share of correct answers. Additionally, the results show that while most people were able to pick out the correct definition of the different date labels from a list, this understanding was not present to the majority of people in an unprompted situation. Thus, there seems to be a difference between 'technical' understanding and practical interpretation of date labels.

The results show further that there are three major factors that influence the use of date labels and storage guidance by consumers: age, product group, and risk aversion. With respect to age the results show that younger consumers rely more strongly on date labels which might be caused by a lack of experience with food in general. In this context Bond et al. (2013) highlight that food waste levels are typically higher in younger and single-person households due to inexperience with food management skills. Moreover, consumers use date labels differently across food product groups. There is a much stronger orientation on date labels for dairy and meat products in comparison to other food groups such as cereals. Furthermore, there is a clear link between use of date labels and consumers' degree of risk aversion. **Overall, the results stress that food management skills comprising cooking, shopping and home stock management skills are a key determinant both of food waste behaviour and of the use of date labels and storage guidance in particular. A clear conclusion of that report is that a crucial element in reducing food waste at the household level should be to target at the improvement of food management skills (WRAP, 2011a).**

Similar conclusions are drawn by Stancu et al. (2016) and Stefan et al. (2013). Stancu et al. (2016) report results from a study investigating how household food-related routines, skills and psycho-social factors are

[20] Even though date labelling might not generally be thought of as a packaging attribute, the authors decided to include it as a packaging aspect since the packaging is a potential information carrier that can inform and explain how the consumer can use the best-before-date, for example by explaining that it is safe to taste the content and judge if it is good.

associated with household food waste behaviour. Based on an online-survey with 1062 Danish consumers carried out in 2012 the authors show that routines related to shopping and leftover use are the main drivers of food waste. Analogue, Stefan et al. (2013) investigating the role of food choices and other food-related activities in producing food waste for a sample of 244 Romanian consumers conclude that planning and shopping routines are the most important drivers of food waste.

Moreover, with respect to food management skills several studies highlight that many consumers do not set the temperature of their fridge in an optimal way because of energy savings condition or simply lack of knowledge about the recommended storage temperatures (e.g., WRAP, 2011a; Jedermann et al., 2014). Several studies from different countries show that a rather large share of household's fridges is operated at temperatures higher than the recommended optimal fridge temperature of 5°C (for a review on the topic of food safety practices including fridge use see Redmond & Griffith, 2003). Such a sub-optimal storage reduces a product's shelf-life and thus contributes to FLW. For example, fruits are often stored in ways that are likely to reduce their shelf-life and thus lead to fruits being discarded (e.g., apples are stored at room temperature rather than in the fridge because a filled fruit bowl looks nice on the table).

Another interesting study looking at food waste behaviour among low-income households was conducted by Porpino et al. (2015) in Brazil. The authors specifically aimed at identifying causes of food waste among lower-middle class families, which seems to be a paradox, given the financial constraints such households face. Empirical data were collected from 14 lower-middle income Brazilian households using a combination of observations, in-depth interviews, and focus group discussions. The study identified five major categories of food waste drivers: excessive purchasing, over-preparation, caring for a pet, avoidance of leftovers and inappropriate food conservation. Several subcategories were also found such as impulse buying, lack of planning and preference for large packages. These findings provide two important results. First, strategies used primarily to save money such as buying groceries in bulk and monthly shopping trips actually led to more food waste. Second, even though the data were collected in a rather different cultural context, the results are fully in line with results presented above for European households.

Other studies taking a sociological approach investigating food waste behaviour are Evans (2011, 2012), Graham-Rowe et al. (2014), and Gjerris and Gaiani (2013). Graham-Rowe et al. (2014) highlight once again the importance of cooking and food-storage management skills in reducing food waste. Besides, the studies find further that a major barrier in minimizing food waste is the wish to be a good provider in terms of providing enough and nutritious food to your family and guests. Due to this wish too much food is bought and prepared leading to higher food waste levels. Minimizing inconvenience is discussed as another major barrier to reduce food waste (Graham-Rowe et al., 2014). Minimizing inconvenience in this context refers for example to the

fact that consumers prefer to purchase larger packages to avoid frequent shopping even though they might not be able to finish the larger packages.

To sum up, the existing empirical evidence indicates that there are common underlying drivers of food waste at the household level independent of the country or cultural context studied. The most important technology-related drivers at the household level are inadequate cooling and storage practices as well as insufficient or inadequate packaging. From an institutional & business perspective the following drivers are considered as most important: (i) low prices of food which de-values or erodes the perceived value of food); (ii) date labels and food safety concerns (confusion about correct date use); (iii) dietary guidelines that promote the consumption of fresh fruits and vegetables which are highly perishable and often not used in time; and (iv) waste collection infrastructure. The last point refers to the fact that it has been shown that if consumers compost their discarded food themselves most consumers do not consider this food as wasted (e.g., Neff et al., 2015). Besides, numerous social drivers are of relevance at the household level as explained above. They can be summarized under the umbrella terms consumer knowledge & awareness (e.g. cooking & food preparation skills), consumer preferences (e.g. preference for variety, freshness, convenience) and demographics (e.g., age, female employment status).

4.7 Conclusions

The discussion above has highlighted that FLW is caused by a large number of different, often interrelated reasons, which means that there will be not only one approach that will lead to reduced FLW levels. In fact, a mix of approaches will be needed to achieve this goal. However, the discussion has also shown that some drivers are relevant for several or even all stages (e.g., aesthetic standards) and thus if these drivers are addressed there might be an impact on all stages simultaneously. In the following section, we will focus on proposed actions and incentives to reduce FLW levels and the existing knowledge with respect to the expected impacts.

5 Potential prevention approaches and impact assessment

5.1 Overview

Few studies are currently available providing an overview of suggested FLW prevention approaches (e.g., Monier et al., 2010; Priefer et al., 2013; HLPE, 2014). The existing knowledge on this topic will be summarized in the following section. Moreover, to make informed decisions with respect to which approaches seem most promising to pursue, an impact assessment might provide useful insights. An impact assessment (either *ex ante* or *ex post*) should typically consider the advantages and disadvantages of possible policy options by

assessing their potential impacts (e.g., costs, feasibility, environmental benefits) thus enabling to identify the most effective and efficient approaches. Since resources are limited, this is an important step to ensure that resources are used in an optimal way.

However, as the report by HLPE (2014) already pointed out carrying out cost-benefit analyses of FLW and the prevention of it are extremely challenging due to the complexity of the topic. As has been highlighted above, FLW is not a single variable to optimize such as for example farmer's profits. FLW occurs at different stages of the supply chain and for different crops. Moreover, many benefits of FLW prevention are positive externalities such as for example reduced pressure on land resource or reduced greenhouse gas emissions. These benefits are hard to quantify in monetary terms since there is no respective pricing system in force. Nevertheless, few studies are available which carried out impact assessments of different FLW prevention approaches. The following section will provide an overview about these studies and the derived results.

The section is structured as follows. First, some basic theoretical economic considerations, which are important while discussing about FLW prevention, are presented. Second, so-called cross-cutting prevention approaches are discussed. These approaches target at a certain driver that is relevant for more than one stage. Third, an overview of possible actions specifically targeting at a certain stage in the supply chain is given.

5.2 Theoretical economic considerations

Even though the literature on FLW is expanding, Rutten et al. (2013) pointed out that studies analysing the impacts of reducing FLW by economic modelling are nearly non-existent. The majority of studies on this topic estimate the amount of FLW, calculate the benefits in terms of possible household monetary savings if food waste levels could be reduced (see section 3), and discuss possible strategies to reduce it (e.g., Parfitt et al., 2010; Jensen, 2011; Buzby & Hyman, 2012; Kranert et al., 2012). These studies are definitely needed and provide valuable insights for the understanding of the extent of the problem. However, these studies do not model or predict impacts of reducing FLW, since costs are usually only calculated as the costs embodied in the food wasted. It has been stressed by several scholars that such an approach is not sufficient to appropriately assess the costs and benefits of reducing FLW since supply and demand interactions, substitution effects and vertical linkages among sectors and the role of the price mechanism are not taken into account (e.g., Rutten, 2013; Britz et al., 2014; HLPE, 2014).

Rutten (2013) provided first insights into the effects of FLW prevention by using a simplified economic theoretical framework. The major outcome of her theoretical analysis is that the impacts of FLW prevention, notably on food security and welfare, are ambiguous and not straightforward. Trade-offs occur on the demand side where a reallocation of spending on previously wasted foods causes some producers to be worse and

some to be better off. More specifically with respect to reducing FLW, the welfare effects depend on the extent of FLW in relation to the total market and on the elasticities of supply and demand for the specific commodity. In general, preventing FLW leads to trade-offs between consumers and producers and it needs also to be taken into account how consumers will spend their saved expenses. In case savings from reduced FLW levels will be spent on other food or non-food commodities, there will be welfare gains in other markets.

One possible empirical outcome is reported by WRAP (2015) for the UK. These results indicate that as a consequence of food waste awareness campaigns, households reduced the quantity of food purchased but food intake and food sales revenues remained the same. Thus, households seemed to have upgraded their food intake by purchasing smaller quantities of higher quality meaning higher-priced food[21].

Even though this simple theoretical analysis helps to structure the problem, it rests on a set of assumptions and does not cover the complete picture. One important assumption refers to the costs of FLW prevention since costs will have counteracting welfare effects. However, current knowledge about costs of FLW prevention is scarce making reliable impact assessment statements rather difficult. Moreover, as pointed out above many benefits of FLW prevention approaches are positive externalities, which usually do not have a price and thus cannot be easily included in a cost-benefit analysis.

Thus as Koester (2014) and the report by the HLPE (2014) stresses more research is needed to assess how the prevention of FLW can lead to a more resource-efficient food system, and specifically, how costly it might be to reduce FLW and which trade-offs might occur. In investigating measures to reduce FLW, it needs first to be assessed whether a lack of incentive compatibility exists. This term indicates that individual actions are based on incentives, but if the market incentives do not lead to socially acceptable consequences, incentive compatibility is not warranted. Hence, in case there is a lack of incentive compatibility for reducing FLW there is a market failure that is a necessary condition for governmental interference in a market economy[22].

In this context, it has been pointed out that due to high opportunity costs in some cases the acceptance of FLW might be rational for private actors, meaning that a market failure does not exist (e.g., Koester et al., 2013, HLPE, 2014). In primary production, it could be profitable not to harvest the crops in times of very low market prices for certain crops, especially if these crops have positive effects on the next crops in the crop rotation process. At the retail level, it is rational to accept some level of FLW if there is a trade-off between the costs of delivery frequency and FLW. In case high-frequency delivery is costlier than the monetary loss due to FLW retailers might chose to order larger quantities to avoid too many deliveries and accept at the

[21] This in turn raises follow-up research questions about which kind of higher-quality products are demanded and possible environmental impacts (e.g. meat products replace vegetables).

[22] A market failure arises when the market does not allocate goods and services efficiently. Possible causes for a market failure are among others imperfect competition, imperfect information and negative externalities (DEFRA, 2011b).

same time higher FLW rates. From a consumer perspective, reducing FLW incurs also several opportunity costs such as time spent on shopping and meal preparation. If more frequent shopping is linked to high costs, it may be more economically reasonable to do the shopping once a week or once every two weeks, even if this leads to higher FLW than more frequent shopping.

These points are closely related to questions surrounding the "optimal" amount of FLW (HLPE, 2014). From an economic perspective, the optimal amount of FLW is reached when the marginal cost of FLW prevention equals the marginal benefit of it. Thus, for individual actors the current amount of FLW might be optimal since marginal costs of preventing FLW would outweigh the benefits. However, even if from an individual perspective the given amount of FLW might be optimal; this does not imply that from a societal perspective the given amount of FLW is optimal. First, environmental externalities such as greenhouse gas emissions caused by FLW are not fully internalized. Second, information failures may exist both among businesses and consumers, who are unaware of the full financial benefits of producing less waste. Third, there may be a co-ordination failure among stakeholders in the supply chain due to competitive pressures and a focus on profit maximizing. Thus, under current circumstances minimizing FLW might not be in line with profit maximizing behaviour (see for empirical evidence on this point Miljøstyrelsen, 2014c; and Segrè et al., 2014). These points indicate that governmental interventions to overcome these market failures might be warranted.

However, even though interventions might be warranted these interventions might have cascading, re-bound[23] and side-effects that need to be taken into account for a meaningful impact assessment (Koester, 2014). Rebound effects are discussed by Bernstad Saraiva Schott and Cánovas (2015) in their review on the current practice in environmental evaluations of FLW prevention. They highlight that FLW minimization will not only provide environmental benefits but can also decrease potential environmental benefits related to efficient food waste management. Therefore, they recommend studying FLW prevention from a life-cycle thinking (LCT) perspective to be able to assess both benefits and losses related to FLW prevention.

Based on the reviewed literature they conclude that existing studies on FLW prevention so far did not address rebound effects with the exception of Chitnis et al. (2014). These authors investigated rebound effects for ten widely advocated measures for reducing GHG emissions from UK households. One of the measures studied is reduced food waste levels. The results indicate that even though food waste has the largest technical potential to reduce greenhouse gas (GHG) emissions, it is also the measure with the largest rebound effect.

[23] In energy economics, the rebound effect is the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioral or other systemic responses. These responses usually tend to offset the beneficial effects of the new technology taken. An example of a direct rebound effect is if households who replaced traditional light-bulbs with compact fluorescents may choose to use higher levels of illumination or not switch lights off in unoccupied rooms due to the fact that lightning became cheaper. In contrast, indirect rebound effects refer to an increased consumption of other goods and services (e.g., clothing) due to the cost savings from more energy efficient lighting (Chitnis et al., 2014). For a more detailed discussion of rebound effects see Gillingham (2014).

This result is mainly driven by the fact that reduced food waste levels lead to relatively modest GHG savings but relatively high cost savings. These cost savings are assumed to be spent on other activities with rather high emission intensity leading to high rebound effects. As a result, the net contribution to emission reductions from reducing food waste levels is less than a quarter of its technical potential. The results show further that the rebound effects might be especially pronounced for low-income households which may be expected to have the strongest financial motivation to reduce food waste. Consequently, one major outcome is that the major driver of environmental benefits and losses of FLW prevention is the assumption about how the savings from the prevention will be used. Other existing studies on the topic usually do not take these aspects into account.[24]

Besides rebound effects, cascading and side-effects of FLW prevention refer to effects of this activity in indirectly affected systems (Bernstad Saraiva Schott & Cánovas, 2015). An example of a cascading effect would be the decision how to use the agricultural land that would become available if FLW levels were decreased. This land could be used for example for energy crop production or not used at all. The environmental impacts of such land-use changes can be substantial and thus taking into account cascading effects could alter results of environmental consequences of FLW prevention substantially. Another example in the case of FLW prevention is that it might occur that due to prevention strategies food fed to animals is reduced. Because of this prevention strategy there might be a reduction in animal production (meat, milk or eggs) or other feed will have to be used. Ideally, such effects need to be anticipated and included in economic modelling of potential impacts of FLW prevention measures to derive meaningful policy recommendations.

To sum up, studies analysing the impacts of reducing FLW by economic modelling are currently almost non-existent. The majority of available studies estimates the amount of FLW, calculates the benefits in terms of possible household monetary savings if food waste levels could be reduced and discusses possible intervention strategies to reduce FLW. Even though these studies provide valuable insights for the understanding of the extent of the problem, these studies do not model or predict impacts of reducing FLW, since costs are usually only calculated as the costs embodied in the food wasted. More specifically, supply and demand interactions, substitution effects and vertical linkages among sectors and the role of the price mechanism are usually not taken into account. However, such an approach is needed to derive meaningful policy recommendations. Thus, more research is needed to assess how the prevention of FLW can lead to a more resource-efficient food system, by particularly investigating how costly it might be to reduce FLW and which trade-offs might occur among different stakeholders.

[24] It is important to note in this context that unless there are large external costs associated with rebound effects, they are generally social welfare improving. However, while they may be beneficial for social welfare, their existence may still reduce the benefits from certain efficiency policies and thus may impact which policies are first-best policies to address externalities (Gillingham, 2014).

5.3 Proposed prevention approaches

5.3.1 Cross-cutting approaches

Improvement of the data basis and target setting

Several studies name a robust and reliable data basis on FLW levels as an important part of prevention activities due to creating awareness and enabling target setting (e.g., Monier et al., 2010, Priefer et al., 2013, European Commission, 2014; UNEP, FAO, WRAP, 2014; WRAP, 2015). The establishment of a standardized methodology for FLW data collection and compulsory reporting by EU Member states is an EU wide action proposed option that is supposed to directly address the objective to increase awareness and improve knowledge on levels and impacts of FLW (Monier et al., 2010; European Commission, 2014). The line of argument is that for an evidence-based strategy reliable data are a necessary precondition for setting up quantitative reduction targets, which are helpful instruments for raising awareness and mobilizing resources towards strategies to reduce food waste (e.g., Parry et al., 2015). Thus, national governments should be obliged to set targets for FLW reduction to be reached within a given timeframe and to establish a systematic monitoring in order to review the progress (Priefer et al., 2013).

