Technology options for feeding 10 billion people

Options for Cutting Food Waste

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Study
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Abstract

The reduction of food waste is seen as an important lever for achieving global food security, freeing up finite resources for other uses, diminishing environmental risks and avoiding financial losses. In its roadmap for a resource efficient Europe the European Commission has set the target to halve the generation of food waste by 2020.

The present study deals with approaches for preventing food waste based on a thorough analysis of the scale, reasons and pattern of food wastage in EU-27. The focus is on measures and instruments that are considered in literature or in the current debate as particularly useful, easy to implement and/or that have already proven their effectiveness in practice. This includes among others the improvement and harmonization of the data basis, the setting of reduction targets on national and regional level, the revision of existing regulations on food date labelling, the enforcement of awareness campaigns, the introduction of economic incentives, the improvement of workflows as well as the implementation of an integrated supply chain management in the manufacturing and wholesale/retail sector including technological innovations which are likely to reduce food waste.
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<th>Description</th>
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<tbody>
<tr>
<td>ALARA</td>
<td>As Low As Reasonably Achievable</td>
</tr>
<tr>
<td>BCFN</td>
<td>Barilla Center for Food &amp; Nutrition</td>
</tr>
<tr>
<td>BIOIS</td>
<td>BIO Intelligence Service</td>
</tr>
<tr>
<td>BMBF</td>
<td>Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research, Germany)</td>
</tr>
<tr>
<td>BMELV</td>
<td>Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (Federal Ministry of Food, Agriculture and Consumer Protection, Germany)</td>
</tr>
<tr>
<td>BOGOF</td>
<td>Buy One Get one Free</td>
</tr>
<tr>
<td>BVE</td>
<td>Bundesvereinigung der Deutschen Ernährungsindustrie (Federal Association of the German Food Industry)</td>
</tr>
<tr>
<td>BVL</td>
<td>Bundesverband des Deutschen Lebensmittelhandels (Federal Association of the German retail)</td>
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<tr>
<td>CCP</td>
<td>Critical Control Points</td>
</tr>
<tr>
<td>CHP</td>
<td>Combined Heat and Power</td>
</tr>
<tr>
<td>DAFNE</td>
<td>Data Food Networking</td>
</tr>
<tr>
<td>DFKI</td>
<td>Deutsches Forschungszentrum für Künstliche Intelligenz (German Research Center for Artificial Intelligence)</td>
</tr>
<tr>
<td>dlv</td>
<td>Deutscher LandFrauenverband (German Rural Women's Association)</td>
</tr>
<tr>
<td>EA-17</td>
<td>Euro Area</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission/European Community</td>
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<tr>
<td>EEC</td>
<td>European Economic Community</td>
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<tr>
<td>EFSA</td>
<td>European Food Safety Authority</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>EUROSTAT</td>
<td>Statistical Office of the European Union</td>
</tr>
<tr>
<td>EU-12</td>
<td>1 November 1993 - 31 December 1994: Belgium, Greece, Luxembourg, Denmark, Spain, Netherlands, Germany, France, Portugal, Ireland, Italy, United Kingdom</td>
</tr>
<tr>
<td>EU-15</td>
<td>1 January 1995 - 30 April 2004: EU-12 + Austria, Finland, Sweden</td>
</tr>
<tr>
<td>EU-25</td>
<td>1 May 2004 - 31 December 2006: EU-15 + Poland, Czech Republic, Cyprus, Latvia, Lithuania, Slovenia, Estonia, Slovakia, Hungary, Malta</td>
</tr>
<tr>
<td>EU-27</td>
<td>from 1 January 2007: EU-25 + Romania, Bulgaria</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organisation of the United Nations</td>
</tr>
<tr>
<td>FUSIONS</td>
<td>Food Use for Social Innovation by Optimising Waste Prevention Strategies</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>HACCP</td>
<td>Hazard Analysis and Critical Control Points</td>
</tr>
<tr>
<td>IMECHE</td>
<td>Institute of Mechanical Engineers</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>---------</td>
<td>-------------</td>
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<tr>
<td>IRL</td>
<td>Innovative Retail Laboratory</td>
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<tr>
<td>ITAS</td>
<td>Institute for Technology Assessment and Systems Analysis</td>
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<tr>
<td>LZ</td>
<td>Landwirtschaftliche Zeitung Rheinland (Agricultural Magazine Rhineland)</td>
</tr>
<tr>
<td>MRL</td>
<td>Maximum Residue Level</td>
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<tr>
<td>NGO</td>
<td>Non-Governmental Organisation</td>
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<tr>
<td>PAYT</td>
<td>Pay-as-you-throw</td>
</tr>
<tr>
<td>PCB</td>
<td>Polychlorinated Biphenyls</td>
</tr>
<tr>
<td>SIK</td>
<td>Swedish Institute for Food and Biotechnology</td>
</tr>
<tr>
<td>STOA</td>
<td>Science and Technology Options Assessment for the European Parliament</td>
</tr>
<tr>
<td>SRU</td>
<td>German Advisory Council on the Environment</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organisation</td>
</tr>
<tr>
<td>USA/US</td>
<td>United States of America</td>
</tr>
<tr>
<td>VZ NRW</td>
<td>Verbraucherzentrale Nordrhein-Westfalen (Consumer Advice Centre North Rhine-Westphalia)</td>
</tr>
<tr>
<td>WRAP</td>
<td>Waste &amp; Resources Action Programme</td>
</tr>
<tr>
<td>WWF</td>
<td>World Wide Fund For Nature</td>
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**Abbreviations**

- e.g.: exempli gratia (example given)
- et seqq.: et sequens (and the following one or ones)
- ibid.: ibidem (at the same place)

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<table>
<thead>
<tr>
<th>Symbol</th>
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<tbody>
<tr>
<td>CO₂-eq</td>
<td>CO₂-equivalent</td>
</tr>
<tr>
<td>€</td>
<td>Euro (European currency)</td>
</tr>
<tr>
<td>£</td>
<td>Pound (British currency)</td>
</tr>
<tr>
<td>kg</td>
<td>kilograms</td>
</tr>
<tr>
<td>kg/capita/a</td>
<td>kilograms per capita and year</td>
</tr>
<tr>
<td>l/kg</td>
<td>litres per kilogram</td>
</tr>
<tr>
<td>m²</td>
<td>square metre</td>
</tr>
<tr>
<td>m³</td>
<td>cubic metre</td>
</tr>
<tr>
<td>t/a</td>
<td>tons per year</td>
</tr>
<tr>
<td>TJ</td>
<td>Terajoule</td>
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EXECUTIVE SUMMARY

Up to now, there has been no commonly accepted definition of the terms ‘food loss’ and ‘food waste’, neither in European and national legal frameworks nor in the scientific literature. The available studies are mostly working with their own definitions narrowed down to their field of investigation. Based on other pertinent studies (BCFN 2012; Teitscheid & Ritter 2011; Waarts et al. 2011; Parfitt et al. 2010) we suggest a distinction between ‘food loss’ and ‘food waste’. ‘Food loss’ is understood to be the amount of food, which has been produced for human consumption, but gets out of the supply chain for different reasons. ‘Food waste’ is a subset of ‘food loss’ and represents the amount of food, still suitable for consumption that is discarded as a result of human action or inaction. We also use the term ‘food waste’ if unconsumed groceries, originally intended for human nutrition, are brought to a non-food utilisation (such as production of fodder, bioenergy or compost). Products that can no longer be sold, but are recovered for human consumption (such as further processing of unsold bakery products into breadcrumbs) are seen to be neither ‘food loss’ nor ‘food waste’.

At the European level, quite a large number of studies on food waste generation have been carried out. National surveys are available for Great Britain, the Netherlands, Denmark, Sweden, Finland and Norway, France, Italy, Portugal, Austria, Germany and Switzerland. Research activities as well as political initiatives mainly originate from Western, Central and Northern Europe, with only a few from Southern European countries. Some Southern and most of the Eastern European countries are scarcely represented in the current debate. Studies on food waste have been published by a variety of different institutions. These include universities, research institutions, NGOs, industrial companies, national ministries, international and European organisations. It should be noted that the findings of different studies, even if they are dealing with the same subject, can hardly be compared due to different assumptions regarding the definition of the terms ‘food loss’ and ‘food waste’, system boundaries, design and scope of investigation as well as methods used for data collection and analysis.

Although the assessment of global losses along the food chain is fraught with considerable uncertainties, there is no doubt that these losses are substantial. The Food and Agriculture Organisation of the United Nations (FAO) estimates that roughly one third of food produced for human nutrition gets lost or wasted globally. This amounts to approximately 1.3 billion tons per year (Gustavsson et al. 2011). Lundqvist et al. (2008) estimate that the global saving potential is approximately 50% along the entire food supply chain. Based on EUROSTAT-data from 2006, updated by the results of various national studies and extrapolations, the Bio Intelligence Service (BIOIS) estimates the amount of food waste across EU-27 to be around 89 million tons, corresponding to 181 kg per capita and year on average (Monier et al. 2010). According to the BIOIS-study there are significant differences in the generation of food waste per capita and year between Member States, ranging from 72 kg in Slovenia, 76 kg in Malta and Romania, 80 kg in Greece, 81 kg in the Czech Republic, 132 kg in Portugal, 135 kg in Spain, 136 kg in France, 146 kg in Denmark, 149 kg in Germany, 179 kg in Italy, 209 kg in Austria, 212 kg in Sweden, 216 kg in Ireland, 236 kg in the United Kingdom, 247 kg in Poland, 265 kg in Estonia, 327 kg in Cyprus, 345 kg in Belgium and up to 541 kg in the Netherlands.

In order to subject the findings of the BIOIS-study to a plausibility check, ITAS carried out own calculations based on the methodology provided by the Swedish Institute for Food and Biotechnology (SIK) using the ‘food balance sheets’ of the FAO (Gustavsson et al. 2013). The results of these model calculations lead to the conclusion that the amount of food waste generated in the Netherlands, Belgium, Cyprus, Estonia and Poland may be overestimated by the BIOIS-study, while food waste in other countries, mainly in Slovenia, Malta, Romania and Greece may be underestimated. However, it should be noted that there are also many obstacles which limit the liability of our own results. Thus, more detailed research is strongly needed to gauge the generation of food waste along the food chain more robustly.
Food losses can occur at every stage of the food supply chain. At the level of agricultural production, losses arise due to poor weather conditions, market prices that do not justify the expenses of harvesting and sorting out due to rigorous quality standards. In food manufacturing and processing, losses occur during washing, peeling, slicing and boiling, through process interruptions or when products are rejected as unsuitable. In distribution (wholesale and retail), losses emerge due to errors in packaging and labelling, non-compliance with food safety requirements, exceeding of expiry dates, inadequate stock management, marketing strategies or logistical constraints. At the stage of final consumption, losses arise due to consumer behaviour, poor purchasing planning, confusion about expiry dates, inadequate storage, cooking of oversized meals and lack of knowledge how to reuse leftovers (BCFN 2012; Möller et al. 2012; Gustavsson et al. 2011; Parfitt et al. 2010). On a per capita basis, much more food is wasted by households in industrialised countries than in developing ones. The FAO estimates that the per capita food waste by consumers in Europe and North America is 95-115 kg/year, while this figure in Sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year (Gustavsson et al. 2011).

Given the fact that over one billion people suffer from malnutrition, wasting food is particularly an ethical issue. Although, the question how consumer behaviour in industrialised countries does affect hunger and rural poverty in developing countries is a contentious issue, it can be assumed that the careless handling of food in rich countries will increase the worldwide demand for food. A globally growing demand will result in higher prices on the world market, which will further weaken the purchasing power of poor people in developing countries. The United Nations mid-range projection for global population growth suggests that the world population will reach 9.3 billion by 2050 (UN 2011). This will be accompanied by a significant shift away from a predominance of grain-based diets towards substantial consumption of animal-derived products, as nations become more affluent (The Government Office of Science 2011). Rising population levels combined with shifting dietary preferences will exert increasing pressure on the global food supply.

Wasting food means losing not only life-supporting nutrition but also scarce resources like land, water and energy that were expended in the production, processing and distribution of food. The production of animal-derived products requires considerably more resources than the production of grain-based food. Complementary to the saving of resources an efficient handling of food would reduce agricultural emissions. According to Monier et al. (2010) the food wastage in Europe is responsible for the release of at least 170 million tons of CO₂-eq which is broadly 1.9 tons of CO₂-eq per ton food waste. Pursuant to the consistent findings of various studies fruit, vegetables and bakery products constitute the greatest percentage of food waste. But, the largest consumption of resources and the highest greenhouse gas emissions per kg are caused by meat products, of which beef products are the most important (Göbel et al. 2012; Venkat 2011; Lee et al. 2010; Fritsche & Eberle 2007).

In addition to negative environmental impacts food wastage causes significant monetary losses, both for the individual consumer as well as for the national economy. Analogous to the ecological impacts, economic losses accumulate along the supply chain, so that one ton of food waste in the household (i.e. at the last stage of the chain) involves much higher environmental and economic costs than one ton of food waste in the agricultural sector. Buzby & Hyman (2012) estimated that in 2008 food waste at consumer level in the United States amounted to 124 kg per capita and year at an estimated retail price of $390 per year. This is roughly 10% of the average expenditure on food per consumer in 2008 and more than 1% of the average disposable income.

All things considered, the reduction of food losses is seen as an important starting point for achieving global food security, freeing up finite resources for other uses, diminishing environmental risks and avoiding financial losses (IMECHE 2013; Grethe et al. 2011; Gustavsson et al. 2011; The Government Office of Science 2011). The implementation of prevention measures to combat food losses, however, requires an understanding of the scale and pattern of wastage.
Recent studies, including our own model calculations, consistently come to the conclusion that one of the largest savings potential in Europe is at household level. Therefore food waste generation on household level is considered more in detail in this report. The report looks into avoidable and unavoidable shares of household food waste and its composition, dietary patterns across EU-27 as well as impacts of the economic situation on household consumption. Furthermore, the results of a survey on food waste generation in households, carried out jointly by the European Commission's Joint Research Centre in Ispra, the University of Bologna and the Karlsruhe Institute of Technology, are presented. Although households represent a relevant source for food waste generation, it is important to take the whole food supply chain into account when considering amounts, causes and prevention measures.

In the current national and international debate there has been submitted, and partially already implemented, a wide range of approaches to reduce food waste. These approaches can be grouped in persuasive, cooperative, regulatory, economic, organisational and technical measures. The present study gives an overview of measures and instruments under discussion, taking into account the experiences already gained in different countries. The focus is on instruments that are considered in literature or in the current debate as particularly useful, easy to implement and able to achieve long-term gains and/or that have already proven their effectiveness in practice. The measures are organised following the stages of the food supply chain.

However, some approaches cut across multiple stages of the food supply chain and therefore cannot be assigned to a certain stage. Among these cross-cutting strategies the following ones were identified as most relevant: Setting mandatory targets for food waste reduction, improving the existing data basis and establishing a systematic monitoring to measure progress, promoting an integrated food supply chain management, using economic incentives in order to stimulate food waste prevention as well as encouraging food redistribution.

For the individual stages most promising approaches were compiled, reaching from a review of the EU-legislation on contamination of food, an amendment of European marketing standards and the promoting of direct marketing systems in the agricultural sector; improving workflows and extending shelf life by means of active packaging in the manufacturing sector; monitoring during distribution, streamlining food date labelling and adapting packaging sizes and special offers in the distribution, wholesale and retail sector; amendment of the food hygiene regime, management guidelines for the hospitality sector and adaption of portion sizes to customers’ real needs in the hospitality sector up to awareness campaigns, early childhood education, economic incentives and sharing networks for surplus food in the household sector.

Based on the discussion of possible approaches to reduce food waste, recommendations for action on European and national level were developed. These options for action are focused on the most relevant issues and address the authorities responsible for the implementation of the proposed measures, especially the European legislator and the national governments. The recommendations are presented in a short version in the following chapter ‘Options Brief’.
OPTIONS BRIEF

The reduction of food waste is seen as an important starting point for achieving global food security, freeing up finite resources for other uses, diminishing environmental risks and avoiding financial losses. In its roadmap for a resource efficient Europe the European Commission has set the target to halve the generation of food waste by 2020. The aim of the present study is to discuss approaches for preventing food waste, based on a thorough analysis of the scale, reasons and pattern of food wastage in EU-27. The focus is on measures and instruments that are considered in literature or in the current debate as particularly useful, easy to implement and/or that have already proven their effectiveness in practice. The following options that have emerged from this discussion are considered urgent to reach the goal set by the European Commission. They address European as well as national governments responsible for their implementation.

Option 1: Target Setting

Under the Waste Framework Directive of the EU, Member States are obliged to develop waste prevention plans by 2013. As part of these plans Member States should set mandatory reduction targets for food waste. Regional and local authorities should break down the national targets to their area of influence. For gauging progress and evaluating the effectiveness of different measures, a regular monitoring of food waste along the entire food chain should be established in all EU-27 States. Individual sectors like manufacturing, retail and hospitality should agree to voluntary commitments on food waste reduction.

Option 2: Improvement of the Data Basis

All available studies revealed the lack of reliable data as main barrier to the development and implementation of measures to reduce food waste. To overcome this obstacle, an agreed and binding definition of the term ‘food waste’, which differentiates between avoidable and unavoidable food waste (referring to the non-edible parts of raw products) and by-products, should be provided within the EUROSTAT-framework. Furthermore, the methods used by the Member States for the collection and calculation of data on food waste generation should be standardised. In order to facilitate monitoring, the separate collection of food waste generated at all stages of the food supply chain should be introduced, whether voluntarily or mandatory.

Option 3: Reviewing EU Legislation on Food Safety

The societal objective of preventing risks to consumers’ life and health, which is anchored in various EU regulations, may come into conflict with the ambition of avoiding food waste. Strict norms for contamination, Maximum Residual Levels for pesticides and veterinarian medicines in food as well as hygienic rules concerning the packaging and storage of food must be seen as significant drivers promoting the discarding of edible food. Thus, the current regime of food safety regulations should be reviewed in order to identify provisions that are not mandatory to protect human life, but lead to unnecessary food waste. Further research is required to decide where limits may be revised without running a risk for food safety.