WRAP (2015) points out further that also for many individual businesses robust data on the amount and types of FLW generated are necessary to overcome currently existing information deficiencies regarding the extent of the problem, which hinders to set credible goals and targets. For such an approach several studies stress that a binding definition of the term FLW as well as a standardization of methods used by the Member States for the collection of data on the generation of FLW should be introduced (e.g., Priefer et al., 2013). However, given the discussion in section 2 about the challenges for a uniform definition it might make sense to set up different definitions according to which research or policy objective is aimed at.

This specific prevention approach has been evaluated by Monier et al. (2010) and the European Commission (2014). Monier et al. (2010) provided an ex ante impact assessment of potential FLW prevention options using a semi-quantitative score matrix. The five options assessed are listed below (see Annex 2 for more details on the impact assessment):

- Option 1: EU Food waste reporting requirements
- Option 2: Date labelling coherence
- Option 3: EU target for food waste prevention
- Option 4: Requirement on separate collection of food waste
- Option 5: Targeted awareness campaigns

Based on their impact assessment, setting up EU food waste reporting requirements is considered essential for future progress in this area and additionally it is considered to be feasible at limited costs.

Another more recent impact assessment of this specific prevention measure is provided by the European Commission (2014). In this report three different policy options were assessed:

- **Policy Option 1** – take no additional action;
- **Policy Option 2** – Establish a standardized methodology for food waste data collection and compulsory reporting by Member states;
- **Policy Option 3** – Setting targets for food waste prevention.
    - **Option 3 a**: Mandatory reporting plus a 15 % reduction in food waste[25] from 2016-2025;
    - **Option 3 b**: Mandatory reporting plus a 20 % reduction in food waste from 2016-2025;
    - **Option 3 c**: Mandatory reporting plus a 30 % reduction in food waste from 2016-2025;
    - **Option 3 d**: Voluntarily national objective of a 30% reduction in food waste from 2016-2025;

All options are considered feasible within the given time frame whereby the 15% reduction option is considered a lower target option and relatively easy to achieve by for example awareness raising campaigns and sharing of best practice examples. The 30% reduction options are considered as being rather ambitious but not impossible. The impact assessment is carried out with the European reference model on municipal waste management, which has been developed, by Eunomia and the Copenhagen Resource Institute (CRI).[26]

The following table illustrates for each policy option the implementation costs, the financial savings from reduced waste management costs, potential environmental benefits, the value of food saved and the assessment of feasibility. Regarding the costs of prevention measures it is assumed that these would be in the range of 17€ per tonne of food waste prevented. This number is based on evidence from several WRAP reports. Moreover, it is assumed that some ongoing communication actions are needed to stop people reverting back to previous behavioural patterns. These communication costs are assumed to be 10% of the initial prevention costs in each year after the initial food waste was prevented.

Table 8: Comparison of impacts of policy options, by 2025

	Option 2	Option 3a	Option 3b	Option 3c	Option 3d
Implementation costs	~5 million € p.a.	~33 million € p.a.	~44 million € p.a.	~66 million € p.a.	5 – 66 million € p.a. depending on take-up
Financial savings from reduced waste management costs	+	~350 million € p.a.	~460 million € p.a.	~630 million € p.a.	Up to 630 million € p.a.
Environmental benefits	+	~1.8 billion € p.a.	~2.5 billion € p.a.	~3.75 billion € p.a.	Up to 3.75 billion € p.a.

[25] Food waste is defined in this report as "food intended for human consumption, lost from the food chain". Thus, food diverted to animal feed or sent for redistribution is not considered wasted.
[26] For more detailed information on this tool please see http://www.wastemodel.eu/section.php/3/1/further_information

Value of food saved to become wasted	+	~35 billion € p.a. (~70 € per person)	~47 billion € p.a. (~95 € per person)	~71 billion € per annum (~140 € per person)	Up to 71 billion € (~140 € per person)
Feasibility	Definitely feasible	Definitely feasible	Feasible	Not clear	Definitely feasible

Notes: Since the model only looks at municipal waste, which does not represent all waste from manufacturing, retail and food services, the results should be considered as conservative estimates.
Source: European Commission (2014), p. 62

Translated into costs for individual member states the report estimates that option 2 would results in costs for major national food waste studies of 200,000-300,000 € per year. With respect to policy options 3a-d the results indicate that consumers annual cost savings due to FLW prevention would range between 70 to 140 € per capita. Also manufacturers and food service institutions would benefit from the FLW prevention measures due to cost savings on the input side meaning that businesses are becoming more resource-efficient. In contrast, food producers and retailers would most likely experience negative welfare effects due to decreased consumer demand. This is in line with the results by Rutten (2013) discussed above.

However, the report stresses that two mitigating factors need to be considered while interpreting the results. First, decreasing EU demand could be offset by increasing exports since there is there is a steadily growing global demand for food. Second, as already mentioned there is evidence from the UK that consumers might demand higher quality food products with decreasing food waste levels ('trade-up') thus offering an opportunity for producers and retailers to compensate lower sales quantities. With respect to the preferred option, the report states that option 2 is considered essential since the scale of the problem is immense and the potential environmental and economic benefits are high in comparison to the costs of implantation. Besides, option 3d is named the preferred approach since it is in line with the proportionality principle, sets very clear objectives for EU member states but is not set up top-down.

Integrated food supply chain management

Integrated supply chain management is considered another important cross-cutting approach to prevent FLW (WRAP, 2011b; House of Lords European Union Committee, 2014; Parry et al., 2015; WRAP, 2015). Integrated supply chain management refers thereby to improved communication and cooperation among all stakeholders. Especially in the context of perishable foods information sharing has been suggested to be one of the most important means to reduce FLW (e.g., Mena et al., 2011, WRAP, 2011b).

However, as Kaipia et al. (2013) point out there is only limited empirical evidence on how companies should actually share and utilize information for FLW reduction in supply chains. Only few studies are available providing empirical evidence on the positive impact of improved supply chain management on reduced FLW levels.

First empirical evidence on supply chain management and FLW reduction has been provided for the UK by several WRAP reports (2011b;c). Based on several case studies it has been shown that increased information sharing among supply chain partners resulted in reduced forecasting error and hence FLW. These reports also describe in more detail what is usually generically termed 'better supplier relations'. In all case studies stakeholders made changes to their working practices by: (i) increasing/introducing daily communications with suppliers; (ii) more detailed forecasting methods linked to an improved order planning process; (iii) improved tools to assess underperforming lines; i(v) improved tools to make order amendment more accurate; and (vi) reviewing the progress on a regular basis. Moreover, the results demonstrate that retailers and suppliers can collaborate to identify and reduce supply chain waste initiated and accelerated with third party facilitation. And most importantly, this can be achieved by ensuring a positive rate of return on investment thereby demonstrating the commercial benefit from preventing FLW. In this context it is important to stress that for businesses reducing FLW is a natural goal and an integrated part of optimization strategies since FLW is costly (Regnell & Stendys, 2016).

For the Nordic countries, Kaipia et al. (2013)[27] provide first explorative empirical evidence on information sharing as a way to reduce FLW in food supply chains. Their study focuses on material and information flow issues, specifically on sharing demand and shelf-life data, in three fresh food supply chains (milk, fresh fish, and fresh poultry). The cases are based on interviews and company data. All cases showed that accurate and thorough use of shared data reduced the effect of demand uncertainty. A particular finding was the impact of store order-placing schedule on shelf availability and waste in the stores. The results indicate that to be able to respond to demand, the store order-placing time needs to be delayed as long as possible. This resulted in more accurate daily ordering and improved management of weekend sales. Moreover, a good forecasting process with the best available data was essential. Implementing this required investments in software, as well as in staff and their capabilities. No formal cost-benefits analysis was carried out but the results indicate net benefits due to significantly lower FLW levels. This is in line with experiences made by Dansk Supermarked Group implementing an automatic ordering system, which optimizes the balance between out of stock and FLW levels (Regnell & Stendys, 2016).

Jedermann et al. (2014) point out further that focusing only on shelf-life-dependent stock rotation in supply chain management to reduce FLW is often not sufficient. Correct cold chain management is at least equally important but unfortunately often not met in practice. Examples of inappropriate cold chain management across the supply chain are that farmers do not pre-cool after harvest even though the 'cut-to-cool' time is

[27] The research presented in this paper is part of the LogiNord-project - Sustainable logistics in Nordic fresh food supply chains (http://www.sintef.no/projectweb/loginord/).

recognized as being very important for many commodities. Since cold chain management will become globally more important given that with increasing income people diversify their diet and demand more fresh products which require chilled transportation, aspects of cold chain management should be central parts of an integrated supply chain management to reduce FLW.

In this context, two studies are available who carried out an *ex ante* impact assessment of lowering temperatures in the cold chain in order to prevent FLW (WRAP, 2013a; Eriksson et al., 2016). The study by WRAP focuses on households in the UK, whereas the study by Eriksson et al. (2016) focuses on supermarkets in Sweden.

At the household level using the cold chain more effectively refers on the one hand to placing more perishable products in in the fridge (e.g. apples) as well as lowering average fridge temperatures from 7° C to 4° C. However, lower temperatures lead to higher energy consumption and thus the major research question addressed by WRAP (2013a) was whether this higher energy consumption can be justified by benefits from lower food waste levels. **Based on a combination of existing data with experimental measurements the report concludes that the two measures (lowering average fridge temperature plus placing more perishables in the fridge) would result in net benefits both financially as well as environmentally.** The annual food savings resulting from improved cold chain management in households are estimated to be worth £280 Million and associated with 580,000t CO_2 emissions, whereas the higher energy consumption would equal £ 81 Million and would lead to additional 370,000 t CO_2 emissions.

A similar approach was taken by Eriksson et al. (2016) investigating the net effect of reducing the storage temperature in Swedish supermarkets to reduce FLW levels. Analog to the study results derived for the household level in the UK, the results presented are based on a simulation of the relationships between food waste reduction, longer shelf life, reduced storage temperature and increased energy costs. The analysis is based on long-term waste data collected in six Swedish supermarkets as part of the normal waste recording routine (see also Eriksson et al., 2012; 2014).

Their results indicate that dairy, meat and deli products have the largest waste reduction potential in terms of mass due to lower storage temperatures. The results show that if the storage temperature used for cheese, deli and dairy products were to be decreased from 8◦C to 5◦C, the waste associated with these products would potentially decrease by 15%. The corresponding reduction for these products if the temperatures were to be reduced from 8◦C to 4◦C and 2◦C would be 18% and 25%, respectively. For meat products a reduction in storage temperature from 4◦C to 2◦C would potentially lead to a 19% reduction in mass of wasted meat. The net effect of reducing the temperature in the cold chain was calculated by taking the benefits to the store in terms of reduced FLW (both potential monetary savings and greenhouse gas emissions) and subtracting from this the increased electricity costs. A negative net effect was found for dairy products, whereas

a positive net effect was found for meat products. The category deli and cheese products had on overall a zero net effect meaning that for this product category the benefits of reduced FLW would equal the increased costs of energy consumption. The negative net effect in case of dairy products is explained by the already very low waste levels of dairy products and the high energy costs to chill dairy products due to the high water content of dairy products. **Thus, these results show that a general reduction in storage temperature would reduce FLW in all product categories. Yet, for certain products such as dairy products this could lead to a negative net effect due to high electricity costs. Consequently, lowering storage temperature in the retail sector might be considered cost-efficient only for certain product categories such as meat.**

To sum up, integrative supply chain management and correct cold chain management seems to be promising ways to reduce FLW levels. However, as the report by the House of Lords European Union Committee (2014) highlights currently there is only limited cooperation among food supply chain stakeholders at the EU level. Thus, there is a need for initiatives addressing to improve cooperation and communication across the supply chain. One example of such cooperation is the Retail Forum, which is part of the Retailers' Environment Action Programme. The Retail Forum was established by the Commission in 2009, and is a multi-stakeholder platform intended to exchange best practices on sustainability in the European retail sector. This platform was created in the belief that retailers can play a significant role in fostering positive changes towards more sustainable consumption patterns through their partnerships with suppliers and through their daily contact with European consumers. Moreover, in June 2010 the Retail Environmental Sustainability Code was launched which is a voluntary environmental code of conduct for the retail sector. The signatories of this code commit themselves to reduce their environmental footprint. Examples of actions taken are sustainable sourcing of specific products such as timber or fish, increased resource efficiency in stores, better waste management practices and improved communication to consumers. However, to the best of our knowledge there is no evidence available so far in which way this retail forum had an impact on increasing supply chain integration and whether the signatories did better than retailers not signing up but setting up their own sustainability plan (see also Hansen & Power, 2010).

Amendment of date labelling standards

The following FLW prevention actions related to date labelling have been proposed in the literature (e.g., Monier et al., 2010; Priefer et al., 2013) : (i) European legislator should consider revising existing regulations on food date labelling in order to improve the visual presentation of expiration dates, (ii) manufacturers should be encouraged to set new best- before dates to the true shelf life of products, (iii) abolishment of expiration dates for non-perishable foods should be considered, and (iv) consumer awareness and education campaigns on date labelling should be initiated. Thereby, making consumer aware and educate about of the

right meaning of date labels would have at the same time the positive effect to decrease the risks of food-borne diseases due to inappropriate handling of food labelled with a use by date.

In the EU date labelling is regulated by Regulation (EC) No 1169/2011 on food information to consumers, which entered into force in all member states in December 2014 (Møller et al., 2014c). There exist two types of legally required date marks: "best before" and "use-by". "Best before" relates to food quality, including flavour, texture, aroma and appearance, and indicates the date until which the food retains its specific properties when properly stored. "Use by" refers to food safety and indicates the date until the food is safe to eat from a microbiological point of view. Thus, a product with a use by date is deemed unsafe to eat after the date is expired and should not be consumed or offered for sale after this date (Regulation EC No 1169/2011, Article 24). Both dates are considered to provide consumers a point of reference regarding guarantees on the quality and the safety of food products (DEFRA, 2011a). No indication on shelf life date is required for a restricted number of pre-packed food products such as fruits, vegetables or wine.

Consumer studies have shown that consumers use date labels as quality cues to infer product safety and quality whereby the importance of date marking differs across food groups with being most important for perishable products such as fresh meat (e.g., WRAP, 2008; Van Boxstael et al., 2014). Put differently, for highly perishable foods such as fresh meat most consumers rely strongly on date labels in their purchasing and consumption decisions, whereas date label do not play an important role for non-perishable products such as flour or pasta. Moreover, these studies have shown that consumers not necessarily know the difference between "best before" and "use by" and tend to associate food safety with best before labelling leading to discarding food that would have been still safe to eat (see section 4).

A very recent survey on the topic has been conducted by TNS political & social at the request of the European Commission, Directorate-General for Health and Food Safety (European Commission, 2015a). The aim of this survey was to understand citizens' perceptions, attitudes and practices related to food management and consumption, and more specifically, to investigate the role of date marking in relation to food waste. For this purpose, 26,601 consumers in the EU were interviewed via phone. With respect to date labelling the results indicate that around 50% of consumers understand the "best before" labelling in a correct way (EU-28: 47%, Denmark: 55%), whereas the share in the case of "use by" labelling drops to 40% (EU-28) and 43% (Denmark), respectively. The results for Denmark are illustrated in figure 3.

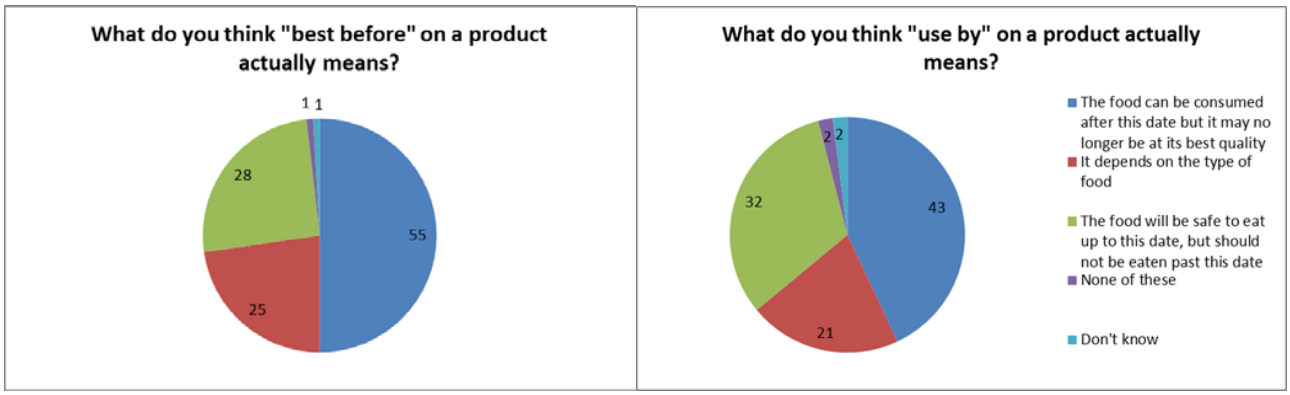


Figure 3: Share of respondents agreeing to the different definitions provided on best before and use by labels in Denmark (in %)

Besides, a question on the abolishment of "best before" labelling on non-perishable foods such as pasta was also included. The results show that over 50% of respondent stated that they do not need the information on "best before" on non-perishable foods (EU-28: 54%, Denmark: 58%)[28]. Furthermore, respondents were asked about their propensity to use non-perishable goods in the absence of any date labelling. Respondents were specifically asked to imagine that they had found a package of spaghetti in their kitchen with no "best before" date, and that they could not remember when they had bought it. They were then asked whether they would use the spaghetti or throw the package away. 70% (EU-28) and 75% (Denmark) of respondents said that they would use the package regardless of the lack of information.