Option 4: Amendment of European Marketing Standards

Given the fact that the repealing of specific marketing standards in 2009 did not reach the desired objectives - reducing food waste and increasing consumers’ choice - the European legislator should consider to abandon the current system entirely. Critics demand the setting of another type of standard not related to the external appearance of a product, but to its quality for human consumption in terms of taste, natural purity, nutrition value and growing conditions. How this new system should
look like, raises a number of difficult questions that should be solved in close cooperation with producers, retailers, civil society organisations and scientific experts.

**Option 5: Opening of Alternative Marketing Channels for Agricultural Products**

To facilitate the marketing of fruit and vegetables that do not meet the European marketing standards alternative marketing strategies should be stimulated. Circumventing the middlemen in the food supply by direct marketing systems in form of e.g. farmers’ markets, producer co-operatives, solidarity purchasing groups and Community Supported Agriculture can contribute significantly to the prevention of food waste in the primary production. They establish a closer link between producers and consumers, shorten transport distances and make consumers aware of the fragile conditions of food production and its natural and seasonal limits. Further research is needed to assess the pros and cons of these approaches in some more detail, including possible rebound effects.

**Option 6: Streamlining Food Data Labelling**

Consumer surveys in various Member States have shown that there exists considerable confusion among consumers on food date labelling and the differences between ‘best-before’ and ‘use-by’ dates. Thus, the European legislator should consider to revise existing regulations on food date labelling in order to improve the visual presentation of expiration dates. In addition, the setting of new best-before dates according to true shelf life of products and the abolition of expiration dates for stable foods should be considered. Information campaigns on labelling should be initiated by national governments and retailers. The retail sector in cooperation with the food industry should think about the abolition of additional labels like ‘display-until’ and the introduction of price reductions for products close to the expiry date.

**Option 7: Improving Workflows and Supply Chain Management**

Improving workflows in the food industry is an important approach for a sparing use of raw materials. Manufacturers should use production equipment according to the latest state of technology that should be regularly inspected. Residuals should be monitored and fallen out goods should be reintegrated in the production process. Production should be arranged in a way that containers have to be minimally cleaned and mixing of ingredients starts as late as possible. Food companies should aim at increasing coordination with retailers to come up with an agreement on the range of products and required amounts. Governments should support these efforts by establishing special advising programmes. The aim should be an integrated Supply Chain Management.

**Option 8: Awareness Campaigns**

All available studies agree on the fact that information and education are crucial measures to influence consumers’ behaviour. Awareness campaigns aim to draw consumers’ attention to the issue of food wastage and to increase their respect for food. They instruct consumers to a more efficient handling of food by providing information and tips on shopping, shelf life, storage, preparation and recovery. National governments should initiate such campaigns, tailored to different target groups, in close cooperation with retailers and the hospitality sector, using various media. Consumer education has to start at infancy; thus, all Member State should include the topic of sparing and careful handling of food into school curricula.

**Option 9: Combating Food Waste in the Hospitality Sector**

The adaption of portion sizes to costumers’ real needs would be a simple, but effective approach to reduce food waste in the hospitality sector. There are several ways to implement this requirement, e.g. offering a choice of portion sizes to graded prices or replacing ‘all you can eat’-buffets by ‘pay by weight’-systems. Restaurants and other food service providers should have the opportunity to test
different options for a certain period of time. If it turns out that they do not use voluntarily any of the available possibilities, national legislators should consider the introduction of a statutory obligation to do so. Besides the adaption of portion sizes to consumers’ real needs, an improvement of the internal routines for purchasing, storing and freezing, the training of staff, a careful menu planning and the collection and documentation of food waste data are crucial for reducing food waste in the hospitality sector.

Option 10: Economic Incentives

There is broad agreement that undervaluing of food arises from its low market value. Against this background, many experts consider economic instruments as particularly promising to recuperate consumers’ esteem of food. The EU Member States should review their tax regulations, mainly the Value Added Tax (VAT) Regulation, in order to remove all incentives that may encourage the generation of food waste. It should be considered to eliminate the reduced VAT-rate on food or to introduce different VAT-rates according to the environmental impacts of food items. Any social hardships, caused by tax harmonisation, should be offset by targeted governmental income support, which could be financed from additional tax revenue. As an alternative to the taxation of food consumption also the taxation of food wastage may be suitable.

Option 11: Taxes and Fees on Waste Treatment

Taxes and fees on waste treatment like landfill or incineration taxes can be seen as an economic incentive to stimulate waste prevention as they escalate the total costs of waste handling. When using taxes on waste treatment as a tool to prevent food waste, certain requirements have to be met. Firstly, a mandatory separate collection of food waste, both in households and in commercial enterprises (mainly in the retail and hospitality sector) should be introduced. Secondly, the tax rate must be high enough to create a sufficiently strong incentive for waste minimisation. Thirdly, the existing regulations to promote and subsidise the use of renewable energies in Europe should be reviewed in order to identify incentives that run contrary to the objective of food waste prevention. It may lead to conflicting incentives, if national legislators on the one hand would impose high taxes for the treatment of food waste and on the other hand subsidise the production of energy from waste.

Option 12: Promotion of Food Redistribution Programmes

Even if all possibilities to combat food waste would be exploited, a certain amount of surplus food would persist. Food redistribution programmes are a proven tool to use this surplus in an efficient way and to the benefit of economically deprived people. It should be checked if the European food law needs an amendment in line with the US American ‘Good Samaritan Act’ in order to limit the liability of donors and charity organisations that redistribute surplus food. Without any amendment to European food law, they may be driven to discard non-marketable goods in order to avoid liability. It should be further assessed if financial incentives are required to stimulate the further development of the European food bank system.

Option 13: Sharing Networks for Surplus Food

Giving away surplus food free of charge to people who have use for it is a reasonable approach to save food from disposal and to make it available for human nutrition also on private level. The goal of consumer-aided networks is not only to provide the infrastructure for food sharing, but also to inform consumers about the right handling of food. National governments should consider to facilitate the further development of private food sharing initiatives by providing financial support and smoothing bureaucratic obstacles. Research projects accompanying the work of food sharing-networks should be initiated in order to measure and improve their effectiveness.
Option 14: Assessment of the Technological Developments

For the different stages of the food chain technological innovations aiming at the reduction of food waste are available. While intelligent ordering systems for retail and RFID-technology collecting data during distribution, are widely used today, various innovations like intelligent labels on packaging, intelligent refrigerators, intelligent supermarket trolleys or intelligent waste bins are highly new technologies. Even if these technologies promise improvements and comfort at the same time, it is not sure if they will really contribute to a reduction of food waste. As all these technological innovations are still in their infancy, there is considerable need for accompanying research and a careful weighing up of the pros and cons. Thus, European as well as national governments should initiate research programmes for evaluating the different technologies, taking into account country-specific conditions. This should also include pilot studies in which the devices are experimentally tested.
1 INTRODUCTION

The Food and Agriculture Organisation of the United Nations (FAO) estimates that roughly one third of the food produced for human nutrition gets lost or wasted globally, which amounts to approximately 1.3 billion tons per year (Gustavsson et al. 2011). Food is lost or wasted throughout the entire supply chain, from initial agricultural production down to final household consumption. In low-income countries food is lost mostly during the early stages of the supply chain as a result of limited harvesting techniques, inadequate storing and cooling facilities, difficult climate conditions, poor infrastructure, insufficient processing, packaging and marketing systems (FAO 2012; Lang & Rayner 2012). In medium- and high-income countries food loss occurs to a significant extent at the consumption stage and is related to a lack of coordination between different actors in the supply chain as well as to consumer behaviour, insufficient purchasing planning and the fact that people simply can afford to waste food (Grethe et al. 2011). On a per capita basis, much more food is wasted by households in industrialised countries than in developing ones. The FAO estimates that the per capita food waste by consumers in Europe and North America is 95-115 kg/year, while this figure in Sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year (Gustavsson et al. 2011). In its resolution on ‘How to avoid food wastage: strategies for a more efficient food chain in the EU’ the European Parliament points out that by 2020 food waste will increase by 40% unless additional preventive actions or measures are taken (European Parliament 2012).

One reason to stop food waste is the rising demand for food to feed a growing world population. The United Nations mid-range projection for global population growth suggests that the number of people will reach 9.3 billion by 2050 (UN 2011). This will be accompanied by a significant shift away from a predominance of grain-based diets towards substantial consumption of animal-derived products, when nations become more affluent (The Government Office of Science 2011). Rising population combined with shifting dietary preferences will exert increasing pressure on global food supply. According to the results of the food balance projections of the FAO (2009) the agricultural production has to increase by 70% to feed the world in 2050.

There are identifiable and known opportunities to enhance yields in the future but there are also several factors having the potential to obstruct progress: The area available for agriculture will be reduced due to environmental degradation, stresses related to global warming, restrictions imposed by nature conservation and competition with other land use demands such as the production of biomass for fuels, urbanisation and leisure needs. Increased competition for water resources will reduce the quantities available for irrigation to improve crop yields. Energy costs, particularly for fossil fuels, are likely to rise substantially with growing demand and reduced availability of easily exploitable sources. This will increase the energy costs for the production of fertilisers and pesticides (IMECHE 2013). Although solutions to these issues may emerge over time, it would be prudent to develop and implement, in parallel to a focus on increased food production, a range of alternative approaches that can help to mitigate the potential impacts. One of these approaches is to recognise the enormous quantity of food wasted annually and to implement prevention measures to reduce this amount. Other approaches might be the restriction of meat consumption and the development of new concepts for a resource-efficient agriculture, e.g. by shifting the cultivation of crops to urban agglomerations (‘urban farming’) or even to high-rise buildings (‘vertical farming’).

A second reason to fight against food wastage is the fact that over one billion people, mainly in developing countries, where the largest population increases are predicted, suffer from malnutrition. However, the question how consumer behaviour in industrialised countries does affect hunger and rural poverty in developing countries is a contentious issue. It is controversial, if and to what extent the reduction of food losses in rich countries could make a contribution to diminish the number of people suffering from hunger in developing countries. Critics argue that our unused food cannot be made available to the hungry. Thus, a reduction in the share of discarded food by one side will not automatically lead to equivalent supply on the other side. Critics further emphasize that people in
poor countries suffer from hunger because they either do not produce food in sufficient quantity and quality or their purchasing power does not allow buying food. Reducing food waste in rich countries will scarcely modify these two roots of hunger (Koester 2012). Nevertheless, it can be assumed, that the careless handling of food in rich countries will increase the worldwide demand for food. A globally growing demand will result in higher prices at the world market which can further weaken the purchasing power of poor people in developing countries.

A third reason to avoid food losses is that the production of food, regardless of whether it is consumed or wasted, is connected to adverse environmental impacts (Buzby & Hyman 2012). Wasting food means losing not only life-supporting nutrients but also scarce resources like land, water and energy that were expended in the production, processing and distribution of food. These losses will be exacerbated by future population growth combined with changing dietary habits. Due to increasing prosperity in developing countries the per capita caloric intake from meat consumption is assumed to rise by 40% until mid-century (IMECHE 2013). The production of animal-derived products requires considerably more resources than the production of grain-based food. Reducing the current level of food waste offers a significant opportunity for diminishing environmental risks and conserving finite resources that could be utilised for other human activities.

A fourth reason for action is that food wastage causes significant monetary losses, both for the individual consumer as well as for the national economy. Analogous to the ecological impacts, economic losses accumulate along the supply chain, so that one ton of food waste in the household (i.e. at the last stage of the chain) involves much higher environmental and economic costs than one ton of food waste in the manufacturing sector. According to WRAP’s report ‘The Food We Waste’ (Ventour 2008, p.38) households within the UK dispose 6.7 million tons of food waste each year what is nearly one third of all food that is purchased (per weight). The average household throws away around 270 kg of food each year of which 170 kg or 61% could have been avoided. This equates to £590 per year, of which £420 could have been avoided.

Implementing prevention measures to combat food wasting, however, requires an understanding of the scale and pattern of wastage, which will build the first part of the present report. The second part will be devoted to the examination of approaches under discussion to avoid food waste generation along the food supply chain and the formulation of options for action.

The report highlights the range of possible definitions of the terms ‘food loss’ and ‘food waste’ (chapter 2), provides an overview of current research activities and political initiatives (chapter 3) and depicts the reasons of the arising of losses along the food chain (chapter 4). Chapter 5 gives deeper insights in the existing data situation and offers the results of our own calculations based on the methodology of SIK and FAO’s ‘food balance sheets’. Chapter 6 investigates the disposal behaviour of households and discusses the influence of dietary patterns and differences in the share of households’ incomes spent for food within EU-27 on the generation of food waste. In chapter 7 results of a survey on food waste generation in households carried out jointly at the University of Bologna (IT), the Joint Research Centre in Ispra (IT) and the Karlsruhe Institute of Technology (GER) are reported. Chapter 8 deals with adverse environmental and economic impacts of food wastage. In chapter 9 initial conclusions from the information presented in the previous parts are drawn, in order to identify hotspots of food wastage within EU-27. Chapter 10 gives an overview of the measures and instruments under discussion to reduce food waste, following the stages of the food supply chain. Based on the discussion of possible approaches to reduce food waste, options for action on European and national level are presented in chapter 11.
2 APPROACHES TO DEFINE THE TERMS ‘FOOD LOSS’ AND ‘FOOD WASTE’

Up to now, there has been no commonly accepted definition of the terms ‘food loss’ and ‘food waste’, neither in European and national legal frameworks nor in the scientific literature. There are legal definitions of the terms ‘food’ and ‘waste’ in European Directives (for example the definition of ‘food’ under Regulation (EC) No. 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, established by the European Food Safety Authority and laying down procedures in matters of food safety), but these terms appear separately in various contexts and not in the combination of ‘food waste’. The term ‘bio waste’, which is defined in the European Commission’s Green Paper on the Management of Bio Waste (approved 3 December 2008), is too broad and not specific enough to be useful to characterise the phenomenon of ‘food waste’.

Recently, the European Parliament has offered a definition of ‘food waste’ in its ‘Report on how to avoid food wastage: Strategies for a more efficient food chain in the EU’ (European Parliament 2011). This was approved as a resolution of the European Parliament on 19 January 2012. Therein, ‘food waste’ is generally understood “to mean all the foodstuffs discarded from the food supply chain for economic or aesthetic reasons or owing to the nearness of the ‘use-by date’, but which are still perfectly edible and fit for human consumption and, in the absence of any alternative use, are ultimately eliminated and disposed of, generating negative externalities from an environmental point of view, economic costs and a loss of revenue for businesses” (ibid. point 14). But even this definition is neither legally binding nor harmonised. Therefore, the European Parliament has called on the Commission to put forward a legislative proposal defining a typology of ‘food waste’ and to establish a separate definition of ‘food residuals for biofuels’ or ‘biowaste’, which are separated from ordinary food waste since they are reutilised (ibid. point 15). To provide an agreed and binding European definition of the terms ‘food waste’ and ‘food loss’ is also one important aim of the on-going FUSIONS-project. The definition, which is currently under discussion with the project partners, will consider a wide variety of special circumstances and different framework conditions for the production and wastage of food.1

In the current debate different definitions of the terms ‘food loss’ and ‘food waste’ are used. The available studies are working mostly with their own definitions narrowed down to their field of investigation. A first definition of ‘food loss’ was provided by the FAO including “wholesome edible material intended for human consumption, arising at any point in the food supply chain that is instead discarded, lost, degraded or consumed by pests” (FAO 1981). A similarly broad definition offer Gustavsson et al. (2011): “Food losses apply to the decrease of edible food mass for human consumption throughout the supply chain”. The authors emphasize that ‘food loss’ is measured only for products that are directed to human consumption, excluding fodder and parts of products which are not edible. Therefore, food that was originally meant for human consumption, but falls out of the human food chain, is considered to be ‘food loss’, even if it is then directed to a non-food use (e.g. production of fodder, bioenergy or compost). This approach differentiates between ‘planned’ and ‘unplanned’ non-food uses, which are accounted under ‘losses’. Buzby & Hyman (2012) point out that food losses can be qualitative, such as reduced nutrient value and undesirable changes in taste, texture or colour, and quantitative as measured by decreased weight or volume.

In the last decades the food chain has become longer and progressively complex due to market globalisation, higher consumer expectations regarding the variety of choices, increasing migration of population from rural to urban areas and the resultant growing distance between locations of

1 FUSIONS Stakeholder Platform Meeting on May 16, 2013 at the University of Hohenheim
production and consumption. Furthermore, the increasing demand for meat, fruit, vegetables and other easily perishable products enhances the risk of losses (BCFN 2012). Food losses can occur at every stage of the food supply chain. On the level of agricultural production, losses may arise due to bad weather conditions, sorting out due to rigorous quality standards and market prices that do not justify the expenses of harvesting. In food manufacturing and processing, losses may occur during washing, peeling, slicing and boiling, during process interruptions or when products are sorted out as not suitable. In distribution (wholesale and retail), losses may emerge due to packaging defects, non-compliance with food safety requirements, exceeding of expiry dates, inadequate stock management, marketing strategies or logistical constraints. At the stage of final consumption losses may arise due to consumer behaviour, wrong purchase planning, inability of correct interpretation of expiry dates, inadequate storage, cooking of oversized meals and lack of knowledge about how to re-use leftovers (BCFN 2012; Møller et al. 2012; Gustavsson et al. 2011; Parfitt et al. 2010).

In view of the different types and causes of food losses along the supply chain some authors (Teitscheid & Ritter 2011; Waarts et al. 2011; Parfitt et al. 2010) distinguish between ‘food losses’ and ‘food waste’. Following this distinction ‘food losses’ take place at the earlier stages of the food supply chain, during cultivation, harvesting, post-harvest treatment and processing, while losses occurring at the end of the food chain, during retail and final consumption, are referred to as ‘food waste’. Thus, ‘food waste’ is related to human behaviour and is seen as a result of decisions, made by business, governments and individual consumers (Bloom 2010). Other authors (Göbel et al. 2012; Monier et al. 2010; Quested & Johnson 2009) make a further differentiation and distinguish between ‘avoidable’, ‘possibly/partially avoidable’ and ‘unavoidable’ food waste:

- **Avoidable food waste**: products that are still fit for human consumption at the time of discarding or products that would have been edible if they had been eaten in time;
- **Possibly/partially avoidable food waste**: products or ingredients which are not consumed due to consumer preferences (e.g. bread crusts, apple skins), or that can be eaten when food is prepared in one way but not in another (the skin of fried poultry is usually eaten, the skin of boiled poultry normally not). This category also covers leftovers in canteens or restaurants as a mixture of avoidable and unavoidable waste;
- **Unavoidable food waste**: products or ingredients which are not suited for human consumption in accordance with today’s food standards. This encompasses non-edible components (e.g. banana peels, bones, egg shells), as well as products that are so damaged due to weather, diseases or pests, that they cannot be consumed.