Another related study by the European Commission (2015b) conducted experiments to investigate consumers' decision to use or dispose non-perishable foods and how this is affected by date marking. The perception of product quality, safety and likelihood of disposal were measured employing different date label scenarios, i.e. the presence of a best before date, a production date or absence of any date on the food package at different points of time (way ahead of the best before date, just before the best before date, just after the best before date, way after the best before date). 500 mostly Italian consumers participated in the study.

The results highlight the following points. First, only 47% of participants indicated the meaning of the best before date correctly. Second, most participants think that they can decide for themselves about expiration of a product, at least in the case of non-perishable products such as pasta, but that a date label helps in make decisions about the product quality, safety and disposal of a product. Thus, the results confirm that date labels are used as external quality cues. Third, whether it is preferable, from a food waste prevention point of view, for a food product to be labelled with a best before date or not, depends very much on how long

[28] The question posed was: "Currently, manufacturers are not required to indicate dates on food labels for certain non-perishable foods, such as salt, sugar, and vinegar. These foods can be consumed safely and their quality does not deteriorate over a long period of time. In future, if you no longer found "best before" dates on other non-perishable foods, such as rice, pasta, coffee, or tea, how would you respond?"

consumers store products at home prior to using them. Before the best before date has been reached, it seems better to have a best before date on products (less disposal; higher perceived product quality and safety perceptions) than no date. However, for the time after the best before date is reached, consumers are less likely to throw out a food product without a date label. This is especially pronounced for products with a long perceived shelf-life by consumers.

Based on these results the authors conclude that it seems to be important to consider at which point consumers typically consume the products stored in their kitchen cabinet[29]. If most products with a long perceived shelf-life are consumed before the best before date is reached the recommendation would be to keep the best before date on long perceived shelf-life products. However, if these products are actually stored for a longer time, it would be better to abolish date marks on products.

Another relevant aspect in this context is the fact that many manufacturers seem to set date labels very conservatively to protect their reputation as high-quality producer. Based on a survey with selected food companies in the four Nordic countries Møller et al. (2014c) report that there are substantial differences in shelf life determined by companies. For fresh milk, cold smoked salmon and cooked ham the shortest and longest shell life set by companies differed by the factor two[30]. In the case of minced beef, the factor even increased to three (shortest shelf life: 6 days, longest shelf life: 18 days) and was even higher for ready-to-eat salads. In the case of minced beef different packaging gas is used across the four countries which leads to a substantially longer shelf life of minced beef in Norway (average: 18 days) in comparison to Sweden and Denmark (average: 8 days).

The results show further that for most of the investigated products Norwegian products have in general a longer shelf life than products in the other three countries. The underlying reasons for these differences are not clear but the authors assume that it might be related to the fact that in Denmark, Finland and Sweden, national food agencies provide more guidance to manufacturers than in Norway. In general, Møller et al. (2014c) conclude that environmental agencies should work together with other authorities like national food administration in order to avoid initiatives that might even increase food waste.

With respect to impact assessments, Monier et al. (2010) considered the clarification and standardization of current EU-mandated food date label application and the dissemination of this information to the public to increase awareness as a policy option worth to pursue. This study assumed that 20% of avoidable food waste at household level is due to date labelling confusion[31]. Therefore, date labelling coherence is assumed to

[29] This aspect was not investigated in the current study.
[30] These products were processed and packed in a similar way and thus provided a good basis for comparison.
[31] This number is taken from WRAP research on date labeling.

have a rather high FLW reduction potential while at the same time the costs involved in implementing this option are considered rather low.

To sum up, providing information to consumers about the correct interpretation of date labels and simplifying date labels as much as possible to avoid consumer confusion are certainly important strategies. However, while evaluating the potential of information strategies on date labels and date labelling amendments with respect to FLW reduction the following points should be kept in mind. First, in quantitative terms products without any date label, i.e. fruits and vegetables, bread (if bought from a bakery) are wasted the most. Date labelling amendments would not affect these product categories. Thus, even though the results presented above on non-perishable products provide some interesting insights, it needs to be kept in mind that the share of non-perishable products wasted in total FLW is rather low in comparison to perishable food products. Thus changing legislation with respect to date marks on non-perishable product will most likely not have a large impact on total FLW levels. **Second, as Kranert et al. (2012) state the effect of amendments of date labelling should not be overvalued since the real reason for discarding food is not the date label itself but the fact that consumers did not use the product on time which is again related to food management skills.** A closely related aspect in this regard is that food is sometimes discarded by consumers because of the perception that the product quality has been deteriorated and they simply do not want to eat food that is not at its best. Put differently, given the fact that food is relatively cheap consumers can afford to be picky in terms of food quality leading to food discarded that would have been still total safe to eat. Such behaviour will most likely not change due to date labelling amendments.

Amendment of marketing standards

Given the fact that most studies conclude that aesthetic standards are a major driver of FLW at all stages of the food supply chain, several studies proposed the amendment of marketing standards of fruits and vegetables to prevent FLW (e.g., Priefer et al., 2013; HLPE, 2014).

In fact, there has been an amendment of EU marketing standards of fruits and vegetables in 2008 but with only limited impacts due to the following reasons. First, the amendment covered 26 types of fruits and vegetables that account for only 25% of all fruit and vegetables marketed in the EU. Thus, major products such as apples and bananas were not included. Second, the trading sector expressed that it had an interest in maintaining the standards since it provides an objective yardstick facilitating business relationships between producers, manufacturers and retailers. Third, logistic processes are currently geared towards standardized products and cannot handle goods with irregular shape and size.

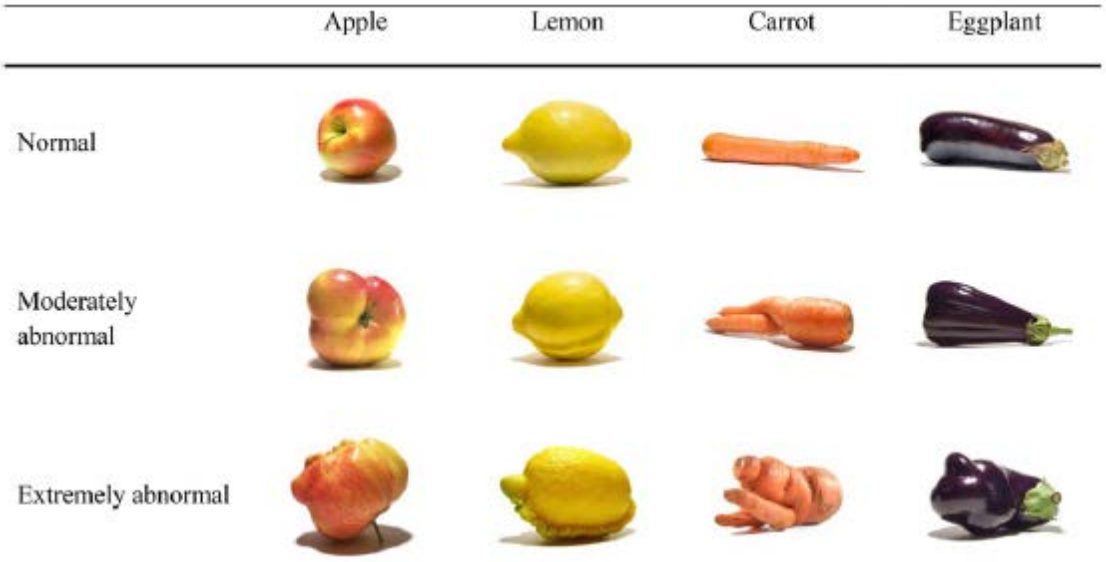
Similar arguments are reported by Segrè et al. (2014) referring to a study by AND International (2010) that repealing marketing standards will not have a significant impact on FLW reduction and that the presence of unsorted products at the retail level would maybe even lead to an increase in FLW at the retail level. A similar conclusion is drawn by Mattsson (2014) in a study focusing on wasted fruits and vegetables in Sweden. It is pointed out that marketing standards are simply a tool for communicating requirements agreed by stakeholders. **Thus, the real reason for FLW is not the standards themselves but rather the market requirements which are usually a result of finding a compromise between retailers, wholesalers and producers.** This suggests that the market sets the standards and not the reverse and requirements would remain even if the governmental standards were removed. This conclusion is backed-up with the finding that major Swedish retailers rarely buy fruits and vegetables of lower quality than class I which is higher than the lowest quality accepted by the marketing standards (lower limit of class II) (see Annex 3 for an overview of the different quality classes). This means retailers set higher quality standards than legally required.

All these findings are in line with the growing literature investigating how voluntary private quality standards are used as strategic tools for stakeholders in the food supply chain (e.g., von Schlippenbach & Teichmann, 2012; Yu & Bouamra-Mechemache, 2016;). In general, voluntary private standards have become increasingly important as mode of market governance in global food chains (e.g., Ponte & Gibbon, 2005). As Hatanaka et al. (2005) point out private standards are nowadays strategically used by companies to achieve a variety of goals such as gaining access to new markets, facilitating the coordination of operations or providing quality and safety assurance to consumers to maintain or improve their reputation. At the same time this implies that the responsibility of establishing and monitoring food safety and quality standards has been shifted from governmental agencies to private companies such as manufacturers, retailers and third-party certifiers.

However, as has been stressed above consumers' actual or anticipated food perceptions and food purchase behaviours influence retailers' decision making substantially. This means that retailers apply aesthetic standards to accept or reject foods based on the assumption that consumers will only buy foods fulfilling these standards. Consequently, one argument is that if consumers would accept fruits and vegetables not in line with the existing standards retailers would have an incentive to sell such fruits and vegetables.

Two interesting studies in this context are Loebnitz et al. (2015) and European Commission (2015b). Both studies investigate how food shape abnormality affects consumer purchase intentions, and thus provide empirical evidence with respect to potentials to reduce FLW by offering abnormally shaped food to consumers. In the study by Loebnitz et al. (2015) 964 Danish consumers took part and the results indicate that consumer purchase intention decreases with increasing abnormality of the presented food. However, this is only true for extremely abnormally shaped foods and not for moderately abnormally shaped ones (see figure 3 for the used stimuli).

Figure 4: Stimuli used in the study



Source: Loebnitz et al. (2015)

The authors discuss further the importance of experiencing and tasting unfamiliar food as an effective strategy to increase consumers' acceptance of unfamiliar products. Consumers might accept, and buy, abnormally shaped food if they simply get used to these products by exposure. Therefore, the authors conclude that it might be a good strategy for retailers to start selling abnormally shaped foods to initiate this process.

The study by the European Commission (2015b) addressed how to increase consumer acceptance of imperfect fruits and vegetables with effective communications. It was specifically investigated whether persuasive messages can be used as an alternative to price reductions on imperfect fruits and vegetables. Two different persuasive messages were analysed: an authenticity message ("Naturally imperfect: Apples the way they actually look!") and an anti-food waste message ("Embrace imperfection: Join the fight against food waste!"). These messages were combined with different price reduction: no price reduction, a moderate price reduction (15%) and a sharp price reduction (30%). The results show that both monetary incentives in terms of price reductions as well as providing persuasive messages increase the share of participants willing to buy the imperfect fruits and vegetables. Furthermore, the preferred promotional message depends on the price level. The results show that the authenticity message leads to highest consumer purchasing in case of moderate price decreases, whereas for no price decrease or 30% price decreases the promotional messages are equally effective. The authors conclude that a combination of price reduction with persuasive message seems

to be most effective. Thereby, authenticity messages seem to increase quality perceptions and thus decrease the necessity of sharp price reductions of imperfect fruits and vegetables.

In several countries, retailers started selling imperfect fruits and vegetables. Examples are the Inglorious Foods & Vegetables campaign by Intermarché, the Ugly Foods project in Germany, and the British retailer ASDA selling wonky fruits & vegetables. In general, these campaigns often use one or a combination of the persuasive messages discussed above, i.e. either an anti-food waste messages or a message stressing the authenticity of imperfect fruits such as "less perfect is more real". Based on the existing evidence these campaigns seem to be rather successful and fit into the picture of increasing consumer demand for sustainable food products on the one hand and an increasing use of sustainable criteria in marketing and building up a sustainable corporate identity by retailers on the other hand.

To sum, given the points discussed above, especially the fact that retailers use (aesthetic) standards as strategic tools and often actually set higher standards than legally required, it seems much unlikely that the amendment of governmental marketing standards would lead to significantly reduced FLW levels. However, given the increasing interest by consumers in sustainability and naturalness, retailers could consider selling oddly shaped vegetables and fruits in order to target this market segment of consumers who are willing to buy such fruits and vegetables.

Improved packaging

Developing and using active or intelligent packaging to increase the shelf life of products is assumed to lower FLW levels.[32] The report by DEPA (Miljøstyrelsen, 2014c) mentions explicitly the micro-filtration of milk and high pressure treatment of meat as possible technical solutions to extend the shelf life of these products and thus reduce FLW at retail and household level. Regnell and Stendys (2016) mentioned that Dansk Supermarked Group is part of projects developing packaging with reduced ethylene content and packaging that signals in an easy way to consumer how best to store the product. The report by CONCITO (2011) pointed out further that in recent years the aim in creating new packaging has been to minimize packaging waste because of environmental reasons. However, current evidence shows that the environmental impact of discarding food is usually much higher than the impact related to add more packaging material (e.g., Silvenius et al., 2014). Consequently, future research should develop packaging solutions that focus on reducing FLW by extending shelf life and being easy to empty.

[32] Active, interactive, smart, clever or intelligent packaging are terms used interchangeably for describing new packaging technologies that are intended to extend the shelf-life or maintain the conditions of packaged food (Dainelli et al., 2008). Examples of such packaging technologies are advances in delayed oxidation and controlled respiration rate, microbial growth, and moisture migration (Restuccia et al., 2010).

Moreover, given the empirical evidence on why food is discarded at the household level, it is argued that smaller package sizes should be offered to allow consumers to finish the whole package in time and thus reduce FLW (e.g., CONCITO, 2011; Stenmarck et al., 2011; Priefer et al., 2013). In this context, the aspect of higher prices per volume for smaller package sizes is discussed as a barrier for consumers to choose the smaller package sizes since they consider this as "a bad deal". Some authors request therefore that the prices of smaller packages should be adjusted so that all package sizes have an equal price per weight (e.g., Priefer et al., 2013). This might be, however, not always feasible due to higher relative packaging costs for smaller packages.[33]

To sum up, even though improved packaging that extends the shelf-life of highly perishable products might contribute to lower FLW levels, the impact is not fully clear-cut. It is a matter of fact that in industrialized countries including Denmark there have been substantial technological improvements to keep food lasting longer over the course of the food supply chain and still a high amount of food is still lost and wasted (e.g., Halloran et al., 2014). Thus, as in the case of date labelling amendment the same line of reasoning might apply; it is not the short shelf-life per se that leads to FLW but general food management skills and shopping and eating routines are more important in driving FLW levels (see section 4). Food management skills and routine will most likely not change by extending the shelf-life of products. As discussed above, consumers might choose to do grocery shopping infrequently given the associated opportunity costs in terms of time and travel costs. At the same time, rather infrequent grocery shopping might result in higher FLW levels. Extended shelf-lives of products might even reinforce this by enabling consumers to shop even less frequently than they do right now and such a behaviour could counterbalance the positive effects of extended shelf-lives. **Thus, even though longer shelf-lives might contribute to lower FLW level, in practice the full potential of this approach might not be realized due to rebound effects as discussed above.**

Fiscal measures: Taxes, fees, subsidies

Besides regulatory amendments and information campaigns, market-based interventions such as taxes or subsidies are proposed by several studies to reduce FLW levels (e.g. Priefer et al., 2013; HLPE, 2014; Segrè et al., 2014). Priefer et al. (2013) recommend that EU member states should review their tax regulations (mainly the value added tax VAT) in order to remove all incentives that may encourage the generation of FLW. Moreover, several studies discuss the option to eliminate the reduced VAT-rate on food or to introduce different

[33] Regnell and Stendys (2016) mentioned in this context that changing package sizes is often not feasible due to investments in equipment to change standardized package sizes in manufacturing.