The Politecnico di Milano (Garrone et al. 2012) distinguishes between ‘surplus food’ and ‘food waste’. ‘Surplus food’ consists of edible food products that, for various reasons, are not consumed by customers or people for whom they are produced, processed, distributed, purchased or served. In contrast ‘food waste’ represents the part of surplus food that is not recovered for human consumption, for feeding animals, for producing goods or energy. The term ‘food waste’ does not include the emergence and processing of non-edible residues as well as surplus food being placed on secondary markets.

There are also authors like e.g. Møller et al. (2012) who reject the term ‘food waste’ due to the negative connotations of the word ‘waste’ in relation to food. They opt for applying the term ‘food loss’ exclusively, which is understood as “food that is not suitable for full price sale and, therefore, must be sent to various types of waste management”. The handling of food losses can be carried out in different ways, including: sale at a reduced price, donation to social institutions, utilisation as an ingredient or co-product, as animal feed or as a component of animal feed, for the production of biogas, incineration (with energy utilisation) or composting.
SUGGESTED DEFINITION OF THE TERMS ‘FOOD LOSS’ AND ‘FOOD WASTE’

Based on the above mentioned authors, we suggest distinguishing between ‘food loss’ and ‘food waste’.

In our definition food loss is understood as the amount of food, which is produced for human consumption, but gets out of the supply chain for different reasons.

Food waste is a subset of food loss and represents the amount of food, still suitable for consumption, which is discarded as a result of human action or inaction.

This differentiation is made because, especially at the earlier stages of the food chain, residues and sorted out products can be reused in the production process. Thus, not all food losses are getting waste. In cases where it is hard to estimate, whether residues are wasted or further processed and directed to human nutrition, the term ‘food loss’ is used, representing the more neutral term. On the other hand, food that was originally dedicated to human consumption, but is removed from the supply chain, is considered as food waste, even if it is brought to a non-food use. Products that cannot longer be sold, but are recovered for human consumption, thus remaining in the food supply chain, are considered neither food loss nor food waste. An example is the further processing of unsold bakery products into breadcrumbs. We suggest distinguishing between ‘avoidable’ and ‘unavoidable’ food waste, abandoning the category ‘possibly/partially avoidable’ food waste, because the emerging quantities in this category play only a minor role.
3 CURRENT STATE OF RESEARCH

The issue of ‘food loss’ was in the 1970s and 1980s first discussed in an international context. At the first World Food Summit in 1974 the reduction of post-harvest losses was identified as a key element to combat hunger. At that time worldwide losses were estimated at 15%. In 1974 the target was set to halve these losses by 1985. For this purpose, the FAO launched a ‘Special Action Programme for the Prevention of Food Losses’ in 1977. Despite these initial efforts to agree on common goals, the issue quickly disappeared from the political agenda. In the late 1990s international organisations such as FAO took the issue up again and launched various initiatives and forums. As no new data were available, the scientific debate largely referred to data from the 1970s and 1980s. Conclusions on the progress of measures were almost impossible due to a lack of data. Since 2002 activities in this field have increased. In the current debate about food security for future generations the issue is further brought to the fore and is currently subject of both research as well as policy initiatives in many European and non-European countries (Göbel et al. 2012; Grethe et al. 2011).

3.1 Activities at International, European and National Level

In January 2012 the European Parliament adopted the resolution ‘How to avoid food wastage: strategies for a more efficient food chain in the EU’ (European Parliament 2012) in which the Commission is requested to take practical measures in order to halve food waste by 2025. The Commission is further asked to make an analysis of the entire food chain, from farm to fork, in order to identify the sectors where food waste is occurring most. Based on this analysis, specific food waste prevention targets for the Member States should be created as part of the waste prevention targets to be reached by each Member State by 2014 (Waste Framework Directive 2008). Furthermore the resolution asks the Council and the Commission to designate 2014 as the European year against food waste. This action is seen as a key initiative to raise awareness among the European citizens and to stimulate the national governments for more commitment in this field. The European Commission has set the target to halve the disposal of edible food in the EU by 2020 in its ‘Roadmap for a Resource efficient Europe’ (European Commission 2011).

In many countries the discussion on the topic of food waste started among the public and was then picked up by the politics. In Germany, for example, the public debate was encouraged by the TV documentary ‘Fresh on the garbage’ and the film ‘Taste the waste’, which were released by the German film producer Valentin Thurn. The issue was subsequently discussed in various roundtables (e.g. in talk shows) involving different stakeholders like the Consumer Minister Ilse Aigner, representatives of trade organisations and market researchers. During these discussions, it became apparent that there has been hardly any research on food loss in Germany and that it is not known how large the losses are, who causes food waste and under which motivations. In order to answer these questions, the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) commissioned a study (Hafner et al. 2012). At the same time, another study of the University of Applied Sciences Münster (Institute for Sustainable Nutrition and Food Production) has been published. It was prepared in cooperation with the Consumer Advice Centre North Rhine-Westphalia with the aim to identify the main causes of food waste and to develop approaches for its reduction (Göbel et al. 2012).

In industrialised as well as in developing countries there are many organisations, initiatives and research activities that are dedicated to the prevention of food waste or the recuperation of edible food

2 Translated from German, the original title is ‘Frisch auf den Müll’.
3 North Rhine-Westphalia is a federal state of Germany.
products that can no longer be sold. In 2011 the FAO launched the SAVE FOOD initiative, in partnership with Messe Düsseldorf GmbH, which is aimed at bringing industry, policy makers, researchers and other stakeholders together. It encourages dialogue and provides expertise to develop solutions for preventing and minimising food losses and food waste along the food supply chain. In 2012 FAO’s Global Forum on Food Security and Nutrition carried out a survey to identify current research and activities on food loss and food waste at a global level. The survey’s findings indicate that 56% of current research and activities are designed and implemented by and in developing countries; 21% originate from industrialised countries and are implemented in developing countries; 12% are from industrialised countries to industrialised countries; 5% have global coverage; and 7% are undefined (Global Forum on Food Security and Nutrition 2012). The timeframe of the activities aims on the period after 2005 with a focus after 2010. Figure 1 gives an overview of the subjects dealt with in research and activities that were identified in the responses.

![Figure 1: Activities and research on food waste within the FAO’s Global Forum on Food Security and Nutrition survey (2012)](image)

With regard to EU-27 Monier et al. (2010) identified more than 100 European initiatives fighting against food wasting. This includes research projects, awareness campaigns, information tools, training programs, logistical improvements, regulatory instruments, food redistribution programs and the development of industrial uses for food waste.

Currently two EU-projects deal with food waste, on the one hand the Interreg-project ‘Green Cook’ and on the other hand the European FP7-project ‘FUSIONS’ (Food Use for Social Innovation by Optimising Waste Prevention Strategies). In the project ‘Green Cook’ different countries such as France, Britain, the Netherlands, Belgium and Germany work on the topic. The aim of the project is to develop a Northern European model for sustainable food management. This includes the establishment of a uniform definition of the term ‘food waste’ and the development of an evaluation framework for food waste (Green Cook 2012). In the FUSIONS-project 21 institutions from 13 EU-Member States are involved. The project will contribute to a harmonisation of food waste monitoring,
social feasibility of innovative measures for optimised food use in the food chain and the development of guidelines for a common food waste policy in EU-27 (IVL 2012).

The following research institutions are, among many others, very active in the area of food waste, especially on the European level:

- the Wageningen University (NL)
- the Swedish Environmental Research Institute, IVL and the Swedish Institute for Food and Biotechnology, SIK (SE)
- MTT Agrifood Research Finland (FI)
- the Bio Intelligence Service, BIOIS (UK)
- the University of Bologna (IT)
- the University of Natural Resources and Life Sciences, BOKU (AT)
- the Institute for Agricultural Research, INRA (FR)
- the Life Science Center of the University Hohenheim (GER), which also coordinates the network of German-speaking countries to avoid food waste, a consortium of research institutions from Germany, Austria and Switzerland (essens-wert 2012).

In Europe the UK has a leading role by virtue of the program WRAP (Waste & Resources Action Programme), which was established in 2000. The objective of this state-sponsored initiative is to reduce all types of waste in the private and industrial sector. The issue ‘food loss’ plays an important role in WRAP and is on the agenda since several years. The primary objective is to estimate the extent of food losses in the UK, to bring the stakeholders together and to draw the consumers’ attention to that issue by using campaigns such as ‘Love Food Hate Waste’. In the beginning WRAP was focused on food waste from households and the retail sector; in 2011 the assessment has been extended to food waste generated in the hospitality and food service sector (Williams et al. 2011).

3.2 Scientific Studies on European and Global Level

Until now there are a number of national studies and one important pan-European study ‘Preparatory study on food waste across EU-27’ (Monier et al. 2010). The authors assess the extent of food losses for Europe, based on EUROSTAT-data and data from national studies. Besides investigations on the emergence and causes for food wastage along the food chain, there are also studies dealing explicitly with the environmental and economic impacts of food waste. The national studies come mainly from Western, Central and Northern Europe, a few from Southern European countries. Some Southern and most of the Eastern European countries are scarcely represented in the current debate. Several general overview studies from the WWF and FAO (Grethe et al. 2011; Gustavsson et al. 2011) and American studies (Buzby & Hyman 2012; Gunders 2012; Hall et al. 2009) are available as well.

As already pointed out, studies on food waste have been published by a variety of different institutions. These include universities, research institutions, NGOs, industrial companies, national ministries, global and European institutions. Assessments of the emergence and extent of food losses are found primarily in the following studies, of which the two first-mentioned refer to the European level, the following to a variety of different European countries and the last five to the global level (see table 1).
## Table 1: Overview of recent studies on food waste generation on European and global level

<table>
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<th>Country</th>
<th>Study</th>
<th>Aims and main results</th>
<th>Reference</th>
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| pan-European | ‘Preparatory study on food waste across EU-27’ on behalf of the European Commission, Directorate General for the Environment. | The study investigates the extent of food waste in the Member States and summarises the reasons that lead to wastage of food. For the analyses EUROSTAT-data from 2006 and results of national studies have been used.  
On this basis, the study estimates annual food waste generation in EU-27 at approximately 89 million tons, or 179 kg per capita. | Monier et al. 2010          |
| pan-European | Study of the Barilla Center for Food & Nutrition with the collaboration of the University of Bologna and the University of Rome. | Based on EUROSTAT-data from 2010 the per capita food waste in Europe is assessed to be 180 kg per year, varying greatly between the Member States: e.g.  
Greece 44 kg, Bulgaria 87 kg, Germany 126 kg, Portugal 132 kg, France 144 kg, Italy 149 kg, Spain 176 kg, Austria 225 kg, Sweden 227 kg, UK 238 kg, Belgium 399 kg, Netherlands 579 kg. | BCFN 2012                   |
| UK            | Various investigations as part of the British initiative WRAP which pursue the goal to identify waste arisings within the UK food and drink supply chain and opportunities for cost savings, improved resource efficiencies and future interventions. | WRAP estimates total food waste arisings in the UK to be 11.3 million tons per year.                                                                                                                                   | e.g. Lee & Willis 2010;  
Quested & Johnson 2009;  
Ventour 2008; Cox & Downing 2007  |
<table>
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<th>Country</th>
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<th>Aims and main results</th>
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<tr>
<td>Scandinavian countries</td>
<td>Report on a project on prevention of food waste in the retail and wholesale trades in the Nordic countries which was initiated by the Nordic Council of Ministers and its waste prevention group.</td>
<td>The project focuses on the amounts of food waste from the retail and wholesale sector, causes for food waste generation, initiatives to reduce food waste and recommendations for measures that could be implemented in order to improve the waste situation. The results are based on a literature review and interviews with representatives from the retail and wholesale sector in the Nordic countries. Estimating the extent of food waste in the retail sector the study refers to national studies in the Nordic countries: For Denmark the total generation of food waste from the retail sector is estimated to 40,000 to 46,000 tons per year, in Finland 65,000 to 75,000 tons (including retail and wholesale) are wasted per year, in Norway 43,000 tons of food get wasted in the retail sector per year and in the Swedish retail sector 83,500 tons of food were thrown away in 2008. It should be noted that the national studies have emerged in different years (2002, 2008, 2011) and that they are also based on different methods of investigation and evaluation.</td>
<td>Stenmarck et al. 2011</td>
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<tr>
<td>Sweden</td>
<td>SMED-report of the Swedish Environmental Research Institute (IVL) in cooperation with Statistics Sweden which presents data about amounts of food waste throughout the Swedish food chain.</td>
<td>According to this study Sweden generated over one million tons of food waste in 2010; this means around 110 kg food waste per capita and year. On the household level 72 kg are wasted per capita and year. Investigations for a master thesis at the Lund University (Andersson 2012) indicate that 297,000 tons or 35% of the food waste in Sweden would be avoidable.</td>
<td>Jensen et al. 2011</td>
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<td>Norway</td>
<td>Different reports from ForMat, which is a joint project between the food and drink industry, the retail and grocery sectors and the supplying industry in Norway, supported by the Ministry of Food and Agriculture and the Ministry of Environment.</td>
<td>The aim of the ForMat-project is to contribute to a 25%-reduction in avoidable food waste in Norway before the end of 2015. The project deals amongst others with food waste at the food manufacturing industry, the grocery and the retail sector, consumer studies and the development of methods for mapping food loss in the food processing industry.</td>
<td>e.g. Møller et al. 2012; Hanssen &amp; Schakenda 2010</td>
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<td>Country</td>
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<td>Aims and main results</td>
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<td>Finland</td>
<td>Study in frame of the Finnish research project FOODSPILL which is carried out by MTT Agrifood Research Finland and funded by the Finnish Ministry of Agriculture and Forestry and participating companies.</td>
<td>The objective of the project is to study the amount, quality and sources of food waste as well as prevention measures. The project covers the Finnish food chain from food industry to the consumers and food service institutions. Special focus lies on households and food service institutions. In Finland the amount of food waste at household level is studied to be around 120,000 to 160,000 tons per year. At the household level the average amount of avoidable food waste is about 50 to 65 kg per household and year. This quantity represents 4.5% of the average food purchases done by Finnish people.</td>
<td>Katajuuri et al. 2011</td>
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<td>Germany</td>
<td>Study 'Calculation of the quantities of discarded food and suggestions for reducing the disposal rate for food in Germany' carried out by the University of Stuttgart on behalf of the Federal Ministry of Food, Agriculture and Consumer Protection.</td>
<td>The estimation is based on extrapolation of data on waste generation in Germany, other European countries and North America. Various supply balances for Germany and data from the 'National Nutrition Survey' are considered as well. Supplementary surveys and random samplings were carried out. The study suggests that in Germany each year nearly 11 million tons of food get lost along the chain, equivalent to about 134 kg per capita. On the household level the food wasted per capita amounts to 82 kg.</td>
<td>Hafner et al. 2012</td>
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<td>Germany</td>
<td>Study of the University of Applied Sciences Münster in cooperation with the Consumer Advice Centre North Rhine-Westphalia commissioned by the Ministry for Climate Protection, Environment, Agriculture, Nature Conservation and Consumer Protection of North Rhine-Westphalia.</td>
<td>Aim of the study is to identify the main causes of food waste along the food chain and to develop recommendations for action in North Rhine-Westphalia. The investigation includes the identification of causes for food waste within relevant product groups along the food chain, consumer surveys, the collection of data on waste quantities and considerations on the social, economic and environmental impacts of food waste. The study concludes that in North Rhine-Westphalia annually about 2.5 million tons of food get lost as waste, this represents 16% of the state’s primary production.</td>
<td>Göbel et al. 2012</td>
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4 Translated from German, the original title is 'Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfstrate bei Lebensmitteln in Deutschland'.