VAT-rates according to the environmental impacts of food items (EC, 2008; BIO Intelligent Service, 2012a; Priefer et al., 2013) [34].

The taxation of food waste is also a discussed option (Priefer et al., 2013; UNEP, FAO, WRAP, 2014). A 'pay - as-you-throw' or PAYT scheme for waste has been implemented in many countries, including several European countries. This measure can create incentives for households and businesses to minimize the amount of food and drink waste they generate. These systems are probably best implemented by municipality, at local authority level or contracted waste management companies (UNEP, FAO, WRAP, 2014). However, at the same time several studies point out that implementing economic incentives for FLW reduction should be considered very carefully (e.g., Quested et al., 2013; Cecere et al., 2014). It is argued that FLW reduction is mainly a hidden action and thus the motivation of reducing FWL is mainly intrinsic and not extrinsic[35]. In such a situation previous studies on other pro-social behaviours have shown that monetary incentives might crowd-out intrinsically motivated people. They stress further that in the context of FLW reduction and recycling the analysis of monetary incentives is more challenging in comparison to other environmental issues, since the related pro-environmental actions generally generate low individual benefits but have high opportunity costs in terms of more time spent for grocery shopping, meal planning and preparation.

Food redistribution[36]

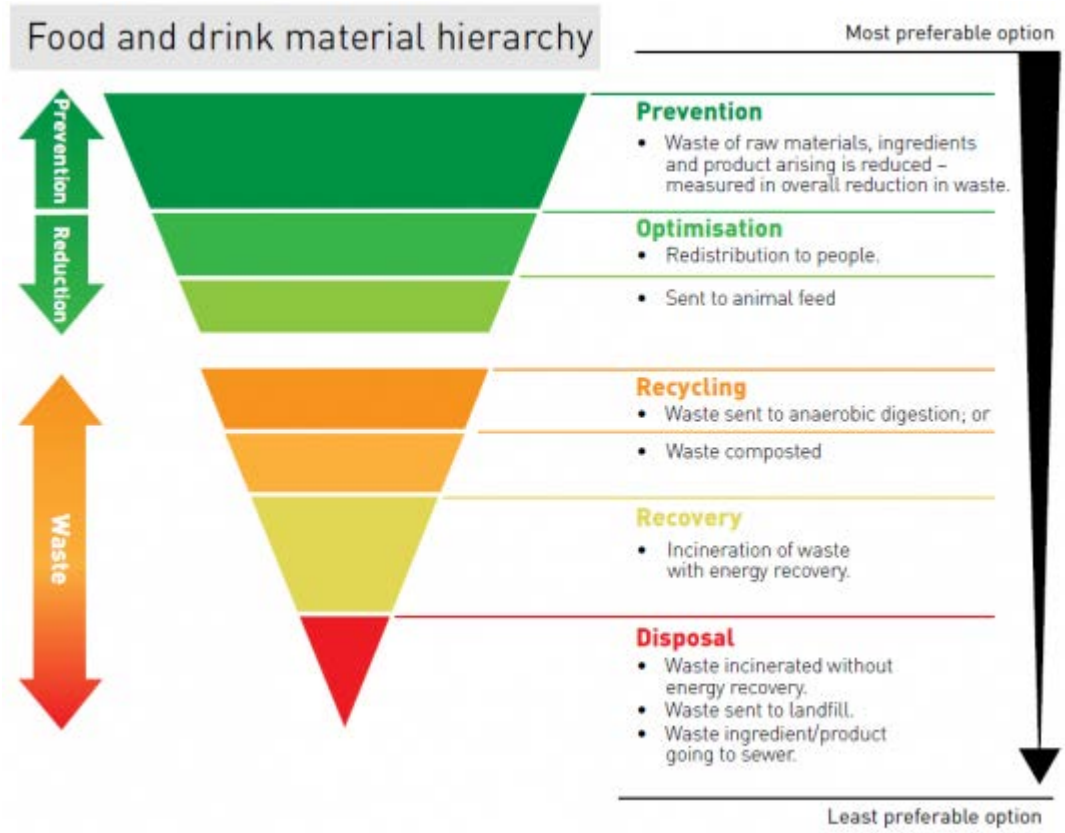
Food redistribution is considered another approach to prevent food becoming wasted. However, it needs to be stressed that it is different to the other approaches discussed so far, which is illustrated by the 'food and drink use' hierarchy in figure 4. The actions presented on top are most preferred with decreasing preference for the actions presented to the bottom. Since food redistribution is not targeting at the primary causes of food waste and does not aim at the primary goal of reducing FLW, i.e. reducing the environmental impact of food produced, it is less preferable than prevention measures, which are placed on top of the hierarchy.

[34] In Denmark food is also taxed at the standard VAT rate of 25%.

[35] Intrinsic motivation is usually defined as a motivation coming from within the person's attitude without any external reward. In contrast extrinsic motivation comes from outside for example in form of financial rewards (Cecere et al., 2014).

[36] Since food redistribution is not targeting at the primary causes of food waste and does not aim at the primary goal of reducing FLW, i.e. reducing the environmental impact of food produced, we discuss this aspect only very briefly. For more details on the topic please see the report by Hanssen et al. (2014).

Figure 5: The 'food and drink use' hierarchy



Source: http://www.wrap.org.uk/content/why-take-action-legalpolicy-case

Food redistribution is considered to connect environmental goals by reducing food waste and social security goals by increased welfare for low-income people (Hanssen et al., 2014). Hanssen et al. (2014) distinguish between two main approaches of food redistribution. The first one refers to redistribution from food supply chain donors via redistribution centres such as food banks to end uses, which are typically charity organizations. In Denmark there is currently one registered food bank called FødevareBanken. This food bank collects and redistributes food from wholesalers and retailers and delivers it to charity organizations. It is estimated that in 2015, FødevareBanken redistributed 651 tonnes of food, which equals around 1,550,000 meals[37]. The second route refers to direct redistribution from food supply chain donors to charity organizations; the typical local redistribution route. Based on interviews with key stakeholders involved in food redistribution such as national food banks and local charity organizations in the Nordic countries, Hanssen et al. (2014) conclude that local food redistribution contributes substantially to food waste prevention while at the same time ensuring social security for low-income people. Furthermore, the results indicate that (i) there is a great potential for expanding food redistribution in all Nordic countries since most charity organizations see the need for

[37] http://www.foedevarebanken.dk/

more food donations; (ii) the current food redistribution in the Nordic region lacks a systems organization and is currently under-financed even though it offers a cost effective way of food waste prevention.

Given the fact that food redistribution does not target at reducing FLW level no impact assessment is provided in this report.

5.3.2 Stage-specific approaches

Primary production

Waarts et al. (2011) discuss several options to reduce FLW in primary production. One recommendation is to review the current practice of setting maximum residue levels (MRL) according to the precautionary principle in order to assess whether they are really justified from the perspective of human health. However, at the same time it is questioned whether this will actually lead to lower levels of FLW losses since many suppliers would most likely adhere to stricter limits than required by law to not run the risk of being part of a "food contamination scandal". Besides these regulatory aspects, tackling food losses and waste by advanced technologies such as breeding more robust crop and animal species and develop cultivation and harvest methods that result in less damage are other approaches discussed in the literature (e.g., Bond et al., 2013; Priefer et al., 2013; Mattsson, 2014).

Besides, finding alternative marketing channels or innovative marketing strategies for "second-class" products has been proposed to reduce FLW levels (e.g. Gustavsson et al., 2011). This might be achieved by increased communication and cooperation among farmers which could also reduce the risk of overproduction by allowing surplus crops from one farm to solve a shortage of crops on another.

However, there are no studies investigating whether farmers were actually interested in such a second-class market since such a market will most likely also affect prices and quantities in the first quality market. Since farmers' profits are influenced both by quantities and prices, the net benefit to farmers from such a second class market does not seem straightforward. These arguments are closely related to the growing literature on the strategic use of standards in food supply chains (e.g. McCluskey, 2007; Vandemoortele & Deconinck, 2014; Yu & Bouamra-Mechemache, 2016). As discussed by Merel and Sexton (2012) in the case of geographically differentiated products the choice of the level of standards is dependent on two effects: a demand-enhancing and a supply-restricting effect. The latter one can be used strategically to increase market prices. Merel and Sexton (2012) as well as Yu and Bouamra-Mechemache (2016) for example derive that producer organizations might have incentives to implement more stringent standards than socially optimal. Given this knowledge, even though the establishment of second-class markets for fruits and vegetables might be effective in reducing FLW levels, it might not necessarily be accepted by stakeholders due to impacts on quantities and prices of fruits and vegetables sold in the first market.

With respect to the fishery sector the discard ban is actively addressing to reduce food waste levels. This ban, which implies that all fish caught needs to be landed, will come into force over the period 2015-2019 and will apply gradually to an increasing number of species (Vittuari et al., 2015).

Processing & Manufacturing

A report by DEFRA (2008) stressed that the promotion of a culture of waste reduction in processing and manufacturing companies seems to be of central importance to reduce FLW levels. The case studies analysed for the UK revealed that the companies with lower FLW levels were the ones that promoted a culture of waste reduction and this culture was driving all other activities such as training, performance measurement and incentives. Especially staff training with the aim to avoid food wastage during the entire production process should be a central part of building up such a culture (Priefer et al., 2013).

Retail level

As has been discussed above, the major challenges for retailers are appropriate demand forecasting and inventory management to maximize sales while minimizing waste (e.g., Bond et al., 2013; Canali et al., 2014). Thus, finding ways to improve these activities would be important steps towards reduced FLW levels at the retail level. Moreover, human factors such as staff skills to handle the products are important and thus prevention approaches should primarily target at the improvement of those skills (e.g., Stenmarck et al., 2011, Priefer et al., 2013). Consequently, information and awareness rising in combination with staff training are considered important prevention approaches. As in the case of processors and manufacturers, DEFRA (2008) highlighted the importance of a culture of waste reduction for retailers that drives all other activities. However, Lebersorger and Schneider (2014) point out that the usually high staff turnover in retail might represent a major challenge for the success of such an approach.

Regarding possible technical solution to reduce FLW it has been proposed to lower the temperature in the cold chain, offer smaller packages, and sell fruits and vegetables per weight instead of per piece as it is done in most other EU countries. This would create the opportunity to sell fruits and vegetables of different size and shape. However, in general all these measures will only be implemented if they “pay off” meaning that the reduced costs due to reduced FLW levels cover the increased investment costs (e.g. cold chain). Similar results are presented by WRAP (2011b) stating that retailers are sales driven and for all those interviewed, „the fear of a lost sale is greater than the fear of waste“. However, REMA 1000 is an example of a retailer in

Denmark who abolished volume discounts and sells certain fruits and vegetables by weight[38]. Moreover, they introduced smaller package sizes for fresh meat and bread. Even though to the best of our knowledge there is no official impact assessment available so far investigating the FLW prevention actions implemented by REMA 1000 some informal evaluation information is available from interviews presented in the report by DEPA (Miljøstyrelsen, 2014c). Important aspects brought in the discussion are the role of social marketing, sustainable corporate identity and positive publicity that might make existing customers more loyal to the chain as well as attract new customers. Thus, maintaining and improving reputation might lead to indirect positive effects of these measures in the middle- and long-run.

With respect to better product ordering mechanisms the results by DEPA (Miljøstyrelsen, 2014c) point out that there is no general agreement among retailers on the benefits of more technically advanced order systems. Those retailers who have automatic ordering systems mentioned some disadvantages such as, for example, ordering of seasonal goods. Those retailers who do not have an automatic ordering system so far want it and believe it may solve some problems, such as reduced FLW levels. Thus, even though an automatic ordering of goods might be helpful it must be accompanied by human skills, such as experience, and in accordance with specific promotional campaigns. In this context, another WRAP report (2011b) pointed out that until so far no analysis have been carried out showing which forecasting approach is most successful and which demand planning methods should be preferred. However, based on the simple β-indicator introduced by Eriksson et al. (2014) it can be seen that longer shelf-life or smaller wholesale pack size might be used to compensate for low turnover in order to decrease FLW levels.

Even though the prevention of FLW should be first priority for retailers it is also clear that a zero FLW level will not be feasible. Thus, efficient use of FLW should also be part of a FLW strategy. According to Stenmarck et al. (2011), possible options for governmental actions could be to establish cost-effective production of biogas from food waste and to send well-sorted and safe food waste to feed pigs and poultry where this is preferred by the retail sector. One positive example in this context is Dansk Supermarked Group pursuing the goal to recycle 100% of their organic waste into biogas. According to Regnell and Stendys (2016), sorting and sending organic waste for biogas production is less costly than sending the organic waste for incineration and currently around 81% of all organic waste produced by Netto stores is recycled (see also Box 1). More specifically, all organic waste, such as overripe fruits, dented cans and outdated cartons of milk are thrown into a special container in each Netto store before being picked up by an external partner and driven to the

[38] It needs to be stressed that until so far there is not much evidence available whether volume discounts actually lead to higher food waste levels at household level. We are only aware of one study by Katajajuuri et al. (2014) who showed that in their sample of Finnish household that those household who bought "Buy one, get one free" and discounted food products more often did not waste less or more compared to other households.

waste handling stations. There the waste is separated by machines. 75% of the waste is reused as pulp for biogas, which is sent directly into the Danish biogas network and the rest is recycled or incinerated.

To sum up, reducing FLW at the retail level is a natural part of retailers' optimization strategies. However, it has also been pointed out that at the retail level the "optimal" FLW level is not equal to zero FLW since retailers optimize foremost profits and for parts of the FLW, the costs of preventive actions may exceed the retailers' cost of wasted products. Thus, implementation of FLW prevention strategies are clearly determined by consumer acceptance and profitability (see also box 1).

Box 1: Dansk Supermarked Group (Netto, Føtex, Bilka)

Retailer's perspective on FLW (based on a personal interview with Regnell and Stendys (2016)):

First of all, minimizing FLW is a natural interest of retailers and an integrated part of optimization strategies since FLW are costly. Second, the usual focus of retailers in terms of optimization spans from the distribution center to the store meaning that primary production, manufacturing and consumers are outside the boundaries of influence. Third, optimizing FLW levels does not mean zero FLW since this would imply that stores might run out of stock. Thus, the optimal FLW level is determined by maximizing profits that usually means ensuring full shelves during all opening hours. Fourth, most FLW stems from promotions and thus promotional amounts delivered to the stores need to be optimized. Due to an implemented automatic ordering system that allows a much better refinement of ordering the "right" quantities there has been quite some progress in recent years to reduce FLW levels caused by promotions.

Has there been an increase in sales of products close to the expiry date over time?
This question was posed due to the assumption that over time due to either increasing consumer awareness or simply the fact those products are considered a good deal there has been an increasing consumer demand for products close to the expiry date which in turn would lead to lower FLW levels at the retail level. However, given the current system it is not possible to keep track of sales of products close to the expiry date. Products that are reduced in price keep their bar code and so sales (now reduced sales) are registered along with products sold at full price. Moreover, this is not a primary indicator, in which retailers are interested. The goal is to optimize the ordering in a way that the range of products close to the expiry date is minimized and products are sold before the expiry date.

Would there be an interest in returning overripe fruits & vegetables back to wholesalers for producing jam or juice?
This question was discussed given the fact that there is some discussion at the EU level to make these shipments legal in order to reduce FLW levels (Dittlau, 2015). As discussed above from a retailer perspective the aim is to optimize processes in a way that fruits and vegetables are sold in the store. However, it has been also argued that a certain FLW will be unavoidable. Nevertheless, there is no primary interest in setting up such a system since this would be most likely logistically too costly. The same is for example true for food redistribution. Usually no food including overripe fruits and vegetables is donated directly from stores since the quantities per store are rather small. This limited and spread out supply poses a logistic challenge. Most fruits and vegetables are donated at the stage of the distribution center since this is logistically manageable. Moreover, donations are usually only done to FødevareBanken and WeFood since they are able to do the logistics. Only in some cases, where these two companies do not operate, local solutions such as donating bread for pig feed are implemented.

Adjusting certain marketing strategies such as e.g. selling fruits and vegetables per weight instead of per piece or offering oddly shaped fruits & vegetables
Danske Supermarked Group is in close contact with their customers (e.g. weekly focus groups with consumers) and there seems to be clear evidence that Danish consumers would not accept fruits and vegetables sold per weight instead of piece. Thus, there is no incentive from a retailer perspective to change this system since there is no business case. The same applies to offering oddly shaped fruits and vegetables. The business case with regard to selling oddly shaped fruits and vegetables might be to gain a positive profile on the food waste agenda. However, this strategy only works for first movers.

Waste management
Danske Supermarked Group has started to implement a separate collection of organic waste from their retails stores and currently around 81% of all organic waste from Netto stores and around 55-60% of organic waste from Føtex and Bilka stores is recycled into biogas. According to their experience, this system results in lower disposal costs for waste disposal since it is cheaper to send the organic waste to biogas than for incineration.

Food service sector

Several approaches have been proposed to prevent FLW in food service institutions. Since existing studies show that the largest amount of FLW in this sector is due to plate and servings waste, the most effective and efficient options to prevent FLW at this stage should target at staff training and customer awareness (e.g., Priefer et al., 2013; WRAP, 2015).

Thorsen et al. (2014) report further that food service institutions could reduce their FLW significantly by serving fewer dishes every day but in return diversifying what is offered during the week and by recycling excess food into new dishes. These findings are based on a study investigating the conversion process of two Danish cantinas from conventional to organic food.

Furthermore, several studies show that certain changes in the choice architecture ("nudges") can be used to reduce FLW levels, specifically plate waste levels (e.g., Kallbekken & Sælen, 2013; Wansink & van Ittersum, 2014; Aschemann-Witzel et al., 2015)[39]. Kallbekken and Sælen (2013) report results from experiments carried out in restaurants with two different nudging treatments, namely reduced plate size and a sign pointing out that guest can help themselves more than once at the buffet. Their empirical findings indicate that both interventions reduced plate waste by around 20% [40] Whitehair et al. (2013) found in their study that a simple awareness sign ("eat what you take, don't waste food") reduced plate waste by 15%. Wansink and van Ittersum (2014) show in several experiments that if one wishes to influence consumers' food intake a simple solution is to replace larger dinnerware with smaller plates and bowls. The authors stress further that this nudge will most likely not only reduce food waste levels but at the same time also decrease costs (via serving size) without decreasing customer satisfaction and might even prevent people from overeating thus fighting overconsumption.

Moreover, one recent study addressed the topic of using 2nd grade vegetables in industrial kitchens in Denmark by collecting data concerning the amount of time used and vegetable weight before and after preparation and conducting semi-structured interviews with kitchen employees (Lynnerup et al., 2016). The study focused on carrots, onions and leeks and calculating the economic consequences and extra costs involved in using 1st and 2nd grade vegetables. The project's main conclusion is that parameters such as working time spent, purchasing price, rate of use and application are imperative to the savings potential for 2nd grade

[39] The term nudge and nudge theory was introduced by Thaler & Sunstein (2008). A nudge is defined as any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives.

[40] The authors point out further that one potential concern in this context could be a negative effect on customer satisfaction due to the fact that customers have to return to the buffet more often or because larger plates produce a more luxurious feeling. The hotels who took part in the experiment use an online survey tool to record customer satisfaction with the restaurants. These surveys indicate that customer satisfaction with the buffet breakfast within each treatment group was constant from the pretreatment period to the treatment period.

vegetables. More specifically, the results indicate an economic advantage in using 2nd grade onions, whilst there is a moderate advantage in using 2nd grade leeks and almost no advantage in using 2nd grade carrots.

Household level

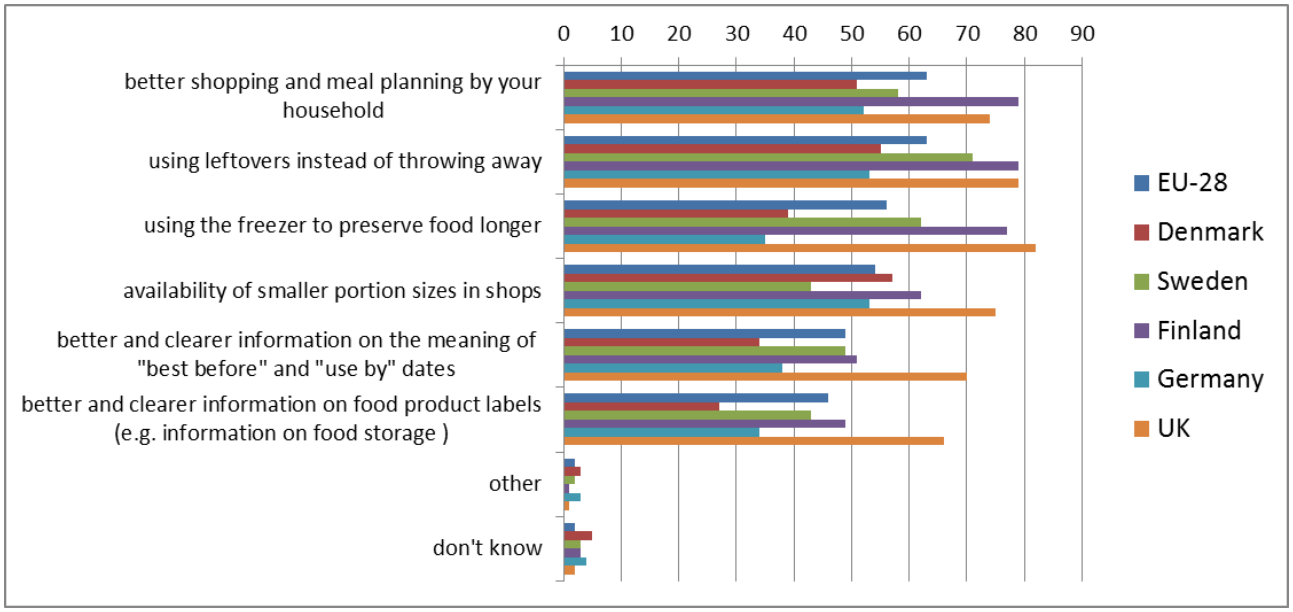
WRAP (2015) concludes that based on the experience gained in the UK a strategy for reducing household food waste should consist of three parts: (i) large scale communications campaigns, (ii) local engagement and (iii) changes to products in terms of packaging and labelling (see sub-section 5.3.1 cross-cutting approaches date labelling and improved packaging).

With respect to the design of communication campaigns it is important to take into account the current motivations and barriers to reduce food waste at the household level. For example, knowing that for most consumers, ethical considerations and the potential to save money (and not necessarily environmental concerns) are the strongest drivers to reduce food waste is an important aspect in setting up an effective information and awareness campaign (e.g., Stancu et al., 2016).

Moreover, since the existing empirical evidence suggests that household routines and food management skills are major drivers of food waste, campaigns should target at improving these skills and changing those household routines that lead to FLW (e.g. shopping only once a week, not using leftovers). However, since routines are hard to change and people tend to switch back to routines such behavioural changes should be tackled on a middle- and long-term perspective. In this context educating consumers "right from the beginning" is one central request by several organizations, which means to include the topic of home economics and food management skills already in school curricula (e.g., Stenmarck et al., 2011; Priefer et al., 2013; HLPE, 2014).

The recent Flash Eurobarometer 425 on date labelling provides some interesting insights in this regard. **According to these results, most Europeans are aware of their own role in reducing food waste. For Denmark the share of consumers stating that they themselves are responsible for reducing food waste is 85%, one of the highest shares among the EU countries (EU-28 average: 76%). While many consumers think that other stakeholders in the food supply chain such as retailers or restaurants also play an important role in reducing waste, significantly fewer consumers think that public authorities or farmers are responsible for taking action in this area**. Moreover, with respect to the question of how to reduce food waste at home most consumers stress the importance of better food management such as better shopping and meal planning (EU-28: 63%), using leftovers (EU-28: 63%), and using the freezer to preserve food longer (EU-28:56%). The responses from Danish participants in comparison to consumers in Sweden, Finland, Germany and the UK are illustrated in the following figure.

Figure 6: What would you help to waste less food at home? (multiple answers possible), in %



Source: Own presentation based on European Commission (2015a), Flash Eurobarometer 425, p. 11

Several important points can be derived from figure 5. First, there are rather large differences across countries. Overall, Danish participants agreed less to the statements than participants from Sweden, Germany, Finland and the UK. Only 51% of Danish participants agreed that better shopping and meal planning would help them to waste less food. In contrast, 74% of UK participants and 78% of Finish participants agreed to this statement.

These results raise several important research questions definitely worth to tackle further. Does a higher share of Danish participants perceive their food management skills as already appropriate in order to not waste food in comparison to participants in the UK and Finland? Which role does consumer awareness about prevention approaches play in this regard? The UK is considered the leading country in terms of food waste awareness due to their “Love Food – Hate Waste”- campaign that also included several studies on appropriate fridge and freezer use. Might this explain the large difference between Danish and UK participants with respect to the statement on freezer use? Whereas among UK participants 82% agreed that using the freezer to preserve food longer would help to waste less food at home, only 39% of Danish participants agreed. Do Danish participants use the freezer already in a more optimal way than consumers in the UK or are they simply not aware of the benefit of freezing products close to the expiry date?

Unfortunately, the survey does not provide any evidence on these underlying important questions. These aspects should definitely be assessed in future research on preventing food waste at the household level

since it is not clear to which extent households already use some of these strategies to reduce food waste at home and why there might be such large cross-country differences within the EU.

Even though the results from this survey indicate that most European consumers are aware of their responsibility in terms of food waste prevention it must be kept in mind that awareness and knowledge about the "right" behaviour is only a necessary precondition for achieving behavioural change. Awareness and knowledge might often not be sufficient to induce behavioural change since daily routines such as grocery shopping and eating are deeply internalized and hard to change (e.g., Evans, 2011; Holm et al., 2015). **As discussed above given the relatively low prices of food, consumer preferences for convenience and variety, and the rather high opportunity costs of meal planning and food preparation, FLW prevention might not be considered the most favourable option from a consumer point of view.**

Thus, providing economic incentives for behavioural change and nudging consumers should be seen as necessary complementary actions. In this context, Steg et al. (2014) provide some interesting insights on the role of values, situational factors and goals in pro-environmental behaviour. Based on the so-called goal framing theory three different types of goals can be distinguished: hedonic, gain, and normative goals. Thus, they argue that people engage in pro-environmental behaviour due to hedonic reasons (e.g. it is enjoyable), gain reasons (e.g. it saves money) or for normative reasons (e.g. wasting food is immoral). They add further that many pro-environmental actions involve a trade-off between hedonic and gain goals versus normative goals. This conflict often impedes the adoption of more environmental-friendly behaviour.

Transferred to the case of FLW prevention, consumers also face similar trade-offs. All consumers would most likely agree that wasting food is not the right thing to do. However, wasting less food might have rather high opportunity costs in terms of less convenience or flexibility, thus certain hedonic goals might impede the reduction of FLW. With respect to gain goals the existing literature stresses that consumers would gain from reduced FLW levels in terms of reduced spending on food. Consequently, some studies stressed that awareness and information campaigns should highlight the economic benefits for households by reducing food waste levels (e.g., Stancu et al., 2016). However, at the same time there is evidence that people derive more pleasure from pro-environmental behaviour if it is advertised as morally preferable instead of economically beneficial (e.g., Steg et al., 2014**). Thus, it might be important to use different information and awareness campaigns for different consumer segments accompanied by nudges and economic incentives to foster FLW prevention.**

Several studies are available providing an impact assessment of prevention approaches targeting at the household level.

Rutten et al. (2013) and Britz et al. (2014) analyse the welfare impacts of FLW prevention at household level using scenario analysis.[41] Rutten et al. (2013) model the impacts of reducing food waste at the EU retail and household level and compare the outcomes of this scenario with a scenario in which EU households adopt a healthier diet in terms of reduced animal-based products. They specifically model three different FLW reduction scenarios: 30%, 40% and 50% reduction.

The major findings are the following. First, reducing food waste at the household level would result in annual savings of 92€ per capita (30% reduction), 123€ per capita (40% reduction) and 153 € per capita (50% reduction), respectively. This would equal a relative saving rate (in relation to the total budget spent on food) of 5%, 7% and 9%, respectively. Second, land use for agricultural production would substantially decrease as a result of reduced food waste levels (~30.000 km^2). Third, the overall economy represented by GDP would be nearly unaffected by reducing food waste. Fourth, the impact of reducing food waste in the EU on food security in Sub-Saharan Africa is positive but rather small. Thus, if the policy objective is to increase food security in other regions of the world, other policy measures seem to be more effective and efficient in achieving this goal. Fifth, the healthy diet scenario leads to higher welfare gains than the food waste reduction scenarios, especially with respect to land use. The latter result is of great importance with respect to evaluating which policy actions and measures might be preferred over others in terms of effectiveness and efficiency. The results by Rutten et al. (2013) indicate that fostering a behavioural change among consumers towards healthier eating patterns in terms of lower intake levels of animal-based products will have a larger impact with respect to reducing pressure on land resources than the reduction of current food waste levels.

Overall, the results make clear that there are trade-offs involved when reducing food waste and there will be groups that might benefit and groups that might lose. According to these results, producers of agro-food products will belong to the latter group by being negatively affected if food waste by households is reduced.

Britz et al. (2014) model food waste at two levels, industry and household level. At industry level, the authors assume profit maximizing behaviour meaning that food waste reflects on one hand the existing technology, e.g. the costs of cool chains, and on the other might be the outcome of regulatory restrictions (e.g. certain parts of the carcass cannot be used in production). At household level it is assumed that the current level of waste is the outcome of a "rational" choice at given preferences. According to Britz et al. (2014), this assumption seems to be reasonable given existing knowledge on consumer behaviour towards food waste.[42]

[41] Both studies rely on global computable general equilibrium (CGE) models. Rutten et al. (2013) report results based on the MAGNET (Modular Applied GeNeral Equilibrium Tool) model, whereas Britz et al. (2014) employ a modified version of the RegCgeEU+ model. RegCgeEU+ is a comparative static CGE model that consists of 250 NUTS-II regions in the EU.

[42] They argue that waste is for example linked to storage time and shopping frequency. Thus, in order to reduce storage times or to reduce the impact of storage on quality, household might need to shop more often or to remove parts affecting the quality early and more carefully. Since this is time consuming and maybe inconvenient the decision to

The scenario results show that it is of immense importance to take into account the costs of reducing food waste in determining the final impact on the economy. A very obvious result is that the lower the cost of food waste reduction, the more the economy benefits from it. Thus, the authors conclude that an important pillar for the policies targeting to reduce food waste is reducing its costs. **Another major factor driving the results is the trade-off between the time spent for food preparation and reduction in food waste.** This is a very important result with respect to how to define or calculate costs of FLW prevention. **Several studies argue that awareness and education campaigns targeting at changing consumer behaviour are usually rather inexpensive (e.g., Monier et al., 2010). However, in existing studies opportunity costs consumers might have to face while reducing food waste levels such as for example more time spent for grocery shopping, preparation and cooking, are usually not addressed and taken into account.** Thus, policies to loosen this trade-off such as encouraging technological improvements that would simultaneously save food and time spent in food preparation at the household level and in the food processing industry turns out to be crucial according to the results presented by Britz et al. (2014).

The only *ex post* impact assessments of FLW prevention approaches we are aware of are a study by WRAP (2014) and a study for Denmark evaluating the campaign "brug mere – spild mindre"[43] (Miljøstyrelsen, 2011). Both studies investigate the impact of awareness campaigns.

The impact assessment of the Danish campaign encompassed a quantitative survey of Danish consumers (N=1578) before and after the campaign with respect to awareness levels and 5 qualitative interviews with network partners. The results from the consumer survey indicate that consumer awareness was significantly higher after the campaign than before. Before the campaign 57% of survey participants agreed that food waste is a problem of very high relevance for the Danish society, whereas after the campaign 69% of survey participants agreed to this statement.[44] Besides, survey participants were asked about the priority given to different arguments to reduce food waste such as "it is unethical to waste food in a world where people suffer from hunger" or "food waste has negative climate impacts." The priority given to different arguments

waste a certain amount of food might be fully in line with existing preference structures. This assumption is fully in line with the empirical evidence presented in section 4 showing that other objectives (convenience, variety seeking, being a good food provider, freshness) are considered more important than the objective to reduce food waste.

[43] "Use more – Waste Less" was a nationwide information campaign carried out in Denmark in 2010 and relaunched in 2012. The aim of the campaign was to encourage Danes to reduce their amount of household waste. The campaign had three focus areas: reducing food waste; increasing levels of reuse/repair/share/swap; and reducing waste during Christmas.

[44] In order to conclude that this increase in awareness is due to the campaign we would need to assume that all other influencing factors were constant over time, which is most unlikely. Thus, we can derive that there has been an increasing awareness level among Danish consumers with respect to the importance of food waste, whereas we cannot derive to which extent this increasing awareness is attributable to the campaign itself.

was not significant different after the campaign than before the campaign with the ethical argument ranked first, followed by the climate impact argument.