5 Translated from German, the original title is 'Nationale Verzehrstudie'.
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<th>Country</th>
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<tr>
<td>France</td>
<td>Study of the Ministry of Ecology, Sustainable Development, Transport and Housing and the Ministry of Economy, Finances and Employment which was written on behalf of the Waste prevention Working group in order to get deeper knowledge in terms of food wastage.</td>
<td>The study summarises available research in France and Europe. The authors refer to a study of ADEME from 2007 called ‘MODECOM’ (characterization methods for household waste). This study investigated that in France 79 kg of foodstuffs are lost per capita and year, which corresponds to 4.74 million tons of food waste per year. It has been calculated that the proportion of avoidable food waste is 1.2 million tons.</td>
<td>Viel &amp; Prigent 2011</td>
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<tr>
<td>Austria</td>
<td>Various studies of the University of Natural Resources and Life Sciences, Vienna.</td>
<td>These investigations consider inter alia emergence, causes and monetary value of food waste. Also methodological questions for data collection are considered.</td>
<td>e.g. Lebersorger &amp; Schneider 2011; Bernhofer 2009; Schneider &amp; Lebersorger 2009; Schneider &amp; Scherhaufer 2009; Schneider 2008; Obersteiner &amp; Schneider 2006; Schneider &amp; Wassermann 2004</td>
</tr>
<tr>
<td>Switzerland</td>
<td>WWF-report on food losses in Switzerland, which was published in cooperation with the association ‘foodwaste.ch’.</td>
<td>The report is based on the master theses of Almeida (University Basel) and Beretta (ETH Zurich) which used literature data, results of interviews and empirical inquiries to estimate food losses in Switzerland. They estimated that every year one third of the food produced for Swiss consumption and accordingly 2 million tons of immaculate food is wasted. This represents a loss of 300 kg per capita and year.</td>
<td>WWF 2012</td>
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<tr>
<td>Italy</td>
<td>Preliminary results of an Italian research project on surplus food and food waste which was carried out by Politecnico di Milano and Fondazione per la Sussidiarietà in collaboration with different partners (inter alia Nestlé Italia).</td>
<td>It was assessed that in Italy every year 5.5 million tons of food are disposed of, this amount represents 92.5% of surplus food and 16% of annual consumption in Italy.</td>
<td>Garrone et al. 2011</td>
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<td>Country</td>
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<tr>
<td>Italy</td>
<td>Report edited by the Italian food recovery initiative ‘Last Minute Market’ on food waste in Italy.</td>
<td>Besides making aware of the phenomenon of food wastage and its social, economic and ecological impacts, the objective of the study is the quantification of food losses along the entire food supply chain in Italy with a focus on fruit and vegetables. Based on data provided by ISTAT the authors estimate that 3.3% of Italy’s agricultural harvest remains in the fields, losses in manufacturing amount to 2.6% and distribution accounts for 1.2% of the total production of fruit and vegetables, while in Italian households 17% of fruit and vegetables purchased are discarded.</td>
<td>Segrè &amp; Falasconi 2011</td>
</tr>
<tr>
<td>Portugal</td>
<td>Study by the Centre of Studies and Strategies for Sustainability (CESTRAS) on food losses in Portugal which is based on results of the project PERDA (Projecto de Estudo e Reflexão sobre Desperdício Alimentar).</td>
<td>Data from National Statistics was used to estimate the extent of food wastage along the food chain. Additional data about food waste in households has been collected through an online survey and interviews with families. The study found out that in Portugal 1 million tons of food is wasted every year which represents 17% of Portugal’s total food production. This means that food waste is about 97 kg per capita and year.</td>
<td>Baptista 2012</td>
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<tr>
<td>Spain, Catalonia</td>
<td>Summary of a study carried out by the Agència de Residus de Catalunya (Waste Agency of Catalonia) and the Autonomous University of Barcelona.</td>
<td>The study presents empirical data on food waste generation in Catalonia and gives insight into various initiatives for food waste prevention along the food chain. It was found out that in Catalonia 34.9 kg of food gets wasted per capita and year (referring to losses in retail, restaurants and households).</td>
<td>ARC 2012</td>
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<tr>
<td>USA</td>
<td>Report of the Natural Resources Defense Council (NRDC) on food waste and potential prevention strategies in the United States.</td>
<td>The report summarizes results of various studies and refers also to research in Europe. On the basis of data from the FAO-study (Gustavsson et al. 2011) the author concludes that in the US annually 40% of the production get lost, which represents more than 120 kg per capita and year.</td>
<td>Gunders 2012</td>
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<td>Country</td>
<td>Study</td>
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<td>USA</td>
<td>Study on the economic value of food loss at the retail and consumer levels in the United States.</td>
<td>The authors calculate that in 2008 124 kg of edible food were lost at the consumer level per capita, including both eating at home and eating out.</td>
<td>Buzby &amp; Hyman 2012</td>
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<td>Global</td>
<td>Review article on food waste within food supply chains which summarises worldwide research on food waste and points out future challenges in this field.</td>
<td>The analysis includes an international literature review and interviews with international food supply chain experts. The study found out that there is no consensus on the proportion of global food loss. Ranges between 10 and 50% of total global food production are quoted.</td>
<td>Parfitt et al. 2011</td>
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<tr>
<td>Global</td>
<td>Study of the FAO on food loss, its reasons and possible prevention strategies at the global level.</td>
<td>The study estimates that worldwide one-third or 1.3 billion tons of all food produced for human consumption is lost along the supply chain every year.</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td>Global</td>
<td>Study of the Heinrich Böll Foundation in cooperation with the WWF.</td>
<td>The study aims to provide a better understanding of the methods used and the assumptions made in the FAO world food projections and to discuss other possibilities to face the world food challenges than the intensification of agricultural production. In this context the report also deals with the food loss problematic at the global level und gives an overview of studies already mentioned in this report.</td>
<td>Grethe et al. 2011</td>
</tr>
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<td>Global</td>
<td>Study of the Institution of Mechanical Engineers.</td>
<td>The study gives an overview of food losses in developing and industrialised countries and looks into the resource and environment aspects. The study lists causes for the generation of waste in the food chain and finally puts the focus on necessary changes and recommendations for action. According to the current state of research the study concludes that 30 to 50% (or 1.2 to 2 billion tons) of all food produced never reaches a human stomach.</td>
<td>IMECHE 2013</td>
</tr>
<tr>
<td>Global</td>
<td>Working paper of the World Resources Institute (WRI).</td>
<td>The study gives insight into the definition of the terms ‘food loss’ and ‘food waste’ used in the working paper and the scale of food wastage in developing and industrialised countries. The study focuses on different approaches for cutting down on food waste and gives recommendations for action on global level.</td>
<td>Lipinski et al. 2013</td>
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4 ORIGINS AND REASONS FOR FOOD LOSSES ALONG THE FOOD CHAIN

Food losses can occur throughout the entire food chain, from farm to fork. This chain essentially includes the following steps: production of vegetable and animal-derived groceries, food industry (including processing), distribution, wholesale, retail and consumption. ‘Hotspots’ for the occurrence of food losses are processing companies, wholesalers, supermarkets, large-scale consumers (restaurants, takeaways, catering companies, canteens, schools and hospitals) and especially private households. With regard to the industrialised countries, Göbel et al. (2012) mention seven central causes for the emergence of food losses: (1) definition of process- and market-based standards and quality requirements, (2) legal framework for ensuring food safety, (3) common market practice, (4) human errors, (5) technical faults or (6) logistic errors, as well as (7) cultural influences.

Most of the available studies describe the problem along the food chain. This approach is also adopted in this study, as it enables a clear structuring. Since the losses in agricultural production and the post-harvest phase are examined in study 2 on plant breeding and innovative agriculture, the problem is only briefly touched upon here.

4.1 Losses in Primary Production

In developing countries the losses at the production stage are significantly higher than in industrialised countries, and are mainly the result of inadequate harvesting technology, improper handling of the crop, not appropriate transport, incorrect storage and insufficient infrastructure (Hensel 2009). According to Grethe et al. (2011) the causes of these losses have to be seen mainly in the context of the socio-economic and technological development in developing and emerging countries. As stated by the authors, further factors for the occurrence of food losses in those countries are: lack of knowledge, lack of management skills (especially in the trading sector), insufficient governmental regulation, lack of political attention to the problem, as well as high costs for the development of new methods and technologies for avoiding losses.

Compared to developing and emerging countries, the losses in the area of agricultural production in industrialised countries are relatively low. A possible cause of the occurrence of losses is seen in the orientation of production towards the needs of the market, which can lead to supply exceeding demand. The deliberately accepted over-production in Europe (butter mountains and milk lakes) belongs to the past. Due to the amendment of agricultural subsidies, the economic self-interest of the farmers now precludes over-production. However, in individual cases this may occur, e.g. in contract farming, which has a substantial share in vegetable production in Germany. In 2005, 31% of the German vegetable production was produced through contract farming (BMELV 2012b). In this agreement the farmer undertakes to supply a certain food manufacturer or food trading company with products of defined quality and specification, and in turn profits from a ‘take or pay’ clause when meeting the requirements. Contract farming is being pushed particularly by the processing industry in order to ensure planning reliability in terms of deadlines and quality requirements (Göbel et al. 2012). Contract farmers produce surpluses in order to balance losses resulting from unforeseeable weather events and pest infestation. At the same time they are pressured to meet the demands and special requests of their customers (Gustavsson et al. 2011).

By harvesting the excess quantities produced in agriculture, the food processing industry will also generate over-production, as contractual conditions can require the customer to take the total harvest yield of the contract farmers (Schneider 2008). However, if the products do not meet the agreed requirements, they do not have to be taken. Due to the fact that fresh fruit and vegetables are sensitive products with a short shelf life, returns or breaks in the cold chain can lead to their deterioration or
spoilage. In addition, producers may be bound by contract not to place their goods otherwise on the market without prior consultation (Göbel et al. 2012).

Surpluses in production can also occur outside contract farming due to trading and quality standards. This is described in more detail in section 4.3. It should be noted that farmers and processing companies generally search for alternative marketing channels for their remaining products. Some of the most important uses of e.g. old bakery products are distribution to social institutions, rework (e.g. breadcrumbs), processing into animal feed and use in a biogas plant (Schneider & Scherhaufer 2009). According to the definition used (see chapter 2), the two latter options are considered as waste, because they do not serve the purposes of human nutrition.

Another important aspect in the analysis of food losses are legal framework conditions. The societal objective of preventing risks to consumers’ life and health, which is anchored in various EU regulations and directives, may come into conflict with the ambition of avoiding food waste. A distinction should be made between contamination of food occurring during production, residues of pesticides on crops and residues of veterinarian medicines in foodstuffs of animal origin. For all these types of contamination maximum concentration limits have been set on European level. A study of Wageningen UR (Waarts et al. 2011) identified these statutory limits for food contamination as a significant driver for the generation of food waste in primary production (for more details see section 10.2.1).

There are only few studies dealing with food losses in the marine area. These occur mainly in the form of bycatch thrown back into the sea, most of the marine animals being dead, dying or severely injured. Worldwide losses are estimated to be 8% (Kelleher 2005). According to Kreutzberger & Thurn (2011), discarding rates are highest in European and Japanese waters; 40 to 50% of the fish caught in Europe is bycatch. Surveys from the years 1994 and 2005 suggest that global losses have been substantially reduced: in a study from 1994, the losses amount to 27 million tons, while a study from 2004 indicates a loss of 7.3 million tons (Gustavsson et al. 2011). Given the great differences in fishing techniques worldwide and the continued practice of techniques leading to large losses by some countries, there is considerable potential for improvement in this area.6

4.2 Losses in Processing and Packaging

The problem of over-production partly also exists in the processing industry. Even though there are many production companies that try to avoid high inventory levels by delivering ‘just in time’ (Göbel et al. 2012), surplus production cannot be excluded. As described above, the purchase guarantees in contract farming can result in surplus raw materials that are processed in the food manufacturing industry. On the producer side, strict contract terms can lead to surplus-oriented production, and quality standards required by the costumers can mean that products that do not meet the standards have to be taken back. Extrapolations of data from a bakery chain in Vienna suggest that its 32 branches return a surplus of 38 kg per branch to the headquarters each day (Schneider & Wassermann 2004). The returns amount to almost 12 tons per branch and year, which corresponds to a surplus in bakery products of 17% for the entire bakery chain. Possible reasons for the high returns are deliberate over-production and planning errors. Over-production allows producers greater flexibility (e.g. if additional quantities are ordered within a short time) and thus increased competitiveness. As stated by Göbel et al. (2012) the ordering and delivery system in the bread and bakery sector is still characterised by traditional means of communication, in spite of numerous new technologies. This would imply a high administrative burden with many potential sources of error. These deficits are assumed to apply to many medium-sized processing companies.

6 Priefer & Jörissen (2012), p.16, translated by the authors
Technology options for feeding 10 billion people - Options for Cutting Food Waste

The industry requires specific sizes and standards for the processing of products, which is similar to the requirements of fresh produce. Several selections during the different processing stages result in high waste rates. As in retail, the quality is mainly measured by aesthetical properties, such as size or colour. Vegetables and fruit, frequently sold in packages, are usually selected during processing to achieve package units of uniform size and weight. Sale in packages also leads to losses in retail, because in case of a damaged product it is too expensive to open the package and offer the remaining, saleable goods. Moreover, the individual product cannot be identified, because the cash systems currently do not provide for a code in this case (Göbel et al. 2012).

Food processing leads to residues which still could be used for human nutrition. This includes residues resulting from cutting the products to a specific size and shape, as well as rejected goods that deviate from the standard due to faults in the production process or with damaged packaging. These products are sometimes used in other areas, but usually they are disposed of because this involves less effort or expense (Gustavsson et al. 2011). In the industrial processing of bread and bakery products, losses occur due to the use of a punch technology (e.g. for bread rolls), which are no longer processed in the rework but disposed of (Göbel et al. 2012). The punch scrap could be avoided by shaping the bakery products. According to Lee & Willis (2010) 16% of the raw materials used in food and beverage production in Great Britain are lost during processing. In the production of milk and dairy products, one of the largest food industries in Germany, side-products such as e.g. buttermilk, skimmed milk and whey are produced, which are sold on the market or reintroduced into the production process. In Austria about 5% of the processed milk leaves the manufacturing process and is either disposed of or reutilised (e.g. in pig fodder) (Walter et al. 2008).

Interviews with producers of frozen food showed that goods are left over because of inadequate storage and warehousing, seasonality (Easter, Christmas, barbecue season) or changes in the range of products. In addition, the minimum durability of seasonal goods is usually too low to offer them again in the next season. From the producers‘ perspective, limited storage capacities and high storage costs are also arguments against longer storage periods (Schneider & Wassermann 2004).

Such calculations of costs can also be observed in the meat processing sector, which works under high time and cost pressure. As the personnel costs in this sector are almost identical to the costs of materials, it is not considered to be economic to remove 100% of the meat from the bone; head meat is disposed of with the same argument. Losses during animal transport in Germany are less than 2% (Göbel et al. 2012). However, 2% among 59.3 million pigs slaughtered in Germany in the year 2011 correspond to a loss of 1.2 million individuals. In the case of bovine animals, the loss amounts to 74,000 individuals in 2011 (VDF 2012). The meat industry shows a high level of professionalism in reutilisation. Parts of the residues like fat, skin, joints and tendons are used for fat melting and the production of gelatine. Other uses are the production of animal food and meat-and-bone meal (used as fertiliser or fuel) or the pharmaceutical industry. Meat parts such as tails, paws and certain offal, which are hardly accepted as food in the Western culture, are partly exported (Göbel et al. 2012).

The production of different brands and certain trademarks of a product can also result in losses. Dairy products are represented on the market with a wide range of brands and belong to the perishable food products. Due to different recipes, batch changes are required in the production of the different brands. Thus, a mixed phase is produced in the filling machine, which is usually discarded for reasons of allergen management. Frequent batch changes also lead to increased amounts of cleaning residues (Göbel et al. 2012). In addition, producers of supermarket own brands cannot sell their over-productions elsewhere, which ultimately results in the disposal of the products (Parfitt et al. 2010).

The handling of animal-derived products such as milk, dairy products, meat and sausages is governed by a variety of EU regulations imposing a strict regime of hygiene rules. The EU regulations also stipulate a clear documentation of the food chain, which must be traceable through an identification mark on the packaging (for more details see section 10.5.1). A large part of the meat and sausage products are highly perishable goods due to their microbial sensitivity. Especially the processing of
raw materials requires strict adherence to the cold chain. In supermarkets and discounters, which always offer large quantities and a great variety of raw meat products, the risk of disposal is particularly high due to short turnaround times. Breaks in the cold chain, excesses of temperature and contaminations mostly result in the disposal of goods (Göbel et al. 2012; Waarts et al. 2011).

This problem may occur in meat production, processing and transport but also in retail. The legal provisions are of fundamental importance with regard to food safety. If a risk to human health is assumed, the food is mostly disposed of as a matter of precaution. Many food scandals such as BSE in cattle, dioxin in eggs and EHEC in shoots resulted in a massive destruction of the product group concerned. Such precautionary destructions are effected if contaminations are detected in a certain foodstuff by sampling, but also upon a mere presumption of contamination. In Germany, for example, huge quantities of tomatoes, cucumbers and salad were destroyed on suspicion after a wave of EHEC infections in summer 2012, until shoots from a company in Lower Saxony\(^7\) were finally identified as the cause.

### 4.3 Losses in Distribution, Wholesale and Retail

Before food is placed on the market, it has to be transported and distributed. Losses may occur when transport companies exceed the planned time window for the delivery and unloading of the goods, e.g. due to traffic delays. To avoid a disturbance of the entire delivery process, the unloading is prohibited in this case. The goods become the property of the freight forwarding company in accordance with the contractual arrangements, which is then responsible for their reuse or exploitation. Moreover, losses or damages to goods or packaging may occur during transport because of improper transportation, e.g. sharp braking, speeding, insufficient securing of the palettes, accidents, breaks in the cold chain, but also ice cooling of non-frozen goods. Damage may also occur during the loading or unloading of goods or during stacking. Another problem in logistics is warehousing, where over-storage of goods can have the effect that the date of minimum durability no longer meets the requirements of sale or even that the goods are spoiled (Göbel et al. 2012). The surplus problem especially applies to seasonal products like Christmas and Easter products or barbecue offers in summer. Wrong storage conditions and handling of food also impair the product quality (Stenmarck et al. 2011).

While retailers consider the consumer to be the main contributor to food waste (EHI 2011), there are also voices that emphasize the responsibility of the trading sector, seeing the struggle for profit under strong competition as the main cause of food waste (Kreutzberger & Thurn 2011; Stuart 2009). Criticism relates to the fact that the retailers only indicate the amount of waste incurring on site, while shifting their potential losses to the areas of production and consumption (Monier et al. 2010).

The influence of large retailers on other parts of the food chain is evident, for example, in the acceptance of goods from food processors. As retailers often do not make clear pre-orders, the producers are usually guided by past experience. The processing company must have certain minimum stocks to be able to deliver the desired amounts in case of short-term orders. If the retailer takes a smaller quantity than usual, the rest remains with the producer. For products with short expiry dates, such as dairy products, longer storage times bear the risk that the goods either expire or are no longer accepted by the retailer in case of a new order. Furthermore, contractual provisions allow for the return of goods and order cancellations by retail companies (Göbel et al. 2012; Parfitt et al. 2010).

The trading sector has a strong influence on agricultural production as it determines the quality standards for agricultural products and leaves the rejected goods with the producers. Thus, food gets

\(^7\) Lower Saxony is a federal state of Germany.
lost because the fixed standards in terms of size, shape, colour and appearance of the products require selection.

Although the number of specific European marketing standards for fresh fruit and vegetables was cut back from 36 to 10 in 2009, the trading sector still demands standardised products, because the logistic processes in storage, packaging and distribution cannot handle goods with irregular size and shape. Furthermore, the trading sector has an interest in maintaining the standards, providing an objective yardstick, which facilitates business relationships between producers, manufacturers and retailers. Thus, the original statutory standards are further used by different food companies in form of private norms (for more details see section 10.2.2). Stuart (2009) reports that the British carrot producer M.H. Poskitt Carrots, as main supplier of the supermarket chain Asda, removes 25 to 30% of the carrots with a photographic sensor before they reach the supermarkets. According to Gustavsson et al. (2011), the loss in the production stage of fruit and vegetables in Europe, North America, Oceania and the industrialised part of Asia is very high with about 20%. Roots and tubers like potatoes are particularly affected by losses due to the quality standards demanded by retail companies.