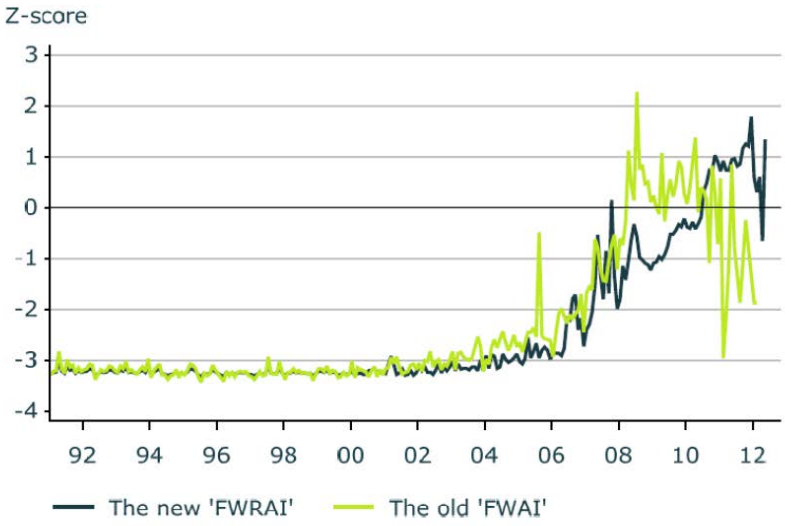
Thus, these results indicate that food waste is foremost considered a moral issue by Danish consumers. Even though these results show an increasing awareness level, unfortunately they do not tell us anything about behavioural changes over time with respect to food waste.

The report for the UK examined the interplay between macroeconomic factors, such as household incomes and food prices, household awareness of food waste and the weight of food purchased and wasted by households (WRAP, 2014). The study was motivated by the fact that WRAP announced a reduction in total household food and drink waste between 2007 and 2011 of 1.1 million tonnes, with an estimated reduction in avoidable food and drink waste by 950,000 tonnes. Thus, an econometric model was proposed and estimated with the aim to decompose this reduction in food waste into contributions from higher food prices, lower relative incomes and an increasing household awareness of food waste (see Box 2 for methodological details).

Box 2: Methodology

For operationalizing the last mentioned variable, household awareness of food waste, a food waste reduction activity index (FWRAI) was calculated based on five components. Thereby, each component is a time series capturing a certain aspect of food waste reduction activity. Three components are derived from responses to WRAP's consumer food waste prevention tracker survey. These are the proportion of respondents who (i) state that they plan household meals for the week ahead, (ii) check what is in the cupboard before shopping, and (iii) make a shopping list. The other two components are the number of monthly unique visitors to www.lovefoodhatewaste.com and the number of articles published each month, either in print or on line, that contain the phrase 'food waste'. The following graphic depicts the development of the FWRAI index over time. This index illustrates nicely the increasing media attention and consumer awareness related to food waste in the UK in recent years. Before 2004 there has been almost no "food waste reduction activity" at all, whereas from 2006 onwards there has been a steep increase. Interestingly, the peak in media attention (the old FWAI) has been in 2008 with decreasing media attention since then.

Figure B1: The development of the food waste awareness index over time



Source: WRAP (2014), p. 4

Note: The old FWAI refers to the food waste awareness indicator used in previous modelling. The FWAI is only based on a single input, the number of times the phrase 'food waste' appeared in news articles captured by the google news service in a given month.

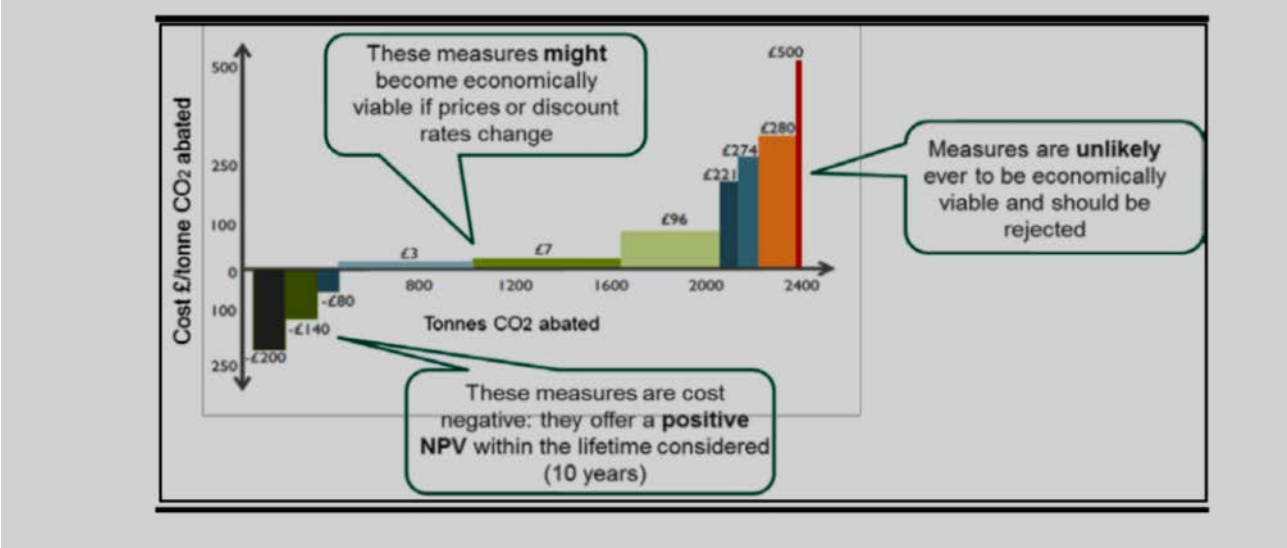
Source: WRAP (2014), Econometric modelling and household food waste. Online available at http://www.wrap.org.uk/sites/files/wrap/Econometrics%20Report.pdf

[45] In case this results is reliable and will hold in other studies the trading up hypothesis actually raises other follow-up questions related to food waste such as for example decreasing consumer demand for lower-quality cuts.

5.3.3 Other impact assessment approaches

Another impact assessment on FLW prevention measures was carried out by DEFRA (2012a) as part of their work to prepare a Waste Prevention Plan for England. They developed a policy tool for the economic analysis of waste prevention measures and selected six waste streams (textiles, construction, food waste, furniture, waste electrical and electronic equipment, and paper & board) for an initial assessment of selected waste prevention measures. **The chosen tool for the economic analysis is the calculation of marginal abatement cost curves (MACCs) which allow ranking graphically the cost effectiveness of different environmental impact reduction measures.** MACCs are widely used in climate change modelling (e.g., FAO, 2012). The marginal abatement cost curve plots the cost of the measures against the cumulative amount saved by the measures. How a MACC can look like is illustrated in figure 7.

Figure 7: Example of a MACC



Source: DEFRA (2012a), p. 4

Each bar in the marginal abatement cost curve represents a different abatement measure whereby the

- **Height of a bar** represents the unit cost of the measure in currency/t waste or CO2 abated. By convention, negative costs are savings and measures are ranked according to their unit costs, with the least costly on the left;
- **Width of a bar** represents the abatement potential available from the measure that is tonnes of waste or CO2. The total width of the MACC shows the total savings available from all measures considered;
- **Area of a bar** represents the total cost of the measure. The total area of the marginal abatement cost curve represents the total cost of all the measures considered.

Such a ranking of prevention approaches has the advantage that it allows to quickly determine which actions offer the greatest financial and environmental benefits. Approaches with a negative marginal abatement cost

have a positive net present value (NPV) when discounted over the lifetime considered, and are therefore associated with both financial and environmental benefits. In contrast, approaches above the x-axis have a negative net present value and therefore have an overall financial cost. These measures are not cost-efficient and the implementation of these measures will most likely be not recommended (DEFRA, 2012).

In the case of FLW prevention modelling these MACCS can provide an indication of the waste prevention potential in total and per each measure; the financial and economic costs and benefits associated with different measures; who bears the costs and who benefits (e.g. private sector, public sector, household, civil society); and which measures have the greatest net benefit (or lowest net cost) per tonne of waste or CO2 equivalent (CO2e) saved, and are therefore most worthy of further consideration. Twelve different FLW prevention measures were assessed in terms of saving potential, costs and benefits. These measures are grouped into three different categories: (i) FLW in the supply chain, (ii) hospitality and food service management and (iii) household food waste. These twelve measures are assumed to address around 16% of the potential FLW savings potential present in the UK. A description of each measure can be found in table 9, whereby a very detailed description of each measure is provided in Annex 4.

Table 9: List of considered FLW prevention measures

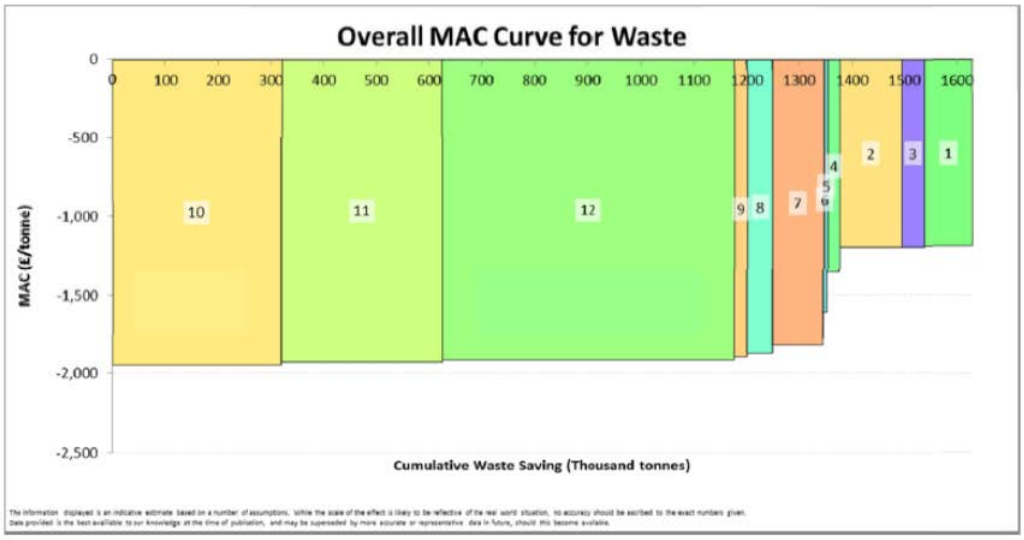
No.	Name	Action
Approaches addressing FLW reduction along the food supply chain		
1	Extend continual improvement in food and drink manufacturing through consultancy support	Continual improvement techniques with manufacturers achieves reduction in FLW by 2.1%
2	Increase waste prevention across supply chains through consultancy support	Systems improvements across F&D supply chains, e.g. through direct consultancy support on procurement processes, achieves a reduction of FLW by 2.8%
3	Increase redistribution of food for human consumption	Increase redistribution of surplus supply chain food to human consumption to 15%, achieves 1% FLW reduction.
4	Increase surplus food and ingredient waste distribution to animal feed	Increase distribution of food and ingredient waste from manufacture and supply chains to animal feed, e.g. through development and dissemination of good practice guidance on distribution requirements, achieves 0.5% FLW reduction
Approaches addressing FLW prevention in the hospitality and food service sector		
5	Reduce food service food waste in distribution through legislative engagement.	Increase staff engagement on reducing food waste in distribution and retail, e.g. through guidance on legislative requirements on labelling and storage, achieves 2% FLW reduction
6	Increase redistribution of surplus food service food to human consumption	Develop good practice guidance on staff training to increase redistribution of surplus food to human consumption by 17.5%, achieving 0.2% overall FLW reduction
7	Reduce food service food waste in stockroom processes and food delivery	Increase staff engagement in stockroom processes and food delivery, e.g. through development and dissemination of good practice guidance on storage and menu planning, achieves 7% FLW reduction
8	Reduce food service food waste through improved procurement practices	Increase staff engagement on procurement and ordering practices, e.g. through development and dissemination of good practice guidance on forecasting and ordering, achieves 3.4% FLW reduction
9	Reduce food service food waste through consumer engagement	Increase consumer engagement on food wastage, e.g. through improved guidance on menu choice and portion size, achieving 1.7% FLW reduction
Approaches addressing food waste prevention at the household level		
10	Reduce household food waste through changes to food products, packaging & labelling	Change food products to make it easier for consumers to waste less, e.g. through development of good practice in packaging, labelling and methods of sale, achieves 6.4% FLW reduction
11	Reduce household food waste through large scale communications campaign	Consumer behaviour change through national communications campaign, e.g. via website, other social media and PR, achieves a reduction of FLW levels by 6%
12	Reduce household food waste through National community engagement & support	Consumer behaviour change through national scale intensive community engagement, achieves a reduction of FLW by 11%

Source: DEFRA (2012b)

The following two figures illustrate the derived results with figure 8 showing the potential waste savings and figure 9 showing the potential carbon savings. The authors stress explicitly that the presented results should be only considered as indicative of the relative order of the potential savings due to significant remaining uncertainties in the underlying data.[46]

[46] According to DEFRA (2012, p. 10), the results should only be reported with the following caveat: "The information displayed is an indicative estimate based on a number of assumptions. While the scale of the effect is likely to be reflective of the real world situation, no accuracy should be ascribed to the numbers given. Data provided is the best available

Figure 8: Overall MACC for FLW prevention measures, waste savings in thousand tonnes



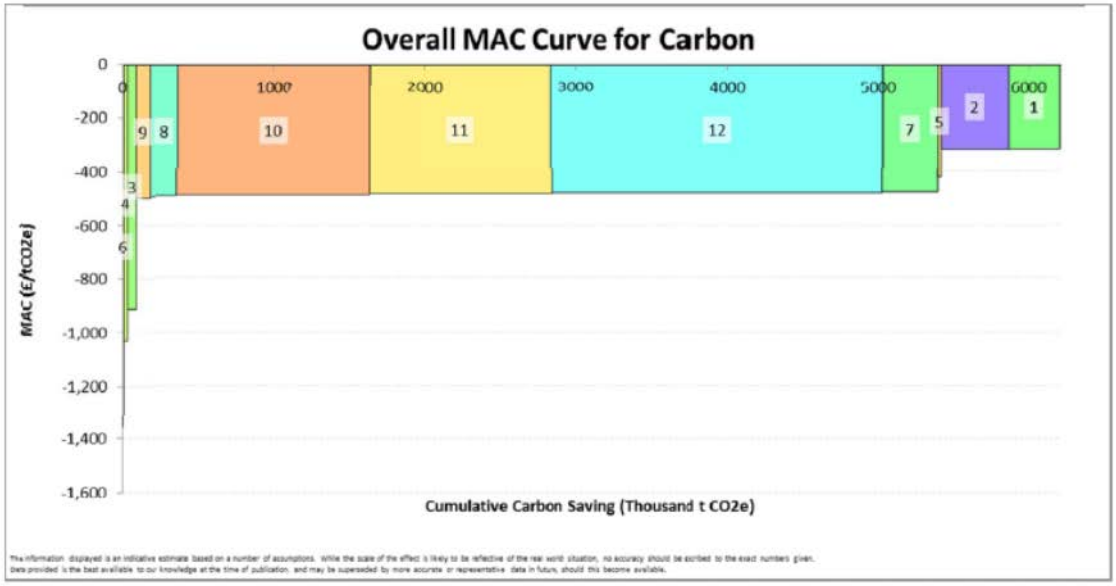
Source: DEFRA (2012b)

As can be seen from figure 8 all actions lie under the x-Axis and thus lead to a positive NPV. Moreover, the results indicate that all actions have rather similar marginal abatement costs ranging between 1,200 and 1,900 £/ ton.

However, in terms of cumulative waste savings three measures, namely 10, 11 and 12 represent 70% of the annual saving potential. As can be seen from table 9 these three measures all target food waste prevention at the household level. The large monetary impact of these approaches is mainly due to the high value of food at the household level. In general preventing food waste at a later stage in the supply chain has a much larger impact both in terms of environmental as well as economic costs than in the early stages of the supply chain due to added value in terms of processing, storage and transportation services.

at the time of publication and may be superseded by more accurate or representative data in future, should this become available**."**

Figure 9: Overall MACC for FLW prevention measures, carbon savings in thousand tonnes CO_2e



Source: DEFRA (2012b)

With respect to the carbon savings potential the results presented in figure 9 indicate significant differences across the different measures. Thereby, the measures can be mainly divided into measures aiming at waste reduction versus measures aiming at waste re-use (i.e. redistribution) with the former ones having much higher carbon savings potential than the latter ones. However, since measures addressing waste reduction are costlier than measures targeting at waste re-use the net present value of measures addressing re-use and redistribution is much higher whereas the total carbon saving potential is much lower.

Put into a broader context, the relative contribution of each waste stream to potential savings in terms of weight, value and carbon were assessed. These results highlight that FLW together with the waste streams construction and textiles offers the greatest potential for savings. In fact, according to these results FLW offers the largest potential for savings in both monetary and environmental terms (DEFRA, 2012).

To sum up, the presented results indicate that all considered FLW prevention actions are more or less equal in terms of cost effectiveness. However, the greatest waste saving potential might be achieved through consumer education as well as changes to food products and packaging. Even though these results provide some first guidance on which actions seems to most promising for further considerations the report explicitly

stresses that these results should be considered as a first step since the MACC approach has several limitations (e.g., limited treatment of uncertainty, no consideration of non-financial costs and benefits) and the model does not include indirect rebound effects and secondary (cascading) impacts[47].

As pointed out above while direct costs to change consumer behaviour might be rather low (information campaigns, education programmes) indirect or perceived costs by the consumer in terms of opportunity costs (e.g., more physical and mental efforts needed for planning and preparing meals) might be rather high. Moreover, as has been stressed in the sociological research on food consumption, food consumption is embedded in a wider system of social organization, social interactions, personal values and norms (e.g, Holm et al., 2015). This means that measures addressing dietary habits including FLW generation and prevention must take this broader context of food consumption into account.

5.4 Conclusions

To sum up, studies modelling economic and environmental impacts of FLW prevention measures are still scarce. Most studies available so far focus on the economic costs and environmental impacts of FLW itself but not on the impacts of FLW prevention. This is mainly due to the complexity of the topic as well as the fact that many prevention approaches have just been established recently. However, impact assessments are of central importance in the discussion about FLW prevention. Thus, there is a clear need for more research on the potential impacts of establishing different FLW prevention measures in terms of economic and environmental costs and benefits.

It is clear that FLW prevention is not a "free lunch scenario" as indirectly assumed by some studies. FLW prevention will involve costs as well as cascading and rebound effects that need to be taken into account to derive meaningful policy recommendations. Especially efficiency considerations are of great importance in this context since policies focusing solely on FLW prevention might be for example not as efficient in reducing pressure on global land use resources as policy measures targeting at healthier diets in terms of reduced meat consumption.

So far the existing evidence indicates that FLW prevention measures in industrialized countries should mainly target at the consumer level (awareness campaigns, education) given the relative large share of FLW generated and the high monetary value of food at this last stage of the supply chain. However, it has also been pointed out that there are several obstacles (relative low costs of food, dietary patterns are embedded in

[47] However, since indirect rebound effects are assumed to impact predominantly on the environmental assessment and secondary impacts are largely related to the redistribution of costs between actors including these aspects is not likely to change the highly aggregated results.

daily life routines, high opportunity costs of grocery shopping and meal preparation) that might hamper that awareness campaigns alone will lead to a substantial reduction in household food waste levels. Unfortunately, we are not aware of any study for Denmark analysing these aspects in more detail.

6 Utilizing FLW as a bio-resource in Denmark

Even though it is clearly stated in the EU Waste Framework Directive (WFD) that all stakeholders should use the so-called food use hierarchy as a guideline for their actions meaning that (food) waste prevention should be the first priority it has also been worked out above that a certain level of FLW might not be avoidable because of technical or economic reasons[48]. Thus, according to the EU WFD and EU Landfill directive, the management of generated FLW shall be increasingly focused on energy and nutrient recovery as opposed to landfilling (Bernstad Saraiva Schott & Cánovas, 2015).

In general, there is a growing body of research addressing FLW management (e.g., Tuck et al., 2012; Lin et al., 2013). These studies investigate especially the so-called 2nd generation waste valorisation techniques in which FLW is regarded as a sustainable resource for diverse sectors of the chemical industry (Lin et al., 2013). In contrast, 1st generation or conventional waste valorisation techniques refer to anaerobic digestion[49] or composting. This research is thus closely related to the increasing focus on building up a bio-based economy and waste-based bio refinery which places emphasis on recovery, recycling and upgrading of waste

Tuck et al. (2012) provide a quantification of the economic value of different waste valorisation strategies as illustrated in the following table. According to these results the valorisation of biomass to bulk chemicals and transportation fuels is economically more efficient than to use it for animal feed or generating electricity. With respect to the current management practices the results show that animal feed is general the most cost effective route for FLW.

Table 10: Approximate value of different biomass waste valorisation strategies

Valorisation strategy	Value ($/t biomass)
Average bulk chemical	1000
Transportation fuel	200-400
Cattle feed	70-200
Generating electricity	60-150
Landfill	-400

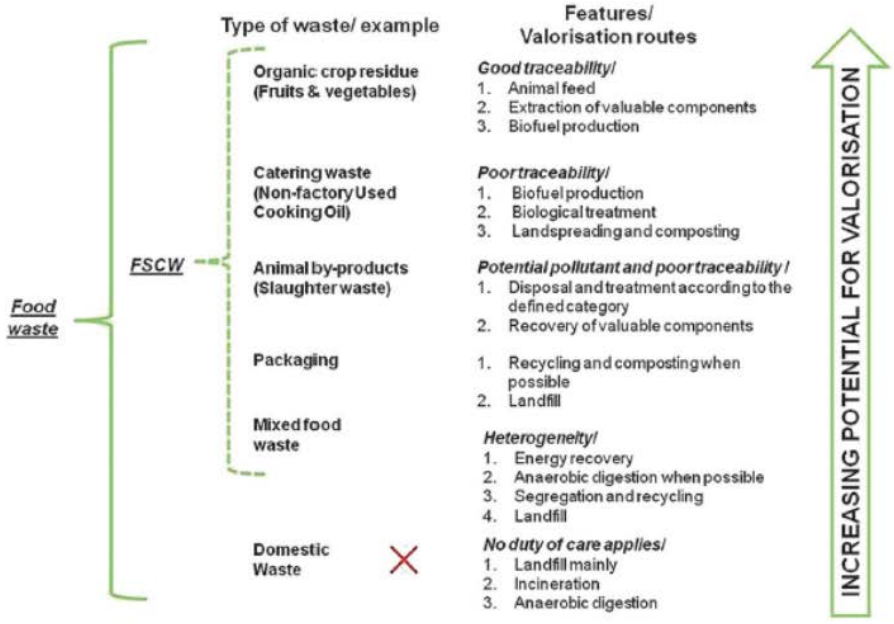
Source: Tuck et al. (2012)

[48] Unavoidable food waste in this context does not only refer to unavoidable in terms of inedible but literally to being unavoidable because of the social and economic circumstances.

[49] Anaerobic digestion is a technology to convert biodegradable organic matter of waste into biogas (Lin et al., 2013).

However, despite this clear picture in terms of economic benefits Lin et al. (2013) point out further that several challenges need to be overcome to be able to foster the valorisation of FLW. Current technological challenges with FLW are for example severe pollution problems due to high associated chemical and biological oxygen demand (COD and BOD); varying pH and chemical composition due to seasonal variations and changes in food processing; materials prone to bacterial contamination, high water content and low calorific value. Besides, there exist several non-technological barriers such as the grey area in distinguishing FLW and by-products (see section 3), strong political drivers for using FLW in anaerobic digestion and strict regulations with respect to animal FLW (Lin et al., 2013). Figure 9 illustrates the different FLW types and their valorisation potentials. Co-products with a high potential for valorisation are vegetable-derived waste due to regulatory and technical reasons (e.g., consistency, traceability, health and safety issues). In contrast, catering waste and animal by-products are highly regulated in the EU limiting their valorisation potential to non-feed/non-pharma applications.[50]

Figure 10: Classification of food waste types and their valorisation potentials



Source: Lin et al. (2013)

A report by the House of Lords European Union Committee (2014) stresses further that even though the food use hierarchy is widely accepted by most stakeholders; existing economic incentives are currently not always in line with this hierarchy. Some existing economic incentives foster the less-preferred alternatives in the

[50] EC Regulation 1774/2002 was introduced in the EU in 2002 and bans the use of catering wastes for use as animal feed.

presented food use hierarchy such as for example energy recovery over redistribution. Stenmarck et al. (2011) report for the Nordic context that in Norway, Finland and Denmark sending mixed waste to incineration is still quite cheap compared to biological treatment and thus the economic invective scheme is favouring incineration over biological treatment.

For Denmark specifically, the report points out that almost no food waste at the retail level is sorted for biological treatment but instead incinerated with energy recovery. There are possibilities for bio energy but this is the exception than the rule. In this regard, it must be noted that the management of municipal solid waste (MSW) in Denmark is characterized by a high degree of incineration in general, amounting to 54% in 2010 (Kjær, 2013). This is the highest percentage and the highest amount per capita in EU-27. With respect to the responsibility for waste there is a difference between recycling and incineration. Waste for recycling is the responsibility of the retail sector, while waste for incineration is the responsibility of the local government, which directs the waste to a specific incineration plant (Stenmarck et al., 2011).

As already mentioned above a special food waste stream is animal food waste. Meat waste is subject to the EU regulation No. 1774/2002 about animal by-products, which is laying down health rules concerning animal by-products not intended for human consumption. Thus, animal food waste needs to be handled in a special way, which complicates sorting, and valorisation. According to Stenmarck et al. (2011), this has been identified as a problem in all Nordic countries and the option of sending food waste to animal food production is less favourable for retailers compared to biological treatment since this would require more work in terms of separating the food waste. However, it is mentioned in this report that some stores separate and sort their food waste and in these cases the food waste is normally used for animal feed. Biological treatment of food waste is only available in a few places and it is only a viable solution if the treatment facility can handle packed food. However, eco-labelling of stores (e.g. Svanen) is pushing towards sorting.

A similar picture is described by CONCITO (2011) stating that in Denmark there seems to be a standstill concerning the utilization of food waste from households and retailers. There are fewer energy advantages by producing biogas compared to incineration but it is more expensive for the cities to collect several waste fractions from the households. Another study from the Danish Ministry of Environment from 2006 concludes that is makes good sense for grocery shops to separate their organic waste for biological treatment since if the waste is treated in a biogas facility the energy production is larger than on an incineration plant – large enough to also cover the energy use of collecting the waste. However, the major problem seems to be that the economic incentive hierarchy favours incineration over biogas. Nevertheless, there are examples that retailers started to send organic waste to biogas plants and that this is economically favourably (see box 1).
A very recent and relevant study in this context is the one by zu Ermgassen et al. (2016) quantifying the land use saving that could be realized when the EU legislation on using catering food waste to feed animals would

be changed[51]. They argue that allowing again the use of catering food waste to feed pigs would substantially reduce the land use impacts of EU pork production. Since pig production is of high importance in Denmark the discussion about re-legalizing the use of catering waste for feeding pigs should be of great relevance.

To sum up, until so far only few initiatives with respect to using FLW as a resource have been implemented in Denmark (see for example box 1, case study Dansk Supermarked Group), and there is still much potential to use FLW more efficiently.

7 Discussion and recommendations

The prevention of food losses and food waste has become a widely debated topic and ranks high on the policy agenda of many countries and international organizations. It is now well acknowledged that food losses and food waste is a multifaceted, interconnected problem across all stages of the supply chain. Moreover, it is multi-sectoral and therefore needs to be addressed by different policy areas (food policy, agricultural policy, waste policy) and at different levels (national, regional, individual).

However, it is also important to highlight that the debate on FLW is part of a broader debate on resource efficiency and environmental impacts of the global food system (e.g. BIO Intelligent Service, 2012b; Garnett, 2014). This means that FLW and the prevention of it should be considered from a system perspective as being one part of the whole food system. Consequently, reducing FLW will also have consequences on the whole system (i.e., supply, demand, price mechanism, vertical linkages). In this context it has been pointed out that currently no consistent resource-efficient thinking in regulation and no integrated policy framework to ensure consistency of policy objectives in relation to the food system as a whole exist (e.g., European Commission, 2014, HLPE, 2014). In fact, currently a large variety of different policy areas and measures have an impact on the food system and thus also on FLW.

Reducing FLW and changing dietary patterns towards less consumption of resource-intensive foods are considered the two major demand-side options to increase resource efficiency and thus reduce the pressure on limited resources (e.g., BIO Intelligent Service, 2012b, Smith et al., 2013; Bajželj et al., 2014). Consequently, increasing attention has been paid in recent years not only to FLW but to the broader concept of sustainable food systems and sustainable diets, i.e. diets that have a low environmental impact while at the same time contributing to food and nutrition security (van Dooren et al., 2014)[52].

[51]

[52] The FAO (2010) defines sustainable diets as “diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources”.

However, even though there is empirical evidence showing that dietary change could play an important role in achieving environmental goals the current available evidence on sustainable diets is not always straightforward and clear-cut (see for current reviews on the topic Auestad & Fulgoni, 2015; Hallström et al., 2015). Contradicting results are, for example, derived depending on the functional unit chosen, i.e. whether greenhouse gas emissions are calculated per weight or per nutritional value. These findings and discussions in the context of sustainable diets are closely related to FLW and the prevention of it. **In the current literature FLW are most often reported in mass. Yet it has been also pointed out that this might not always be very meaningful for deriving policy recommendations (e.g. Koester, 2014)**. Even though fruits & vegetables are most important in terms of wasted mass, their environmental impact is rather low in comparison to meat and cereal products (see section 3.3). **Since economic resources are limited, governmental actions might focus primarily on reducing FLW in food categories with a high environmental impact. According to the existing knowledge this would be meat (specifically beef), cereal products (specifically bread) and several selected fruits and vegetables (e.g., bananas)**.

Such aspects need to be taken into account when discussing about potential prevention approaches. There are for example discussions going on to make it legal to send back overripe fruits and vegetables from retailers to wholesalers to process them into jam or juice; a procedure that is currently not legal (Dittlau, 2015). Even though from a mass perspective this might make sense, from an environmental and economic perspective such a procedure seems not very preferable given the high administrative and logistical costs related to such a procedure.[53]

As was highlighted in section 5 many consumers consider reducing food waste as important foremost due to a moral component. It seems unethical to waste food while other people suffer from hunger. Thus, FLW seems to be perceived differently than other resource-efficiency problems such as for example energy consumption. As Koester et al. (2013) put it: ”Most people would agree that food waste is an ethical issue; in contrast, they may not mind other people using cars with high fuel consumption, which drain limited resources, or spending money on luxury clothes or jewelry. It seems engrained in our mental models that food waste has a negative impact on worldwide hunger. Therefore, it is not a surprise that policy makers in many countries and representatives of international organizations have been discussing this topic intensively in recent years.” This ethical component seems to be relevant for the ease of changing consumer’s behaviour in comparison to other approaches to reduce environmental impacts of the food system. Reducing food losses and waste is considered to be less controversial than changing dietary patterns towards less dairy and meat consumption (Garnett, 2011).

[53] Of course, this does not rule out that there might be circumstances at the local level where such a procedure might be feasible and cost-effective.

Moreover, as Garnett (2014) elaborated taking into account the vision one has about a future food system is important when speaking about FLW prevention. Increasing efficiency by improving technologies and extending boundaries without limiting consumption signals something else than stating clearly that consumption patterns need to change, maybe even substantially.

These aspects were already discussed in a report for the Nordic Council of Ministers on sustainable consumption by Mont et al. (2013). This report aimed at identifying certain misconceptions about sustainable consumption and to derive recommendations, which strategies policy makers might chose to achieve the overall goal of more sustainable consumption patterns. One major message of that report is that one of the most important misconceptions is that technological innovation aiming at production and product efficiency alone will lead to more sustainable consumption patterns. Even though there is no doubt that technological innovations are necessary and important in order to make the food supply chain more efficient such a technocratic approach will be most likely not sufficient to achieve a substantial change towards more sustainable consumption patterns as rebound effects can be rather pronounced[54]. One example could be the point of improved technologies to extend the shelf life of products. This should in theory decrease food waste levels. However, given the fact that this might enable consumers to shop even less frequently, the planning horizon grows larger and might in the end prevent in practice lower food waste levels. Another related aspect is the fact that extending the shelf-life of perishable products such as fruits and vegetables might enable longer distance trade which would be in contrast to the usually recommendations for sustainable food consumption patterns to prefer local, in-season products.

On the other hand, it also seems clear that consumers alone cannot change existing food systems through their individual consumption choices given the complexity of current food systems (e.g., Gjerris et al., 2016). Sustainable food choices are not easy to derive and define and usually always involve trade-offs between different values and objectives. Thus, choice editing (e.g. bans on certain products) and regulatory measures might be needed to induce substantial changes in the existing food system.

Based on these considerations and the existing knowledge we recommend the following policy actions and areas for future research projects:

Policy Recommendations:

- **Setting up a national database on projects & initiatives related to food losses and food waste**

[54] One typical example of rebound effects in this context is the one about cars becoming more and more fuel-efficient over time but at the same time people drive more due to this higher fuel-efficiency (Mont et al., 2013).