Moreover, these standards lead to over-production among farmers. Although plant breeding enables the use of plants with desired characteristics, farmers cannot exactly predict the proportion of standardised goods in their harvest, not least because of varying environmental conditions. On the other hand, a farmer has to supply the quantity agreed upon in perfect quality to be able to receive the agreed price. The resulting excess of supply leads to reduced market opportunities, and farmers do not receive adequate remuneration for their work. This in turn has the effect that some of the food produced is left in the fields (Schneider 2008). According to Jones (2005), 15% of the orange harvest in Florida is not brought in because the market prices are not profitable for farmers. Parts of the rejected products are reused, e.g. for animal feed and compost production, or are energetically used in fermentation plants (Schneider 2008). But also in that case we speak about ‘food waste’, because the products were originally produced with the intention to serve human nutrition.8

The trading sector itself is confronted with the problems of oversupply. Retailers have to take a variety of products and brands from the producers to be able to get lucrative prices. Moreover, consumers expect a wide range of products and full shelves. This permanent availability of goods is a problem especially with so-called ‘ultra-fresh products’ such as bakery products. Some lease contracts of external bakery stores in food retail include clauses on the availability of products until closing time. Consumers expect bread and pastries to be very fresh and available in great variety. Stenmarck et al. (2011) who interviewed various retail and wholesale operators in the Scandinavian countries found out that there is a surplus production in bakery products of 7% in order to meet the customer’s expectations.

Customers avoid buying food close to the expiry date and consciously search for the freshest goods, because there is no financial incentive to buy older ones. Schneider & Wassermann (2004), who among others studied the amounts of food waste in the retail sector, come to the conclusion that even products with a remaining minimum durability of up to half a year are removed from the usual sales channel due to the complex logistic chains. According to the EHI Retail Institute (2011), special offers and price cuts are daily practice and are well received by consumers. However, test consumers who were commissioned by the Consumer Advice Centre North Rhine-Westphalia to search for price-reduced products close to the minimum durability date in the stores of various supermarket chains could not find any in six out of ten chains. Also, such products would not be advertised, but were usually found in a hidden ‘extra’ corner of the refrigerated counter or in the midst of the normal priced products. The consumer organisation concludes that most enterprises feel uncomfortable about this subject, not least due to the companies’ reluctance to provide information (VZ NRW 2011). On the

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8 Priefer & Jörissen (2012), p.19-20, translated by the authors
other hand sales strategies such as ‘buy one, get one for free’ relieve retailers from products that are possibly available in abundance and entice the consumers to buy food that is not needed.⁹

Although a number of reasons are given for the emergence of food losses in the area of distribution, wholesale and retail, the quantities seem to be comparably low. According to the estimations of BIOIS (Monier et al. 2010), the trading sector only accounts for 5% of the total amount of food waste in the EU. For Germany there is for instance a good agreement between the estimate of BIOIS and the results of a national study (Hafner et al. 2012). While the pan-European study suggests that 6% of total food waste in Germany are caused by retail, the national study calculated a very similar value (5%) for this sector. Nevertheless, estimates differ relative widely also in this area. The EHI Retail Institute (2011), a research, education and consultancy institute for the trading sector, estimates the losses occurring in the 41,000 German food retail stores due to breakage, spoilage or exceeded dates of expiry at only 1.1% (310,000 tons). In interviews with Finnish supermarket operators Stenmarck et al. (2011) found out that only 1 to 2% of total food sale would become food waste.

4.4 Losses in the Hospitality Sector¹⁰

The term ‘hospitality sector’ is used here to cover all activities devoted to the preparation and serving of food outside home. This includes commercial enterprises like hotels, restaurants, cafeterias, pubs and catering services as well as municipal companies like workplace canteens, hospitals, retirement homes, schools and prisons.

A certain amount of food is consumed not at home, but in restaurants, cafeterias, canteens or via catering services. In Sweden about one fifth of the meals are consumed in gastronomic facilities. This share is likely to increase in the future since the younger generation is used to this kind of food supply (e.g. in schools) and eats more often out of home than their parent generation (Engström & Carlson-Kanyama 2004). It must be assumed that the urban population makes more use of gastronomic offers than the country population since the offer is larger and more diverse.

One problem which leads to food losses in gastronomy is the portion size. Standardised sizes do not meet the needs of individuals. Whilst pre-filled plates mainly lead to leftovers of food, consumers eat 92% of the food that they put on their plates themselves (Wansink & Cheney 2005). Engström & Carlson-Kanyama (2004) have observed elementary school cafeterias and two restaurants in the centre of Stockholm for several days, weighed their waste and interviewed the employees. On average the food loss was 20%, whereas the main part (50%) was due to leftovers on the plates. The losses due to storage and preparation of food were relatively low.

Especially in school and hospital catering there are other important factors besides portion size. In schools confined budgets and a lack of motivation of the caterers to produce high quality food lead to the kids not enjoying their meal (Monier et al. 2010). The chosen time for lunch plays an important role as well. An US study has shown that a shift of the breaks to before lunch can reduce food losses in elementary schools by 32% (Bergman et al. 2003). A study conducted in the 1990s comes to similar results (Getlinger et al. 1996). In surveys with pupils Engström & Carlson-Kanyama (2004) found out that many of them do not eat their whole meals because they lack the time to finish them. Because there is no separate break time for playing the pupils eat very fast to make use of the rest of their lunch time in different ways. In hospitals patients have no impact on mealtimes or portion sizes. There is a lack of autonomy, which together with indisposition and a lack of food quality makes the patients eat less than under normal circumstances (Monier et al. 2010).

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⁹ Priefer & Jörissen (2012), p.20, translated by the authors
¹¹ Priefer & Jörissen (2012), p.28-31, translated by the authors
In the gastronomic sector there are logistical issues that foster food losses. The varying numbers of guests are a problem since they make planning and purchasing more difficult. Reservations enable an estimate of the goods needed, but they are unusual in cafeterias for example. If there is a buffet the demand can only be estimated to a certain extent via reservation numbers. Usually more meals are prepared than in the estimates to be able to flexibly react to a sudden increase in guest numbers. This problem especially affects ‘all you can eat-buffets’. Additionally, some clients demand that the supplies are constantly filled till the end and that no meals run out (Monier et al. 2010). Due to hygienic reasons the passing on of remains is only legal if the food has not left the kitchen. Besides hygienic and quality reasons, the re-use of remains is difficult since many operators fix their daily offers beforehand and are thus not very flexible in their menu-design and the use of leftovers (Engström & Carlson-Kanyama 2004). It is also the cooking practices that can lead to food losses in gastronomic facilities. Pre-produced meals, as they are usual in canteens, may not be accepted by the customers. The ‘just in time’ preparation, as often found in restaurants, produces foods closer to the actual demand. However, since food is cooked to the point, meals that were produced too late or in too large quantities cannot be served.

If remains shall be used further or offered again, there need to be enough space for refrigeration. In stressful situations it is often easier to dispose of food than to package and freeze it. In most facilities the food waste is not separately collected and weighed. This leaves the amount of wasted food invisible, i.e. there is no measurement and reflection on the losses that could make the use of goods more efficient. Pre-mixing ingredients in large amounts can increase food losses since mixed products often have a shorter shelf life than separately stored goods. Additionally, the separation of products out of catering sized packages, as it is common for breakfast in hotels, leads to food losses (Monier et al. 2010).

Legal aspects also play an important role in the hospitality sector. The two-hour guarantee on unrefrigerated products (part of the EU food hygiene package) results in waste as caterers have to fulfil a two-hour food safety guarantee after delivery. In addition Waarts et al. (2011) found out that chain parties like caterers, retailers and residual flow processors also create stricter norms (e.g. relating to hygiene rules) for themselves as determined in EU-legislation in order to avoid damage to their reputation and that food is often wasted for reasons of product liability (for more details see section 10.5.1).

4.5 Losses in Private Households

Many studies conclude that the largest part of food waste in industrial countries arise in the area of private consumption (e.g. Grethe et al. 2011; Lee & Willis 2010; Monier et al. 2010; Parfitt et al. 2010). In a Forsa-survey commissioned by the BMELV 58% of the respondents said that they throw away food regularly (LZ 2011). Part of the avoidable waste are usually leftovers (on plates), opened food items (half full, cut open) but also sealed groceries. There are many reasons why consumers discard edible foodstuffs, which shall be looked at more closely in the following:

Planning of the Shopping

Consumers plan their daily shopping poorly and buy beyond their own needs. Spontaneous purchases and purchases made to store goods that are not yet needed are a consequence of this lack of planning. If purchases should be efficient, this needs a detailed planning of shopping and meals that shall be cooked. Lee & Willis (2010) come to the result that in the UK about 64% (5.3 million tons) of food waste in households would be evitable. A recent online survey, investigating the relationship between consumer attitudes, consumer behaviour and actually wasted amounts of food, has shown

Priefer & Jörissen (2012), p.23-28, translated by the authors
that 59% of household food waste in Germany is the result of the wrong planning of shopping and suboptimal storage of food (TheConsumerView 2011). A lack of knowledge about preventive measures (proper shopping, storage, preservation of freshness, efficient usage including use of leftovers) leads to higher amounts of waste.

Preferences

Losses emerge due to personal preferences. The large offer of groceries and convenience products leads consumers to try novel and unknown products. A certain amount of food is disposed of since consumers have bought it for the first time and did not like it (Göbel et al. 2012).

Portion Size, Storage and Preservation of Freshness

Large product units minimise the need for packaging material and the amount of packaging waste, but possibly they cannot be fully consumed whilst the food is still fresh. The offer of individual portion sizes and units that meet the peoples’ needs is still expandable. Furthermore, small portion sizes, e.g. for singles, are much more expensive in comparison to large portions. This leads to large portions being bought instead of the small ones, which would meet the actual needs. Consumers need information for the proper handling of food concerning storage and the preservation of freshness of the goods. Labels and instructions for the proper handling of groceries are, however, not always designed in a clear and standardised manner or are not perceived by the consumer, respectively. Inside households there are different storage conditions concerning climate and temperature. These changes in temperature can have a negative effect on the quality and shelf life of products. As well as proper storage, the proper preservation of groceries can increase their shelf life far beyond their best-before date (through resealable packaging, air tight sealing of cans etc.). Göbel et al. (2012) additionally explain that through the increased consumption of convenience products people loose fundamental skills of cooking and knowledge about food.

Food Date Labelling

Prepackaged food has to be labelled according to the rules of food labelling regulations. An important element is the ‘best-before date’. This shows the date until which the product keeps its specific characteristics under appropriate storage conditions. The best-before date does not show the spoilage of a product, but is a warranty by the producer, who is liable for specific characteristics of the product concerning taste, colour, consistency etc. within the indicated time span. Whether a product is inedible after this date can be easily judged by consumers using their sensorial abilities (look, smell, taste). In contrast, the ‘use-by date’ refers to the ultimate possible consumption of a product. This date is used for highly perishable products (from the microbiological point of view), which can constitute an immediate danger for human health (Article 3, EU Directive 2000/13/EC on labelling, presentation and advertising of foodstuffs).

There is considerable confusion among consumers about the different meaning of the two labels. Many groceries are disposed of before or at their best-before date since consumers think that the date indicates the spoilage of the product. Studies in the UK show that almost 50% of consumers understand the labels ‘best-before’ or ‘use-by’ wrongly. It is estimated that one million tons of food or more than 20% of the avoidable waste in the UK are due to ambiguities concerning food labelling (Lee & Willis 2010). Contrary to this, Göbel et al. (2012) on the basis of a survey among German households found out that consumers know the meaning of the different dates and that the majority check whether a product is still edible or not. Furthermore, the authors highlight that vegetables, fruit and bakery products, which account for the largest amount of losses, often have no best-before date.

Besides these rather everyday causes for food losses, Grethe et al. (2011) identified several socio-economic trends, which promote the waste of food. Amongst these are increasing incomes and related
changes in consumer behaviour, demographic change and urbanisation. These three points will be discussed in the following:

**Increasing Incomes and Changes in Consumer Behaviour**

Several studies reveal that the wastage of food tends to augment with rising prosperity. Even in countries with a low to medium average income the upper classes are living wasteful concerning food (Parfitt et al. 2010). In addition, the world market prices for food constantly decreased over the last century and have only slightly increased since the first decade of the new century. As a consequence the expenses for food represent an ever shrinking part of the family’s spending. While an average household at the beginning of the 20th century had to spend more than half of its disposable income for food, the share is now between less than 10% and up to 20% across EU-27 (for more details see section 6.4). Due to this development, the general appreciation of food has declined.

Consumers are not aware of their wasteful lifestyles since they do not experience any consequences of them. Their consumption behaviour neither leads to a shortage of food, nor to major economic disadvantages for the individual. Austrian research showed that even high quality and flawless products are disposed of. For example, a packet of free range eggs was found in a bin, which was 15 days before its best-before date. Handmade jam and exquisite foods such as caviar or vacuum sealed organic meat purchased at a farm can be found in households’ bins (Obersteiner & Schneider 2006; Schneider 2008). According to scenario calculations by Monier et al. (2010) food losses in the EU will expand due to increasing incomes until 2020. This estimate is based on EUROSTAT-data, which suggest that the income will increase by 5% by 2015 in comparison to 2006. Furthermore, one can find a relationship between increasing incomes and the composition of the food consumed (Grethe et al. 2011). The risk of food waste is influenced by changing consumption patterns in industrialised countries, i.e. the share of ‘luxury’ groceries is growing and there is a diversification of food towards delicate, often imported and easily perishable goods with short shelf life (for more details see section 6.3).

**Demographic Change**

The raising amount of single households in industrialised countries extends the amount of food waste. Single households show higher waste rates per capita than larger households, since they do not have the possibility to share food. Young people produce more food waste than older people, because they are less experienced in the planning and preparation of meals and are not dealing with the problem of food waste. Additionally, young people eat less often at home, which leads to purchased groceries often not been consumed on time and perish (Grethe et al. 2011; Monier et al. 2010; Cox & Downing 2007; Hamilton et al. 2005). Due to favourable social conditions and medical care the population is getting increasingly older. Young people who are already nowadays producing more waste will probably continue with this behaviour into their higher ages. Accordingly, the problem of food waste will likely become worse in the future (Parfitt et al. 2010). The above mentioned scenario calculations by Monier et al. (2010) predict a rise in food waste in the EU by 4.1% from 89.3 to 93 million tons in the year 2020 due to a growing population. In this calculation an increase of the population by 20.6 million people (4.2%) is expected in comparison to 2006, although the authors expect a slight decline in the population in EU-12 and further population growth in EU-15.

**Increasing Employment of Women**

A third trend which has an impact on the handling of food is the increasing employment of women. Multiple burdens due to work and family reduce the time available for shopping and make it more difficult to do daily food shopping. Thus, larger quantities are bought, which have to last a whole week with an increasing probability that certain food items will be disposed of unused. Schneider
(2008) concludes from waste analyses and surveys that persons with a full time job dispose of more food.

Urbanisation

The growth of cities, especially in newly industrialising countries and developing countries, leads to longer supply chains. This includes longer transport distances, longer cold chains and more intermediaries. In the 1990s a typical grocery in the USA was passed on 33 times before it was available in the supermarket (Kantor et al. 1997). The shifting of the trade routes can lead to impairment of the goods and reduced quality, especially for easily perishable food. Furthermore, the behaviour of city dwellers concerning food is significantly different to that of country dwellers. Based on waste analyses, Obersteiner & Schneider (2006) found out that the amount of food in the garbage bin of city dwellers is much higher than in rural areas. Such effects are thinkable for higher income city dwellers in developing and newly industrialising countries as well.

To conclude this chapter, table 2 gives a summary of the main contributory factors for the wastage of food on the different stages of the food chain.

Table 2: Summary of the main contributory factors leading to food being wasted on the different stages of the food chain in industrialised countries

<table>
<thead>
<tr>
<th>Stages</th>
<th>Contributory Factors</th>
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</table>
| Agricultural Production     | ➢ Sorting out of products at farm gate due to rigorous qualitative standards set up by large-scale distributors on weight, size, shape and appearance  
                               ➢ Market prices that do not justify the expense of harvesting  
                               ➢ Overproduction due to supply agreements with retail chains  
                               ➢ Crop damaged during harvesting                                                                 |
| Manufacturing               | ➢ Irregular sized products trimmed to fit or rejected entirely  
                               ➢ Inconsistency of manufacturing processes leading to misshapen products or product damage  
                               ➢ Contamination in production process causing loss of quality  
                               ➢ Food spoilage due to packaging problems  
                               ➢ Surplus production of supermarket’s own brands that cannot be sold elsewhere  
                               ➢ Excess stock due to ‘take-back’ systems and cancellation of orders                                                                 |
| Distribution and Wholesale/Retail | ➢ Lack of cold storage/interruption of the cold chain  
                               ➢ Packaging defects resulting in product damage  
                               ➢ Overstocking due to inaccurate ordering and forecasting demand  
                               ➢ Obligation for retailers to order a wide range of products and brands from the same producer in order to get beneficial prices  
                               ➢ Failure to comply with minimum food safety standards (e.g. microbial contamination, pesticide residues)  
                               ➢ Marketing strategies like ‘buy one get one free’                                                                 |
| Hospitality Industry and Catering | • Oversized dishes  
• Offer of buffets at fixed prices encouraging people to take more than they can eat  
• Separation out of catering sized packages in hotels and catering (e.g. for jams, cereals, juice and milk) or use of individual portion packs that do not meet the customer’s needs  
• Difficulties in assessing the demand (number of customers)  
• EU hygiene rules, e.g. two-hour guarantee on unrefrigerated products |
|---|---|
| Households | • Lack of planning/knowledge concerning food purchase and storage  
• Impulse purchases (buying items that are not currently needed)  
• Purchasing of new products that the consumer then ‘do not like’  
• Inadequate package sizes (e.g. oversized ready to eat meals)  
• Poor storage management (e.g. inadequate wrapping)  
• Confusion about date labels (‘best before’, ‘use by’)  
• Lack of techniques and skills for food preparation  
• Poor experience in planning meals  
• Preparing oversized meals  
• Lack of skills for recombining leftovers into new meals |

Sources: Parfitt et al. (2010); Monier et al. (2010); Gustavsson et al. (2011); BFCN (2012); IMECHE (2013)
5 AVAILABLE DATA AND THEIR LIABILITY

There are mainly two studies dealing with pan-European data on the emergence of food waste: the study carried out by the Bio Intelligence Service (BIOIS) on behalf of the European Commission (Monier et al. 2010) and the study carried out by the Swedish Institute for Food and Biotechnology (SIK) on behalf of FAO (Gustavsson et al. 2011, 2013). Both studies have their strengths and weaknesses. The BIOIS-study examines the generation of food waste at all stages of the food chain, across EU-27, excluding agricultural production, but does not consider different product groups. The SIK-study addresses the generation of food waste at all stages of the food chain, but including agricultural production and broken down to product types. In contrast to the BIOIS-study the SIK-study has a global focus, grouping the world in different regions. The group of medium/high income countries includes besides EU-27 also Russia and other Eastern European countries which are not part of the EU. The SIK-study is based on FAOSTAT-data from 2007, while the BIOIS-study is based on EUROSTAT-data from 2006 and various national sources.

One can doubt the liability of the EUROSTAT-data, mainly used for the estimates of BIOIS (see section 5.1). Against this background, we carried out own calculations based on Gustavsson et al. (2013) to subject the results of the BIOIS-study to a plausibility check (see section 5.2).

5.1 Discussion of BIOIS’ Estimates

Table 3 is based on the BIOIS-results and gives an overview of the total food production and the generation of food waste across EU-27, broken down to different stages of the food chain.

As far as possible, BIOIS used data from national studies because they were generally considered to be more accurate, based on more intensive research and more precise methodologies than the disclosure of animal and vegetal waste under EUROSTAT. The availability of national sources, other than EUROSTAT, is quite different for the individual steps of the food chain. While national research on food waste generated in the manufacturing sector is most scarce (BIOIS identified only one for the UK), there are quite comprehensive data on food waste of households for a variety of countries. For the wholesale/retail and the food services/catering sector data on food waste are also very limited, there are only very few national studies.

EUROSTAT-data are subject to many uncertainties and limitations. To take the manufacturing sector as an example, the figure of animal and vegetal waste provided from EUROSTAT includes both food waste and by-products that are either reused or recycled. Furthermore the amount of waste, particularly for meat products, involves to a considerable extent components like bones, carcasses and organs that are commonly not eaten and thus are not covered by the term ‘food waste’ according to our definition. So it can be assumed that the estimates of BIOIS for this sector are generally too high.

There are at least two European case studies that provide empirical evidence to confirm this assumption. The WRAP-study mentioned above comes to a share of food waste in the manufacturing sector in the UK which is only half as high as the figure supplied by EUROSTAT (2,591,000 t/a compared to 5,142,864 t/a). For the Netherlands EUROSTAT shows one of the highest amounts of food waste generation in the manufacturing sector: 6,412,330 t/a corresponding to 72.5% of total food waste or 393 kg per capita. More recent calculations for the Netherlands as part of the on-going FUSIONS-project revealed that the figure reported by EUROSTAT is a factor 3.5 to 6 higher than the 12. High rates of food waste generated in the manufacturing sector are pointed out by EUROSTAT also for Poland, Estonia, Hungary and Belgium that cannot be explained by technological inefficiencies or the scale of food production industry in those countries. We agree with the judgement of BIOS that

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12 Personal communication by Toine Timmermans, the coordinator of the FUSIONS-project, 26/03/13
“most discrepancies are likely due to a lack of standardisation in definitions and allocation of data, rather than exceptional differences between Member States” (Monier et al. 2010, p.44).

Sectors other than agriculture, manufacturing and households are grouped together by BIOIS as ‘other sectors’. This category is too broad to give clear insight into the remaining sources of the generation of food waste in the EU. These sources mainly involve the wholesale/retail sector and the food services/catering sector. Food waste from business and institutions (schools, municipal authorities etc.) is usually collected and treated together with municipal waste; so much of this may be covered by the household waste stream under EUROSTAT. In order to allow a differentiation between the wholesale/retail and the food services/catering sector, BIOIS used scenarios based on data from national studies.

For the wholesale/retail sector BIOIS identified only four national studies. The annual per capita figures provided for UK, Denmark and Sweden were seen as quite closely comparable, at 6 kg, 8 kg and 12 kg, whereas the Austrian figure was much higher, at 32 kg per capita. To upgrade this discrepancy, an average of 8.89 kg per capita was calculated using the British, Danish and Swedish data, and excluding the Austrian. Applying this average to all Member States lacking national data, BIOIS estimated the food waste in this sector, based on 2006 populations of those nations (Monier et al. 2010, p.57). These estimates do not seem very trustworthy. Firstly, given the fact that all available data for the wholesale/retail sector originate from EU-15 its pertinence for Member States that joined the EU after 2004 is highly disputable. Secondly, the wholesale/retail sector is regarded to generate the smallest portion of food waste according to the estimates of BIOIS (only 5% on average of total food waste). However, this sector represents also the area where empirical data is particularly limited. Regarding the Austrian figure of 32 kg per capita and year, the generation of food waste in the wholesale/retail sector could also be much higher than calculated by BIOIS. Thus, more detailed research is strongly needed to gauge the generation of food waste in this sector more robustly.

National data for the food services/catering sector came from both the EU-15 (available for Austria, France, Germany, Sweden and UK) and the Member States that joined the EU after 2004 (available for Estonia and Slovenia). Considering the manifest trend towards higher food waste in the hospitality and catering sector for EU-15, BIOIS calculated different averages. The EU-15 average (27 kg per capita and year) and the average for Member States that joined the EU after 2004 (12 kg per capita and year) were used to complete data for all countries lacking other evidence, based on the 2006 population.

For the household sector BIOIS used national studies, as far as possible. When no national research was available, EUROSTAT-data was used, unless the per capita quantity was anomalously low. In those cases BIOIS takes instead a plausible minimum of 22 kg of food waste per capita and year (Monier et al. 2010, p.54).

Intermediate Conclusion

For the BIOIS-study a mixture of data was used, compounded of EUROSTAT, national studies and extrapolations by BIOIS (the different colours in table 3 indicate the origin of data). All figures presented by BIOIS have to be considered as approximate estimates representing best available data. Nevertheless, one can doubt whether they reflect the true quantity of food waste generated at the different stages of the food chain correctly. EUROSTAT-data (mainly used for the manufacturing sector) are submitted by individual Member States, but there is no standardised methodology for the collection and processing of data. Extrapolations by BIOIS (mainly used for the wholesale/retail and the food services/catering sector) apply average values that are based on very few national studies.

13 This lowest minimum scenario was calculated according to the share of bio-waste in municipal waste and the estimated percentage of bio-waste that is home-composted.
Moreover, due to this method any existing differences between Member States are blurred. National studies are deemed to be carried out more carefully, providing more robust data; however, definitions and methodologies of calculations vary widely between Member States, restricting the comparability of results.
Table 3: Food waste generation in EU-27 broken down to different stages of the food chain, excluding agricultural production

<table>
<thead>
<tr>
<th></th>
<th>Total Food Production</th>
<th>Total Food Waste (FW)</th>
<th>FW in Manufacturing</th>
<th>FW in Wholesale/Retail</th>
<th>FW in Food Service/Catering</th>
<th>FW in Households</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in tons +</td>
<td>in tons +</td>
<td>in %*</td>
<td>in tons +</td>
<td>in %**</td>
<td>in tons +</td>
</tr>
<tr>
<td>EU-27</td>
<td>766 179 686</td>
<td>89 154 013</td>
<td>11.6</td>
<td>34 755 711</td>
<td>39.0</td>
<td>4 433 331</td>
</tr>
<tr>
<td>Austria</td>
<td>9 914 359</td>
<td>1 725 614</td>
<td>17.4</td>
<td>570 544</td>
<td>33.1</td>
<td>267 000</td>
</tr>
<tr>
<td>Belgium</td>
<td>27 470 839</td>
<td>3 627 171</td>
<td>13.2</td>
<td>2 311 847</td>
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<td>44.4</td>
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<td>732 646</td>
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<td>888 625</td>
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<td>73 081</td>
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<td>98 872</td>
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<td>1 157 419</td>
<td>65.7</td>
<td>89 553</td>
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<td>Food Production</td>
<td>Food Waste</td>
<td>Food Waste Reduction</td>
<td>Food Lost</td>
<td>Food Saved</td>
<td>Food Saved %</td>
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</tr>
<tr>
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<td>910 658</td>
<td>16.9</td>
<td>465 945</td>
<td>37 407</td>
<td>4.1</td>
</tr>
<tr>
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<td>10 496 732</td>
<td>10.8</td>
<td>5 662 838</td>
<td>522 140</td>
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</tr>
<tr>
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<td>252 500</td>
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<td>125 635</td>
<td>20 393</td>
<td>8.1</td>
</tr>
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<td>404 383</td>
<td>10.1</td>
<td>222 205</td>
<td>30 246</td>
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<tr>
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<td>--</td>
<td>2 665</td>
<td>4 169</td>
<td>5.1</td>
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<tr>
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<td>--</td>
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<td>--</td>
<td>271</td>
<td>3 599</td>
<td>11.7</td>
</tr>
<tr>
<td>Netherlands</td>
<td>50 834 267</td>
<td>8 841 308</td>
<td>17.4</td>
<td>6 412 330</td>
<td>145 166</td>
<td>1.6</td>
</tr>
<tr>
<td>Poland</td>
<td>47 233 940</td>
<td>9 412 145</td>
<td>19.9</td>
<td>6 566 060</td>
<td>339 111</td>
<td>3.6</td>
</tr>
<tr>
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<td>1 400 130</td>
<td>11.2</td>
<td>632 395</td>
<td>93 934</td>
<td>6.7</td>
</tr>
<tr>
<td>Romania</td>
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<td>1 635 495</td>
<td>15.1</td>
<td>487 751</td>
<td>192 055</td>
<td>11.7</td>
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<td>347 773</td>
<td>47 895</td>
<td>8.0</td>
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<td>Slovenia</td>
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<td>143 763</td>
<td>12.2</td>
<td>42 072</td>
<td>17 804</td>
<td>12.4</td>
</tr>
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<td>5.8</td>
<td>2 170 910</td>
<td>388 890</td>
<td>6.6</td>
</tr>
<tr>
<td>Sweden</td>
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<td>1 915 460</td>
<td>36.6</td>
<td>601 327</td>
<td>110 253</td>
<td>5.8</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>87 004 770</td>
<td>14 257 000</td>
<td>16.4</td>
<td>2 591 000</td>
<td>366 000</td>
<td>2.7</td>
</tr>
</tbody>
</table>

* Percentage refer to total food production
** Percentage refer to total food waste
+ **Black** figures are reported by EUROSTAT, **red** figures are based on national studies, **blue** figures are estimates by BIOIS, **green** figures are sums of MS data

Source: Monier et al. (2010), based on 2006 EUROSTAT-data and various national sources, p.48, 63
5.2 Calculations based on FAOSTAT-Data and SIK-Methodology

In this chapter an alternative methodology for calculating the arising of food waste at different stages of the food chain will be described and the results will be discussed and compared with the estimates of the BIOIS-study. This analysis is based on the methodology report of SIK (Gustavsson et al. 2013). Input data for EU-27 are taken from the ‘food balance sheets’ of FAO14. Due to the fact that input data as well as the applied methodology differentiate between food groups, the amount of food waste at different stages of the food chain can also be broken down to food groups.

5.2.1 Methodology Applied to Calculate Food Waste

The processing of data for each food group and each country follows the mass flow diagrams and the description of the calculation procedure given by SIK. The following food groups have been taken into consideration by SIK: Cereals, roots and tubers, oilseeds and pulses, fruit and vegetables, meat, fish and seafood, milk, and eggs. For all these food groups data are available within the FAO food balance sheets. On the food supply side the model includes the following elements: production, import, export and stock variation, resulting in the domestic supply quantity. On the utilisation side the calculated domestic supply quantity can be divided into the elements: feed, seed, other utilities (losses during handling, storage and transport between production and distribution as well as amounts used for non-food purposes), processing (amount which is available for human consumption as part of mixed processed food products) and food. The quantities assigned to feed and seed are not taken into consideration when calculating food losses. Again data for all these mass flow elements are available within the FAO food balance sheets.

The following stages of the food chain have been taken into account by SIK: agricultural production, postharvest handling and storage, processing and packaging, distribution, and consumption. For the food groups mentioned above the methodology report of SIK provides percentages of waste generated on the five different stages of the food chain. These data are based on an extensive literature review (for the literature considered by SIK see Gustavsson et al. 2013) and are average values over all European countries; that means that there is no differentiation between individual countries. Table 4 shows the waste percentages given in the SIK-report for each food group and each step of the food supply chain in Europe.

14 http://faostat3.fao.org/home/index.html#DOWNLOAD, 24/04/13
Table 4: Estimated waste percentages for each food group on different stages of the food supply chain for Europe; ml=milling, fr=fresh, pr=processed

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Agricultural production</th>
<th>Postharvest handling and storage</th>
<th>Processing and packaging</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>2%</td>
<td>4%</td>
<td>0.5% (m), 10% (p)</td>
<td>2%</td>
</tr>
<tr>
<td>Roots and Tubers</td>
<td>20%</td>
<td>9%</td>
<td>15%</td>
<td>7% (fr), 3% (pr)</td>
</tr>
<tr>
<td>Oilseeds and Pulses</td>
<td>10%</td>
<td>1%</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>Fruit and Vegetables</td>
<td>20%</td>
<td>5%</td>
<td>2%</td>
<td>10% (fr), 2% (pr)</td>
</tr>
<tr>
<td>Meat</td>
<td>3.2%</td>
<td>0.7%</td>
<td>5%</td>
<td>4%</td>
</tr>
<tr>
<td>Fish and Seafood</td>
<td>9.4%</td>
<td>0.5%</td>
<td>6%</td>
<td>9% (fr), 5% (pr)</td>
</tr>
<tr>
<td>Milk</td>
<td>3.5%</td>
<td>0.5%</td>
<td>1.2%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Eggs</td>
<td>4%</td>
<td>-</td>
<td>0.5%</td>
<td>2%</td>
</tr>
</tbody>
</table>

Source: Gustavsson et al. (2013)

The calculations were performed separately for each of the EU-27 countries for each of the above mentioned food groups and steps of the food chain. Waste percentages for the step postharvest handling and storage are calculated directly from data given by the food balance sheets and are not based on table 4. Thus, our own calculations for this stage are related to country specific data, whereas the percentages given in table 4 are average values over all European countries, including Russia and other Eastern European countries not belonging to EU-27. In order to allow a comparison with the results of the BIOIS-study our calculations were carried out with data from the food balance sheets for the year 2006.

**Liability of the Results**

The methodology applied allows identifying ‘hotspots’ (e.g. country, type of food, stage of the food chain) which are most responsible for the arising of food waste. Due to the fact that all stages of the food chain can be modelled in a consistent manner, food losses at a specific stage of the food chain directly influence the input data of all succeeding stages. This avoids conflicts resulting from the use of data from different sources.

However, it should be noted that there are also many obstacles, which limit the liability of the results. As described, waste percentages for the individual stages of the food chain are in most of the cases average values over all European countries (including also Russia) and thus do not reflect country-specific behaviours or technologies. The results mainly reflect differences in the food balances between countries. Nevertheless, this approach provides a plausibility check for the results of other studies and allows a better interpretation of available data.

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15 A detailed description of the activities at each stage of the food chain is given by the methodology report of SIK (Gustavsson et al. 2013).
5.2.2 Results of Calculations and Comparison with BIOIS’ Findings

As mentioned above the amount of food waste was calculated along the following stages of the food chain: (1) agricultural production, (2) post-harvest handling and storage, (3) processing and packaging, (4) distribution and (5) consumption. Table 5 shows the total calculated amount of food waste and the percentages for each stage. The share of each individual stage across EU-27 is illustrated in figure 2.