There is already quite some evidence available on the topic of FLW in Denmark, especially for the food service, retail and household level. However, there are still a lot of aspects that have not been addressed so far such as FLW at the processing stage or best case studies on integrated supply chain management. Moreover, impact assessments of established prevention approaches are not available at all. **Thus, based on an inventory of studies for Denmark a database on FLW as part of sustainable diets and food chains should be set up in order to foster an exchange of data and knowledge among scholars, practitioners and policymakers alike**.

- **Linking initiatives fostering sustainable food consumption patterns**

  Reducing and preventing food losses and waste is one aspect of achieving more sustainable consumption patterns. **Thus, linkages between ongoing projects focusing on sustainable consumption need to be established.** The development of the New Nordic Diet has already been an important step in giving recommendations with respect to healthy and sustainable eating patterns in Nordic countries (see e.g., Poulsen et al., 2014; Saxe, 2014).

  The New Nordic Diet (NND) was designed by gastronomic, nutritional, and environmental specialists to be a palatable, healthy, and sustainable diet containing 35% less meat than the Average Danish Diet (ADD); more whole-grain products, nuts, fruit, and vegetables; locally grown food in season; and 75% organic produce. The existing evidence indicates that the NND in comparison to the ADD reduces the disease burden from diet-related disease as well as lowers environmental impacts from food consumption.

  However, the NDD is on average more expensive than the ADD, which may on the one hand give the consumers an economic incentive to waste less. On the other hand, higher cost might also discourage consumers from shifting towards NND. Furthermore, there is a lack of evidence whether Danish consumers are really aware of the concept and adopt in their daily eating patterns. The few available studies addressing acceptance and practicability of the NDD in daily life conclude that the practical acceptance is rather low (Micheelsen et al., 2013; Micheelsen et al., 2014).

  Given these facts there is a need for more research on to which extent Danish consumers adopt this concept, how the adoption can be fostered, either by information, regulation, market incentives, or choice editing, and how this would influence food loss and waste.

- **Focus on choice architecture as a means to foster sustainable food consumption patterns including reduced FLW levels**

Even though information and awareness campaigns are necessary and important, choice editing seems to be equally important helping consumers to make the "right" choice. Several examples of possible nudges have been discussed in this report mainly related to food service institutions such as using smaller dinnerware or selling food per weight. These approaches seem worthwhile to promote. However, in general there is not much knowledge available about choice editing and possible impacts at the retail level. **Thus more research is needed how choice editing might help decreasing FLW at all stages of the supply chain.**

- **Home economics and food management must be part of basic education**
  It should be considered to include sustainable consumption and home economics– including efficient utilization of raw materials - as a topic in day care institutions and school curricula (developing material for schools etc.).

- **Focus on the role of food supply chain interrelations for food loss and waste**
  To the extent that food loss and waste is an outcome of market failures, e.g. imperfections in contracts between different stages in the supply chain, changes in these contracts might lead to reduced FLW levels. For example, it was mentioned that if one entity has the economic control of several stages in the supply chain (e.g. transport, wholesale, retail), the extent of FLW within and between these stages is relatively low, because the costs of FLW are fully internalized.

Recommendations for future research:

- **Studies investigating different Danish food supply chains with respect to market imperfections, market power, vertical integration and the link to FLW**

  Sustainability assessment of different supply chains are needed with a special focus on the role of different standards and contractual agreement under different market structures on the extent of FLW. Until so far no study on these aspects is available. However, it has been argued by several scholars that processors and retailers might exercise a certain degree of market power towards farmers leading to FLW since farmers overproduce to make sure they can fulfil the contract and there is no market for the remaining crops. Yet, there are cooperatives and other producer organizations at the farm level, which specifically aim at, improve farmers' bargaining power. One research question to investigate could be whether significant differences in FLW extent across different value chains due to such schemes exist. This would fit also into the general request that more research is needed to investigate the relationship

between increasing product differentiation, vertical integration and market power in modern agricultural markets (Sexton, 2013).

- **Market interventions targeting the consumer level**

  With respect to market interventions targeting at the consumer level the central question is how far to interfere in eating patterns. The current evidence shows that most polices implemented to foster healthy eating are related to information and awareness raising, whereas only few market interventions have been implemented (Capacci et al., 2012). Information campaigns and education programmes are much easier to implement and less controversial than market interventions. However, the impact of information and awareness rising on consumption changes might be rather marginal, especially in the middle- and long-run due to the observation that most consumers revert to established habits. In the Danish context the experience with the fat tax might pose a problem in having a fruitful discussion about future possible interventions in the field of food taxes and subventions. **Given this background more research is needed to investigate which market interventions might be effective and cost-efficient to foster sustainable consumption patterns including reduced FLW levels.**

- **Cross-country comparisons**

  Given the evidence on rather large differences in shelf life of certain product across Nordic countries the question arises whether these differences in shelf-life are actually reflected in FLW differences across countries. Moreover, the available evidence indicates that FLW levels in Finland are substantially lower than in other countries (Katajajuuri et al., 2014). **Thus, future research is needed to address cross-cultural and cross-country differences in FLW levels and the underlying reasons. Are for example FLW levels in Norway significantly lower than in the other Nordic countries due to longer shelf-life of the products? To the best of our knowledge no such studies are available so far.**

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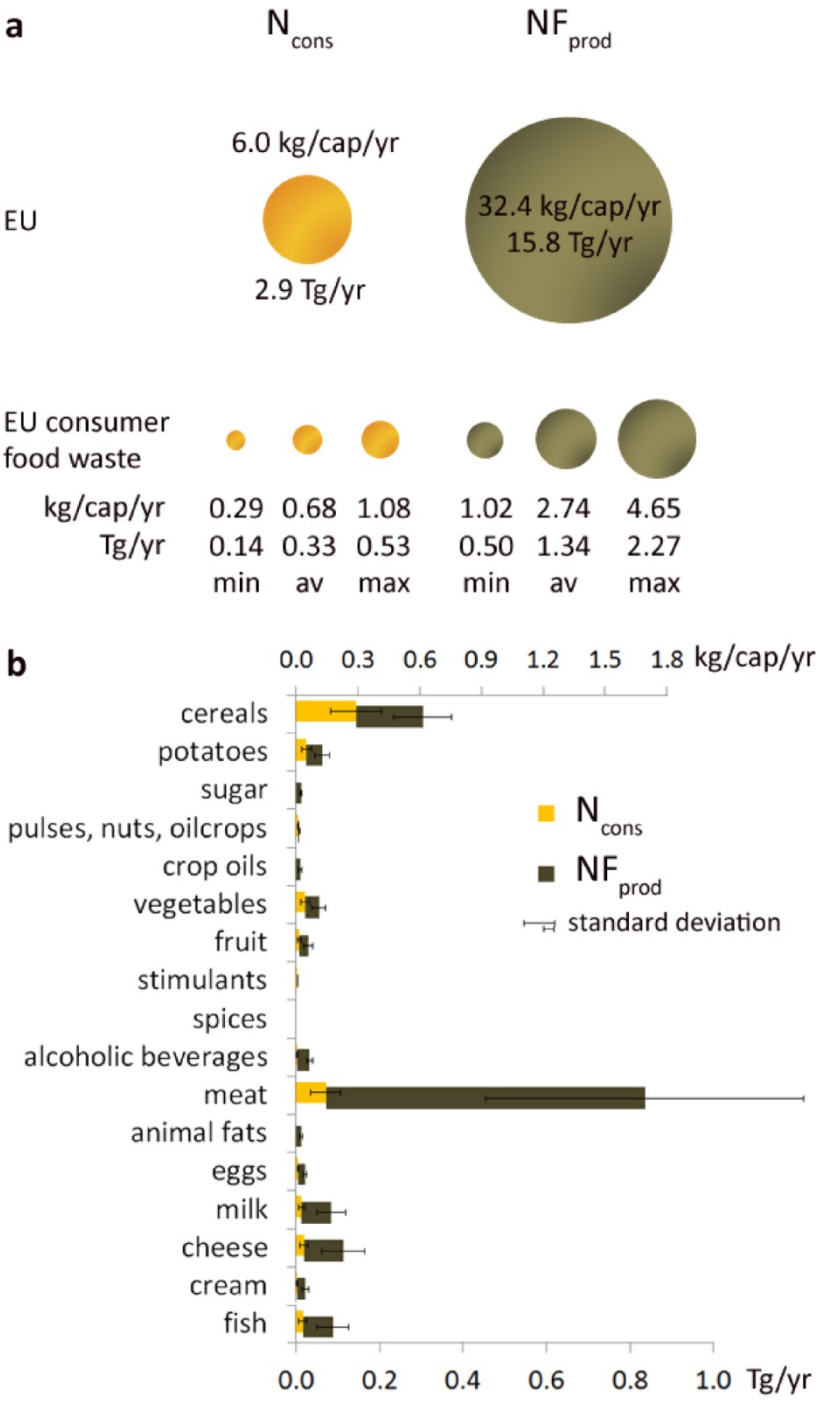
Annex

Annex 1: Nitrogen use related to avoidable food waste in the EU, 1996-2005



Source: Vanham et al. (2015)

Notes: N_{cons} is defined as the nitrogen contained in food and NF_{prod} as the nitrogen used in food production for avoidable food waste. Thus, the N_{cons} quantifies the N-content within a product (based upon the protein content). The NF_{prod} is any nitrogen that has been used in the food chain and has been lost to the environment as emissions of nitrous oxide, nitric oxide, ammonia or molecular nitrogen to the atmosphere, or as nitrate or organic nitrogen to the hydrosphere before the food product is supplied to the consumer

Annex 2: Overview of costs and benefits of the considered policy options to prevent FLW

Options	Costs	Prevention potential	Additional expected benefits
Option 1: EU Food waste reporting requirements	Principle costs linked to research and enforcement required to achieve standardization EU level: 0 to –; MS level: -; Industry level: - to --	0 to +	Possible business prevention effects; enables subsequent strategies possible
Option 2: Date labelling coherence	Principle costs for the industry for potential repacking EU level: - ; MS level: - , Industry level: - to --	+ to ++	Financial savings for households
Option 3: EU target for food waste prevention	Costs fall primarily to MS for implementation of national food waste prevention initiatives to meet targets EU level: - to - - ; MS level: - to - - ; Industry level: - to --	+ to ++	Financial savings for households
Option 4: Requirement on separate collection of food waste	Costs for the EU and for MS will depend upon the level of subsidy and investment. Implementation costs to industry may be followed by profits from separate bio-waste treatment in the longer term EU level: -- to ---; MS level: -- to ---; Industry level: - to +	+	Separates a valuable waste stream from municipal waste
Option 5: Targeted awareness campaigns	Costs are primarily linked with use of various communication mediums EU level: -; MS level: - to –; Industry: 0	+	Financial savings for households, targets behaviour change, potential brand advantage for retailers

Legend: MS- Member state; +++ very high benefit, ++ significant benefit, + moderate benefit, 0- no effect, - moderate costs, -- significant costs, --- very high costs

Source: Monier et al. (2010), p. 157

Annex 3: Scheme of EU quality classes for fruits and vegetables

	Description	Use
Class Extra	Very fine	Fresh consumption
Class I	Fine	Fresh consumption
Class II	Good eating quality but lower requirements regarding external quality	Fresh consumption but sometimes other uses
Unacceptable	Products of non-standard shape or other defects that clearly change their characteristics and/or keeping qualities, and products affected by decay, mould, pests, or that are very dirty	May not be sold for fresh consumption. Products with defects that do not make them unsuitable for consumption may be sold at the grower's own farm, at a supermarket for home processing, to the processing industry, as food or given to charity

Source: Mattsson (2014)

Annex 4: Detailed description of food waste reduction approaches

No.	Name	Action	Detailed description
Approaches addressing food waste reduction along the food supply chain			
1	Extend continual improvement in food and drink manufacturing through consultancy support		Extend continual improvement within F&D manufacture to deepen and widen "lean" improvement techniques within their operations, to identify top opportunities to prevent waste, and to broaden implementation of improvement actions. Cost of action is based on direct consultancy support to 50 sites per year over a 10 years' programme working with both large companies and small and medium enterprises, saving an average of 400 tons per site.
2	Increase waste prevention across supply chains through consultancy support		Increase waste prevention across supply chains through systems improvements, including on procurement processes, effective management of retailer promotions, forecasting and ordering, and effective shelf-life specifications. Cost of action is based on direct consultancy support for 50 organizations per year over a 6 years' programme and dissemination of good practice guidance. Target 80% of industry and say that 30% of the industry change practices.
3	Increase redistribution of food for human consumption		Increase redistribution through action with retailers, manufacturers, charities and Company Shop to develop solutions and good practice guidance to realize potential for redistribution of surplus food within supply chains to human consumption. Cost of action is based on a 2 years' initiative to develop and disseminate good practice guidance
4	Increase surplus food and ingredient waste distribution to animal feed		Increase distribution through action with animal feed companies, manufacturers and retailers. Cost of action based on a two stage programme: Stage one - assess limiting factors and regulations that control what can be fed to animals, and prioritize where there are solutions to increase redistribution. Stage two - to work with the main animal feed companies, the FSA, the BRC, the FDF and CC2 (or similar) signatories to develop and disseminate information that enables manufacturers and retailers to send more waste food to animal feed.
Approaches addressing food waste prevention in the hospitality and food service sector			
5	Reduce food service food waste in distribution through legislative engagement.		Increase staff engagement in legislative requirements on date labelling, food waste regulation, chilled food temperatures etc. Cost of action is based on a 3 years' initiative with sector to develop, disseminate and implement good practice guidance and training and costs of on-going training and reinforcement; posters and information. This will be an area for focus within the Hospitality and Foodservice Agreement
6	Increase redistribution of surplus food service food to human consumption		Action with representative Food service organizations and charities to develop good practice guidance on the opportunities and handling requirements to increase redistribution of surplus food to human consumption. Cost of action is based on 1 year initiative to develop and disseminate good practice guidance and on-going costs to food service companies in managing additional storage requirements.

7	Reduce Food Service food waste in stock-room processes and food delivery	Increase staff engagement in good practice in food purchasing, stockroom processes (e.g. correct fridge temperatures), preparation waste (e.g. keeping skins on vegetables: skin-on potato chips), menu planning (e.g. options for smaller portions) and point of sale engagement with customers - such as helping them understand what they are ordering. This will be an area for focus within the Hospitality and Foodservice Agreement. Cost of action is based on a 3 years' initiative with representative food service organizations to develop and disseminate good practice guidance and costs of on-going training and reinforcement; posters and information; and incentive scheme / waste champion.
8	Reduce food service food waste through improved procurement practices	Increase staff engagement in good practice in food purchasing, including on fit-for-purpose packaging, appropriate purchasing, storage and redistribution both pre-consumer (i.e. food storage and preparation) and post-consumer (i.e. providing meals designed to meet customer expectations). This is based on WRAP evidence (e.g. that portion sizes are not apt for outlets) and includes action to change procurement (packaging as well as food); improve forecasting and careful ordering (e.g. checking stockrooms, matching with patterns of demand); improve forecasting needs and demand, and monitoring of Key Performance Indicators (e.g. weekly waste watch). This will be an area for focus within the Hospitality and Foodservice Agreement. Cost of action is based on a 3 years' initiative with representative food service organizations to develop and disseminate good practice guidance and costs of on-going training on improved procurement practices.
9	Reduce food service food waste through consumer engagement	Increase consumer engagement on food wastage through guidance on menus, ordering appropriate portion sizes, doggy bags, etc. Cost of action is based on work with representative organizations to develop and disseminate consumer messaging. This will be an area for focus within the Hospitality and Foodservice Agreement.
Approaches addressing food waste prevention at the household level		
10	Reduce household food waste through changes to food products, packaging & labelling	Reduce food waste through changes to food products, packaging & labelling, including pack sizes, extended shelf-life, re-closable packs, optimized guidance on storage and freezing, optimized date labels etc. Cost of action assumes a 5 years' programme with retail sector to further develop guidance and case studies to embed good practice within retail sector.
11	Reduce household food waste through large scale communications campaign	Large scale communications campaign could be realized through various combinations of private sector and public sector activities. For example, currently Love Food Hate Waste (LFHW) operates across the UK, also supporting (through the provision of materials and advice) ca 300 local authorities to deliver LFHW locally, whilst Morrisons deliver Great Taste Less Waste across the UK, and the Co-operative use LFHW materials in all of its UK stores. Communication is directly to consumers through website, other social media and PR.
12	Reduce household food waste through National community engagement & support	Intensive engagement with householders and retail customers through community group classes, events, in store activity etc. Could also be associated with communications around roll-out and use of separate food waste collections. These would cover all four nations of the UK (scaled to England). Action delivery could be realized

	through various combinations of private sector and public sector activities, including the current LFHW model.

Source: DEFRA (2012a)