Table 5: Total amount of food waste (in 1000 tons) share of the individual stages of the supply chain across EU-27 in 2006

<table>
<thead>
<tr>
<th>Country</th>
<th>Total amount of food waste</th>
<th>Specific amount of food waste</th>
<th>Agricultural production</th>
<th>Postharvest handling and storage</th>
<th>Processing and Packaging</th>
<th>Distribution</th>
<th>Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU-27</td>
<td>138 019.4</td>
<td>279.8</td>
<td>34.2</td>
<td>7.5</td>
<td>12.0</td>
<td>5.1</td>
<td>41.2</td>
</tr>
<tr>
<td>Austria</td>
<td>2 197.9</td>
<td>266.3</td>
<td>29.1</td>
<td>7.1</td>
<td>13.5</td>
<td>5.6</td>
<td>44.7</td>
</tr>
<tr>
<td>Belgium</td>
<td>3 068.6</td>
<td>291.9</td>
<td>41.1</td>
<td>7.6</td>
<td>10.7</td>
<td>4.5</td>
<td>35.9</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1 452.8</td>
<td>188.2</td>
<td>31.5</td>
<td>8.1</td>
<td>13.6</td>
<td>4.8</td>
<td>42.0</td>
</tr>
<tr>
<td>Cyprus</td>
<td>247.4</td>
<td>322.9</td>
<td>45.0</td>
<td>8.3</td>
<td>8.3</td>
<td>4.6</td>
<td>33.8</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>1 923.0</td>
<td>187.6</td>
<td>23.4</td>
<td>3.8</td>
<td>16.5</td>
<td>6.3</td>
<td>50.1</td>
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<td>1 730.6</td>
<td>318.9</td>
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<td>2.9</td>
<td>15.6</td>
<td>5.5</td>
<td>39.5</td>
</tr>
<tr>
<td>Estonia</td>
<td>302.0</td>
<td>224.6</td>
<td>27.0</td>
<td>2.7</td>
<td>15.8</td>
<td>5.7</td>
<td>48.9</td>
</tr>
<tr>
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<td>17 973.4</td>
<td>218.0</td>
<td>26.8</td>
<td>6.6</td>
<td>14.3</td>
<td>5.7</td>
<td>46.6</td>
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<tr>
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<td>4 305.7</td>
<td>387.0</td>
<td>41.7</td>
<td>8.3</td>
<td>9.1</td>
<td>4.3</td>
<td>36.6</td>
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<td>14.7</td>
<td>5.6</td>
<td>42.3</td>
</tr>
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<td>7.7</td>
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<td>4.7</td>
<td>38.7</td>
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<td>2.9</td>
<td>13.2</td>
<td>5.0</td>
<td>41.8</td>
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<td>Distribution</td>
<td>Consumption</td>
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<tr>
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<td>6 942.9</td>
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<td>36.1</td>
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<td>11.6</td>
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<td></td>
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<tr>
<td>Slovakia</td>
<td>920.3</td>
<td>170.8</td>
<td>25.1</td>
<td>3.1</td>
<td>16.3</td>
<td></td>
<td></td>
</tr>
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<td>27.2</td>
<td>4.1</td>
<td>14.5</td>
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<td></td>
</tr>
<tr>
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<td>15 886.1</td>
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<td>9.5</td>
<td>8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
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<td>222.7</td>
<td>20.7</td>
<td>12.4</td>
<td>13.3</td>
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<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>13 614.2</td>
<td>225.4</td>
<td>20.5</td>
<td>4.4</td>
<td>15.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ITAS-calculation based on the SIK-methodology (Gustavsson et al. 2013)

Figure 2: Share of the different stages of the food chain on total food waste generation across EU-27 in 2006 (ITAS-calculation)
As can be seen from table 5, agricultural production and postharvest handling and storage (losses during handling, storage and transportation between farm and distribution) contribute to a considerable amount to the total food waste arising in EU-27. These two stages have not been taken into consideration in the BIOIS-study. The final consumption on household level amounts to percentages between 28% for the Netherlands and 55% for Luxembourg, followed by the United Kingdom with 53% of total food waste.

The per capita amount of food waste over all stages varies between 170 kg per capita/year for Slovakia and about 400 kg per capita/year for the Netherlands. High values are also calculated for Cyprus, Denmark, Greece, Italy, Romania and Spain. In all of these countries the share from agricultural production is relatively high, meaning that a large portion is exported and therefore not consumed in the country.

Figure 3 shows a comparison of food waste arising between our own calculations [referring only to the stages (3) to (5)] and the results of the BIOIS-study. The BIOIS-study excludes the first two stages – agricultural production and postharvest handling and storage – and takes only into consideration: (A) manufacturing, (B) wholesale and retail, (C) food service and catering and (D) households.

As can be seen from the figure the compliance of the results is relatively good. Exceptions are the Netherlands, Belgium and Poland where the figures of BIOIS, based on data from EUROSTAT, are not plausible as they cannot be explained by technological inefficiencies in the manufacturing sector or the scale of food industry in those countries. A high discrepancy can also be observed for the UK, where the results of BIOIS are based on a national study, not on EUROSTAT. Thus, our calculations confirm the critical judgement above (section 5.1.) that discrepancies between countries are likely the result of lacking standardisation in definitions and data processing, than the result of exceptional differences between Member States.
Table 6 and figure 4 refer to the same contents like figure 2, but present the amount of food waste in kg per capita for the year 2006, sorted in descending order on the basis of data from our own calculations.

Table 6: Total amount of food waste in kg per capita for EU-27 in 2006 - comparison of ITAS-calculations and BIOIS-results, excluding agriculture and postharvest handling

<table>
<thead>
<tr>
<th>Country</th>
<th>ITAS calculations</th>
<th>Results of BIOIS</th>
<th>Country</th>
<th>ITAS calculations</th>
<th>Results of BIOIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU-27</td>
<td>163</td>
<td>181</td>
<td>Malta</td>
<td>162</td>
<td>76</td>
</tr>
<tr>
<td>Greece</td>
<td>193</td>
<td>80</td>
<td>Estonia</td>
<td>158</td>
<td>265</td>
</tr>
<tr>
<td>Denmark</td>
<td>193</td>
<td>146</td>
<td>the Netherlands</td>
<td>158</td>
<td>541</td>
</tr>
<tr>
<td>Romania</td>
<td>182</td>
<td>76</td>
<td>Hungary</td>
<td>155</td>
<td>175</td>
</tr>
<tr>
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<td>179</td>
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<td>Slovenia</td>
<td>154</td>
<td>72</td>
</tr>
<tr>
<td>Italy</td>
<td>177</td>
<td>179</td>
<td>Cyprus</td>
<td>151</td>
<td>327</td>
</tr>
<tr>
<td>Ireland</td>
<td>176</td>
<td>216</td>
<td>Belgium</td>
<td>150</td>
<td>345</td>
</tr>
<tr>
<td>Austria</td>
<td>170</td>
<td>209</td>
<td>Sweden</td>
<td>149</td>
<td>212</td>
</tr>
<tr>
<td>France</td>
<td>170</td>
<td>136</td>
<td>Latvia</td>
<td>148</td>
<td>110</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>169</td>
<td>236</td>
<td>Finland</td>
<td>145</td>
<td>189</td>
</tr>
<tr>
<td>Spain</td>
<td>166</td>
<td>135</td>
<td>Germany</td>
<td>145</td>
<td>149</td>
</tr>
<tr>
<td>Lithuania</td>
<td>166</td>
<td>119</td>
<td>Czech Republic</td>
<td>137</td>
<td>81</td>
</tr>
<tr>
<td>Poland</td>
<td>164</td>
<td>247</td>
<td>Slovakia</td>
<td>123</td>
<td>111</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>163</td>
<td>175</td>
<td>Bulgaria</td>
<td>114</td>
<td>105</td>
</tr>
</tbody>
</table>
Figure 4: Per capita amount of total food waste, excluding agriculture and postharvest handling – comparison of ITAS-calculations and BIOIS-results for EU-27 in 2006

Figure 4 shows major differences for the United Kingdom, Poland, the Netherlands and Belgium due to the reasons explained above. But there are also considerable differences e.g. for Greece, Romania, Slovenia, Malta and the Czech Republic (data from the BIOIS-study are much lower) and for Estonia and Cyprus (data from the BIOIS-study are much higher). The reasons for these discrepancies might be:

- Data used in the BIOIS-study to calculate food waste for these countries are rather uncertain. Due to the lack of empirical evidence, data had to be extrapolated from results of other countries.
- The waste percentages for different stages of the food chain used for our own calculations are average values and do not differentiate between countries.

This underlines the need of better and more reliable data on food waste arising in the different Member States, broken down to different stages of the food chain and food groups.
To conclude the comparison between ITAS calculations and the results of the BIOIS study, figure 5 illustrates the generation of food waste in households.

![Food waste generation in the household sector (per capita)](image)

**Figure 5: Per capita food waste generation at household level – comparison of ITAS calculations and BIOIS results for EU-27 in 2006**

In this figure EU-27 countries have been grouped according to the sources of data for the household sector in the BIOIS study. For countries on the left side of the figure (Greece to Bulgaria) food waste was calculated by BIOIS on the basis of the ‘minimum scenario’ (see also section 5.1). For all these countries the specific amount of food waste (kg per capita) estimated by BIOIS is much lower than the values calculated by ITAS. The reasons for this might be:

- The average value chosen by BIOIS for the minimum scenario is too low and should be modified.
- The waste percentages presented by SIK that we have used in our calculations for the household sector, are identical for all countries and thus do not meet country-specific circumstances.

For countries on the right side of figure 5 data from national studies or from EUROSTAT have been used in the BIOIS study (for the differentiation of data sources see table 1). In general, the compliance is much better than for the countries on the left side. Major differences can be seen for Italy, Poland, Ireland and Estonia, which again may be attributed to the unreliability of EUROSTAT data. For example, the figure for Italy in the BIOIS study is much lower than for other countries with a similar living standard and available household income, and thus do not seem plausible.
5.2.3 Contribution of Different Types of Food to Food Waste Generation within Households

As shown in table 5 the amount of food waste generated in households is similar to, or even higher, than the amount of food waste generated in agriculture. Due to the importance of the households and the fact that agriculture is excluded from the scope of our report, the following section on the arising of food waste split by food types, will concentrate on the household sector.

Figure 6 shows the percentages of different types of food to total food waste generation in the household sector for different countries. On average cereals contribute to 27% (between 17% for Spain and Cyprus and 40% for Bulgaria), roots and tubers to 19% (between 8% for Italy and 31% for Poland), while the contribution of oil crops and pulses is for almost all countries less than 1%. Fruit and vegetables amount to 32% on average (between 19% for Estonia and 43% for Greece and Italy) and meat to 8% (between 5% for Estonia and Romania; 10% for Austria, Cyprus and Luxembourg). Milk and eggs correspond to about 16% (between 11% for Spain and 24% for Finland). In conclusion, due to our own calculations, for the majority of EU-Member States the most important food group is fruit and vegetables, followed by cereals. The share of meat and fish in total food waste is relatively small and the share of oil crops and pulses can be neglected.

![Figure 6: Percentages of different food groups to total food waste generation in the household sector across EU-27 in 2006 (ITAS-calculations)](image-url)
5.3 Results of National Studies

The results of recent national studies concerning the extent of food losses/food waste are hardly comparable because the underlying definitions of the terms ‘food losses’ respectively ‘food waste’, the defined system boundaries, the scope of investigation and the methods used for collecting and analysing the data differ greatly. The available studies consider either different research subjects such as different stages of the food chain, different product groups and different regions or the subjects of the analysis are the same or similar, but the outcomes are diverse due to different assumptions, data collection and evaluation methods. Furthermore, different measurement units are used (tons per year, kg per person and year, calories per person and day) or the reference levels differ (e.g. percentage of food waste in relation to the national total food production, percentage of food waste generated by households in relation to the total national amount of food waste). Table 7 gives a first impression of the different research subjects.

As can be seen from table 7 some studies refer to countries, others to country groups (industrialised, emerging and developing countries), continents or certain regions of the world. The research subjects along the food chain are very heterogeneous as well. There are studies regarding the entire chain or only certain stations, in some cases the agricultural production or the final consumption are excluded. Because of these different starting conditions, a comparison of data is rather difficult.

Table 7: Examples of different research subjects within the calculation of food waste

<table>
<thead>
<tr>
<th>Product Group</th>
<th>Food Waste [in %]</th>
<th>Reference to</th>
<th>Country</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bakery Products</td>
<td>14</td>
<td>Whole chain</td>
<td>Germany</td>
<td>LZ 2011</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>Whole chain</td>
<td>UK</td>
<td>Quested &amp; Johnson 2009</td>
</tr>
<tr>
<td></td>
<td>10 to 15</td>
<td>Bakery branches</td>
<td>Austria</td>
<td>Kainrath 2008</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>Consumption</td>
<td>Austria</td>
<td>Schneider 2008</td>
</tr>
<tr>
<td>Vegetables and Fruit</td>
<td>30</td>
<td>Whole chain</td>
<td>Worldwide</td>
<td>Grethe et al. 2011</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>Whole chain</td>
<td>India</td>
<td>Choudhury 2006</td>
</tr>
<tr>
<td></td>
<td>48</td>
<td>Whole chain</td>
<td>Germany</td>
<td>LZ 2011</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>Without Consumption</td>
<td>Worldwide</td>
<td>Kader 2005</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Without Consumption</td>
<td>USA</td>
<td>Kader 2005</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>Without Consumption</td>
<td>Austria</td>
<td>Wildling 2011</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Without Consumption, without rejections at harvest</td>
<td>UK</td>
<td>Garnett 2006</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Processing and Packaging</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Distribution and</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16 Share of food waste in relation to the total amount of produced food in %.
17 Industrialised Countries means Europe inclusive Russia, North America, Oceania and Industrialised Asia.
<table>
<thead>
<tr>
<th>Sector</th>
<th>Stage</th>
<th>Region</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>Retail, Food Service and Households</td>
<td>USA</td>
<td>Buzby et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Consumption</td>
<td>UK</td>
<td>Qusted &amp; Johnson 2009</td>
</tr>
<tr>
<td></td>
<td>Whole chain</td>
<td>Worldwide</td>
<td>Kader 2005</td>
</tr>
<tr>
<td></td>
<td>Without Consumption</td>
<td>Austria</td>
<td>Wildling 2011</td>
</tr>
<tr>
<td></td>
<td>Transport, Processing and Storage</td>
<td>Worldwide</td>
<td>Lundqvist et al. 2008</td>
</tr>
<tr>
<td></td>
<td>Processing and Packaging</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Distribution and Retail</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Products</td>
<td>Processing and Packaging</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Distribution and Retail</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meat</td>
<td>Processing and Packaging</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Distribution and Retail</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish and Seafood</td>
<td>Processing and Packaging</td>
<td>Industrialised Countries</td>
<td>Gustavsson et al. 2011</td>
</tr>
<tr>
<td></td>
<td>Distribution and Retail</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumption</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8 summarises data on food waste in households in relation to the total amount of food waste for several European countries. The data show that the selected studies come to different results with respect to the same investigation item (food waste in households for selected European countries). For the UK the specified losses range between 58 and 74%, for Italy between 31 and 72% and for Sweden between 44 and 67%. Rarely there are also similarities in the assessments. Thus, for example, Hafner et al. (2012) have calculated for Germany a similar total amount of food waste (11 million tons per year) like Monier et al. (2010) who have estimated 10.4 million tons. The distribution of food waste among the various stages of the supply chain, however, is very unequal in these two studies.
Despite the disparate data material, trends can be identified, which are emerging in the majority of studies. Table 9 presents the extent of food waste along the chain for several European countries.

Table 9: Share of the individual stages of the food chain on total food waste for different European countries in %

<table>
<thead>
<tr>
<th>Country</th>
<th>Germany</th>
<th>Switzerland</th>
<th>UK</th>
<th>Sweden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processing/Manufacturing</td>
<td>17</td>
<td>30</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>Retail and Distribution</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Food Services</td>
<td>17</td>
<td>5</td>
<td>--</td>
<td>13</td>
</tr>
<tr>
<td>Households</td>
<td>61</td>
<td>45</td>
<td>74</td>
<td>67</td>
</tr>
</tbody>
</table>

It turns out that the main source for food waste in European countries is in the household sector. According to Monier et al. (2010) also the food industry is responsible for a large part of the waste (39% on the average of EU-27), while in retail and distribution losses occur least. Trends can also be identified in terms of product groups. Fruit and vegetables, but also bakery products are discarded to a much larger amount than other product groups such as meat (see table 7). Despite little losses in the area of animal-derived products these goods play an important role when regarding the environmental impacts of food wastage.

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18 Share of food waste in households in relation to the total amount of food waste.
In addition to the disparate data stock there are also knowledge gaps regarding the various product groups and stages of the food chain. Cereals, fresh fruit and vegetables are better examined groups while animal-derived products like meat, eggs and milk have been studied little, despite their high ecological relevance. Food that is discarded through municipal waste management (from households, supermarkets, restaurants) can hardly be traced back and quantified as it is not recorded separately. One has to include also alternative disposal routes of households that are difficult to detect (composting, feeding to animals, disposal via sewer). Food waste in public places, in companies and factories as well as in public facilities such as schools and hospitals remain mostly unconsidered when investigating the emergence of food waste. Last but not least, a sizable part of studies such as Monier et al. (2010), Lee & Willis (2010) and Hafner et al. (2012) exclude the agricultural sector from their considerations.

The majority of the studies conclude that a reliable data basis for food waste is missing and therefore a solid estimation of the reduction potential is rather difficult. Grethe et al. (2011) strongly appeal for more systematic research on the extent of losses, which make it possible to quantify the progress of measures in dependence on a global reduction target. The development of a common investigation framework (same definitions, system boundaries, data collection methods etc.) at the national, European and global level would be desirable to make results of different studies comparable. Monier et al. (2010) recommend to carry out time series analyses for all EU Member States in order to obtain reliable data as basis for solid estimates and forecasts. The authors have also criticised that the research investments in this area are very low and that political guidelines are missing.

In order to improve the data basis on food waste in Europe the FUSIONS-project works on a European framework for data collection. This especially includes the development of a handbook, which will be agreed with EUROSTAT and shared with all Member States. A uniform definition of the term ‘food waste’ and how it should be quantified will build the basis. For 2012 a voluntary delivery of national food waste data via EUROSTAT was initiated. 17 Member States are participating in this experiment. The national reports will be finished by the end of 2013.19

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19 Personal communication by Clementine O’Connor, the communications coordinator of the FUSIONS-project, 05/04/13
6 WASTAGE BEHAVIOUR OF HOUSEHOLDS

Even if more robust data on food waste generated at the different stages of the food chain are missing, all studies come unanimously to the conclusion that households are the main source of food wastage in the EU. Our own calculations presented in the previous section confirm these results.

The Dutch Ministry of Agriculture, Nature and Food Quality has estimated that Dutch consumers throw away approximately 8 to 11% of the food purchased (Thönissen 2009). A study, carried out by The ConsumerView for Cofresco (2011) and involving different European countries, came to the result that households in France and Germany waste about 21% of the food purchased, while in Spain this share is with 18% slightly lower. According to WRAP’s report on ‘Household Food and Drink Waste in the UK’ (Quested & Johnson 2009) the amount of food wasted per year is 25% of the food purchased (by weight), including avoidable and unavoidable waste. The British data are deemed to be the most reliable of EU-27 as they emerge from different studies carried out at all stages of the food chain for several years. Thus, the WRAP estimates may provide a rough guide for the whole EU, although the amount of food being wasted as a percentage of food purchased will certainly vary across the Member States.

In order to identify the hotspots of wastage it is important to differ between ‘avoidable’ and ‘unavoidable’ food waste. Due to the fact that food waste contains not edible parts of foodstuff like peelings and bones as well, not the entire amount of kitchen waste can be seen as ‘food waste’ according to our definition.

6.1 Avoidable and Unavoidable Shares of Household Food Waste

Data on the avoidability of food waste were provided in different ways. For Austria, the United Kingdom, the Netherlands, Sweden and Norway data on the avoidability of food waste were collected in frame of food analyses and surveys. These investigations again vary considerably – e.g. in underlying definitions for avoidable and unavoidable food waste, used methodologies, sample size and types of bins (biowaste, residual waste). For Germany results from Austria were transferred into national conditions. Data on waste composition for Austria rely on various analyses of residual waste in selected provinces. In the UK doorstep interviews with householders and waste analyses within nine local authorities in England and two local authorities in Wales were conducted (2715 interviewees, collected waste of 2138 interviewed households). Dutch data are based on analysis of waste from 110 households in 11 local authorities and various districts. In Sweden 24 analyses of household waste in 10 local authorities were carried out and in Norway the waste of 100 households in one local authority was examined and results were compared with available data from another Norwegian community.

Table 10 illustrates the share of avoidable and unavoidable food waste in relation to total food waste in percent for Germany, Austria, the United Kingdom, the Netherlands, Sweden and Norway. The table shows that the share of avoidable food waste varies between 35 and 65% in the studies compared. With the exception of Sweden the proportion of avoidable food waste always outweighs the unavoidable part. All in all, it can be supposed that in all Member States a significant amount of food waste at household level would be avoidable.
Table 10: Food waste in households split by avoidability in %

<table>
<thead>
<tr>
<th></th>
<th>Austria</th>
<th>Germany</th>
<th>UK</th>
<th>the Netherlands</th>
<th>Sweden</th>
<th>Norway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoidable food waste</td>
<td>47</td>
<td>64</td>
<td>60</td>
<td>35</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Partially/possibly avoidable food waste</td>
<td>18</td>
<td>18</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Unavoidable food waste</td>
<td>35</td>
<td>18</td>
<td>40</td>
<td>65</td>
<td>43</td>
<td></td>
</tr>
</tbody>
</table>

1(Hafner et al. 2012), 2(Quested & Johnson 2009), 3(Van Westerhoven & Steenhuisen 2010), 4(Jensen et al. 2011), 5(Fredriksen et al. 2010)

While in the studies for Germany, Austria and the United Kingdom a distinction between avoidable, partially/possibly avoidable and unavoidable food waste is made, information for the Netherlands, Sweden and Norway refers only to the two categories ‘avoidable’ and ‘unavoidable’ food waste. In our opinion the ‘possibly avoidable’ amounts of household food waste play no crucial role for the identification of waste hotspots. On the one hand the share of possibly avoidable waste is rather small in comparison to the avoidable and unavoidable part and on the other hand it will be difficult to change individual eating preferences by governmental measures. Thus, the focus of considerations should be on avoidable waste. Figure 7 shows annual food waste in British households by food groups in million tons, based on WRAP’s research (Quested & Johnson 2009)

![Figure 7: Annual food waste in British households by food groups in million tons, split by avoidability (estimates relate to 2007)](image)

Source: own calculation based on Quested & Johnson 2009, p.32

There are differences in the shares of avoidable waste with regard to different food items. It can be seen from figure 7 that the highest amounts of avoidable waste can be found in the groups: fresh vegetables and salad (860,000 tons), bakery (680,000 tons), dairy and eggs (530,000 tons) and fresh fruit (500,000...
tons). When looking at the avoidable share of waste for each food group, the order changes: The most relevant groups are processed vegetables and salad (99% avoidable), processed fruit (94% avoidable), dairy and eggs (91% avoidable) and bakery (85% avoidable), followed by meat and fish (47%), fresh fruit (45%) and fresh vegetables and salad (45%).

6.2 Composition of Household Food Waste

There are significant differences in the disposal behaviour of households related to individual food groups, which can be identified with various methodological approaches. The available studies used household surveys, sometimes combined with household diaries, or waste composition analyses. Due to the method used, the amount of food waste is indicated as a percentage of food purchased (first approach) or as a percentage of food discarded (second approach). Both approaches have their pros and cons.

The implementation of household surveys is methodically simple, but usually it can provide only qualitative information, because quantitative estimates out of memory regarding the weight of food purchased and discarded are very prone to error (Schneider 2008). Experience also teaches that consumers substantially underestimate their losses when self-reporting (Beretta et al. 2013). The keeping of household diaries yields reliable data, however it is time-consuming for the test persons and may lead, as a result of the conscious participation, to changes in the handling of food stuff by the household members; this applies even more since the topic of ‘wasting food’ is associated with emotional and moral judgements (Schneider 2008). Against this background, waste composition analyses, which can be carried out without the knowledge and active participation of households, are considered to be the more objective and accurate method for determining the amount of food waste on the consumer level. The weakness of this approach is that there is no international standardised collection methodology and no consistency of the definitions used (Lebersorger & Schneider 2011).

Table 11 gives an overview of WRAP’s estimates (Quested & Johnson 2009) regarding the proportion of different food groups purchased and then thrown away in the UK. It is obvious that there is no direct relationship between the amount of food purchased and the proportion wasted. For example, dairy products and eggs represent by far the largest group in the grocery shopping of British households, but only 8% of the purchases are disposed of as waste. In contrast, bakery products account quantitatively for less than a third of dairy purchases, however, 32% of bakery products become kitchen waste. The highest share of avoidable waste (35%) is associated with home-made and pre-prepared meals. Due to their rapid perishability, also high proportions of the purchased fresh fruit (18%) and fresh vegetables (20%) end up in the bin.
Table 11: Proportion of food purchased that is thrown away

<table>
<thead>
<tr>
<th>Types of food</th>
<th>Amount purchased kg/cap/year</th>
<th>Amount wasted that could have been avoided kg/cap/year</th>
<th>Food being wasted as percentage of food purchased*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat and fish</td>
<td>44</td>
<td>5</td>
<td>11%</td>
</tr>
<tr>
<td>Dairy and eggs</td>
<td>111</td>
<td>9</td>
<td>8%</td>
</tr>
<tr>
<td>Bakery</td>
<td>34</td>
<td>11</td>
<td>32%</td>
</tr>
<tr>
<td>Cake and desserts</td>
<td>23</td>
<td>3</td>
<td>14%</td>
</tr>
<tr>
<td>Staple food</td>
<td>21</td>
<td>3</td>
<td>15%</td>
</tr>
<tr>
<td>Fresh fruit</td>
<td>44</td>
<td>8</td>
<td>18%</td>
</tr>
<tr>
<td>Processed fruit</td>
<td>3</td>
<td>0.5</td>
<td>16%</td>
</tr>
<tr>
<td>Fresh vegetables and salad</td>
<td>69</td>
<td>14</td>
<td>20%</td>
</tr>
<tr>
<td>Processed vegetables</td>
<td>25</td>
<td>3</td>
<td>14%</td>
</tr>
<tr>
<td>Confectionery</td>
<td>20</td>
<td>1</td>
<td>6%</td>
</tr>
<tr>
<td>Condiments &amp; spices</td>
<td>16</td>
<td>3</td>
<td>20%</td>
</tr>
<tr>
<td>Meals (home-made and pre-prepared)</td>
<td>31</td>
<td>11</td>
<td>35%</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>1</td>
<td>5%</td>
</tr>
<tr>
<td>All food</td>
<td>435</td>
<td>73</td>
<td>16%</td>
</tr>
</tbody>
</table>

* Percentages have been worked out on the unrounded data

Source: own calculation based on Quested & Johnson (2009), table 51, p.89

The vast majority of the available studies applies the second approach and specifies the amount of waste, broken down by food groups, as a percentage of household waste. Few studies like WRAP used both approaches: interviews with householders and kitchen diaries, and several weeks later, the collection and analysis of household waste. Table 12 gives an overview of households’ waste composition in different European countries.
Table 12: Composition of household food waste in seven European countries in %

<table>
<thead>
<tr>
<th>Target Region</th>
<th>Meat and fish</th>
<th>Dairy</th>
<th>Fresh vegetables</th>
<th>Fresh fruit</th>
<th>Bakery</th>
<th>Meals</th>
<th>All other</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK1</td>
<td>9</td>
<td>8</td>
<td>27</td>
<td>16</td>
<td>11</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Netherlands2</td>
<td>6</td>
<td>13</td>
<td>23</td>
<td>10</td>
<td>17</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>Sweden3</td>
<td>10</td>
<td>3</td>
<td>38</td>
<td>15</td>
<td>27</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Norway4</td>
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<td>Finland5</td>
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<tr>
<td>Austria6</td>
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<td>8</td>
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<td>15</td>
<td>24</td>
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<tr>
<td>Germany7</td>
<td>7</td>
<td>9</td>
<td>27</td>
<td>19</td>
<td>16</td>
<td>13</td>
<td>9</td>
</tr>
</tbody>
</table>

1(Pathak & Johnson 2009), 2(Van Westerhoven & Steenhuisen 2010), 3(Andersen 2012), 4(Syversen & Marthinsen 2010), 5(Silvennoinen et al. 2012), 6(Schneider 2008), 7(Hafner et al. 2012)

It should be noted that the findings are poorly comparable due to the non-uniform classification of food categories. Despite this limitation, the results confirm in some respects the insights gained from table 11. In all countries studied, fresh fruit and vegetables represent the largest group in household food waste. However, it should be taken into account that the figures in question here include, in contrast to table 11, also the non-edible parts of fruit and vegetables (unavoidable waste). Also meals (home-made and pre-prepared) and bakery products account for relatively large fractions in household waste.

6.3 Dietary Patterns across EU-27

It can be assumed that differences in dietary patterns that may exist between the EU Member States have an impact on the amount and composition of food items purchased and wasted in the individual countries.

Large-scale studies in the late 1990s (Dubuisson 2010; Elmadfa 2009; Trichopoulou et al. 2007; Naska et al. 2006; Schmidhuber & Traill 2006; Trichopoulou et al. 2002) based on FAO’s food balance sheets and information from ‘Data Food Networking’ (DAFNE), revealed that there have been quite dramatic changes in European diets over a 40-year-period (1961-2001). The availability of individual dietary components has significantly increased across Europe due to economic integration, urbanisation, improved infrastructure, decreases in the real price of food and the growing dominance of supermarkets. Europeans eat enough of everything, probably too much in total and certainly too much sugar and lipids. The overall caloric intake has risen from an average of 2,984 kcal per person and day in 1961 to 3,505 kcal per person and day in 2001 (Schmidhuber & Traill 2006).

Geographic proximity has traditionally been a crucial determinant for the conformity of food consumption patterns. Over time, however, the influence of geographic proximity on shaping of eating habits has declined. The importance of distance decreases in the extent to which economic integration proceeds and trade barriers as well as transportation costs descend (Schmidhuber & Traill 2006). The dietary patterns identified through the use of the DAFNE-databank point towards a progressive narrowing of differences in the food choices of European countries (Dubuisson 2010; Trichopoulou et al. 2007; Naska et al. 2006). When integrated in the EU, the Southern countries (Spain, Portugal, Italy, Greece and Cyprus) gradually abandoned their traditional diet and adopted the eating habits of the core EU Member States. Over the past 40 years the Mediterraneans have strongly increased their meat consumption and now appear to surpass the Central/Nordic countries in the availability of red meat (Naska et al. 2006). Figure 8 shows the increase of meat supply in Southern European countries from the 1960s up to 2006.
While the proportion of animal-derived products in total energy supply increased markedly in the South, it remained relatively constant in the West region (Belgium, Luxembourg, France, Ireland, the Netherlands, and the United Kingdom), decreased slightly in the North region (Denmark, Estonia, Finland, Lithuania, Norway, Sweden) and increased in the Central and Eastern region (Austria, Czech Republic, Germany, Hungary, Poland, Romania and Slovenia) (Elmadfa 2009). The large differences in the consumption of fruit and vegetables between the Mediterranean and the Central/Northern countries identified in the 1960s have been levelled out (Naska et al. 2006). In every region of the EU the mean supply of fruit and vegetables increased from 1961 to 2003. Also the average supply of milk and dairy products expanded in every region, except the North where it remained relatively constant, at the highest level compared to all other regions (Elmadfa 2009).

Figure 8: Meat supply in Southern European countries for the years 1966, 1986 and 2006

Source: own illustration based on FAO’s food supply sheets

Despite the harmonisation of dietary patterns, some disparities remain. Greece, Italy and Spain still follow a Mediterranean pattern with regard to the intake of lipids, which clearly differentiates from those found in the Central/Nordic countries. Considerable disparities between North and South are also observed in the consumption of pulses, which are still characteristic for the Mediterranean diet and seem to be, together with olive oil, the only two food items that show a clear North/South gradient (Trichopoulou et al. 2007; Naska et al. 2006). The average availability of meat is highest in the Central and Eastern region and lowest in the North, although differences between regions are not that large. The Central and Eastern region also show the highest availability of processed meat and the South the lowest. In contrast, the availability of fish and seafood is highest in the South and even exceeds the levels of processed meat in all and that of poultry in most of the other countries. In the North, the availability of fish is also above the average of all regions, while it was lowest in the Central and Eastern region (Elmadfa 2009).
There are also data available from representative dietary surveys carried out in different European countries that have been compiled by the European Food Safety Authority (EFSA). Notable results revealing disparities between countries are: The Central and Eastern region show the highest consumption of starchy roots and potatoes, followed by the Northern and Western regions, while this value for the South is exceptionally low. The consumption of vegetables is very high in the South as well as in the Central and Eastern region, while the North is far below average. Also concerning fruit the highest intake is reported in the South and the Central/Eastern region, while fruit consumption in the Northern and Western region is considerably lower. The consumption of fish and seafood is more than twice as high in the South compared to the Central and Eastern region. The highest consumption of milk and dairy products is reported in the North, while the lowest intake was found in the South (Elmadfa 2009).

On the long run, the available studies confirm a growing harmonisation of food consumption patterns across EU-27. European diets have not only become more homogeneous, but also increasingly differentiable from dietary patterns outside the EU (Schmidhuber & Traill 2006; similar also Dubuisson 2010). Despite the levelling of eating habits, there are still significant disparities. For example Mediterraneans consume greater amounts of red meat, fish and seafood as well as fresh fruit and vegetables than the rest of Europe. These are highly perishable goods, especially under the weather conditions of the South, related to more than average household losses. Thus, it can be assumed, that the amount of food waste generated by households varies from country to country due to climatic and dietary differences (similar also Beretta et al. 2013). However, this remains a hypothesis only, until there are reliable studies on the influence of these two factors on the generation of food waste in households.

Some further insight into the wastage behaviour of households will be presented in chapter 7. They are based on the results of a survey on households’ food waste generation, which was carried out by the Commission’s Joint Research Centre in Ispra, the University of Bologna and the Karlsruhe Institute of Technology in December 2012.

6.4 Impacts of the Economic Situation on Household Consumption

A recent analysis of the effects of the economic and financial crisis in EU-27 shows that the impact on household final consumption expenditure\(^20\) was relatively moderate (Gerstberger & Yaneva 2013). In comparison to a drop of 4.6% in GDP (Gross Domestic Product) in 2009, the worst year of the crisis, household consumption fell by only 1.8% on average. However, the effects of the economic and financial crises varied significantly across countries. Greece and the Baltic economies were worst affected, with losses in actual individual consumption\(^21\) of 12% to 15% between 2008 and 2011. In Romania, Hungary, Bulgaria, and Ireland the actual individual consumption also declined by between 5% and 9% from 2008 to 2011, while it increased by between 5% and 8% in Luxembourg, Sweden and Poland. In 2011, the situation started to recover in the most Member States, with Ireland, Portugal and Greece being the main exceptions.

\(^{20}\)Household final consumption expenditure consists of the total outlay on individual goods and services by resident households, including those sold at below-market prices. HCFE includes imputed expenditures or transactions which do not occur in monetary terms and can therefore not be measured directly.

\(^{21}\)Actual individual consumption (AIC) refers to all goods and services actually consumed by households taking into account consumer goods and services purchased directly by households, as well as services provided by non-profit organisations and the government or individual consumption (e.g., health and education services).

European commission: Statistics explained (ibid).
The analysis shows further, that the composition of household final consumption expenditure in EU-27 changed only gradually over the past decade. As a medium-term trend a rising share of expenditure on electricity, gas and other fuels could be observed. Some effects of the economic and financial crises could be discerned in a drop of the shares for miscellaneous goods and services, furniture, clothing, communications and leisure related activities between 2007 and 2009. On the other hand the shares for food and non-alcoholic beverages, health, housing rents and other dwelling services seem to have increased within the same period. This observation conforms the finding that expenditure on basic needs tends to be more resilient than other consumption items in an economic recession.

There are large differences in actual individual consumption per capita, ranging from €35,000 in Luxembourg and €29,600 in Denmark to €6,400 in Hungary in 2011, respectively €4,200 in Romania and €3,400 in Bulgaria (based on last available data from 2010). Similarly there are quite large differences in the expenditure of households for certain goods across EU-27. Figure 9 shows that Southern and Eastern Member States generally spent a higher than average proportion on food and non-alcoholic beverages. This share is largest in Latvia and Estonia with 20%, while Luxembourg, Austria and the United Kingdom spent below 10%. On the other hand the proportion of household consumption spent for housing rents is generally lower in these countries, below 10% in Poland, Slovakia and Malta, in comparison to Finland with up to 23% (Gerstberger & Yaneva 2013).

Figure 9: Comparison of final consumption expenditures on food and housing across EU-27 in 2011 (% of total household expenditure)

Source: Gerstberger & Yaneva 2013

Based on this analysis of Gerstberger & Yaneva it can be assumed that countries spending a relatively large proportion of household income on food will have a more careful and economical use of these goods. This may lead to the hypothesis that Southern and Eastern European countries generate generally lower waste rates than Northern, Western and Central ones. The results of the BIOIS-study seem to confirm this assumption. However, it should be noted that BIOIS used for all countries under question a minimum scenario based on a very low average value. Thus, their results are not able to back this speculation. Whether the hypothesis matches with reality, needs further research.
7 SURVEY ON FOOD WASTE GENERATION IN HOUSEHOLDS CARRIED OUT IN BOLOGNA, ISPRA AND KARLSRUHE

In the end of 2012 a survey, based on a questionnaire dealing with food waste generation in households was carried out jointly by the European Commission's Joint Research Centre in Ispra/Italy, the University of Bologna/Italy and the Karlsruhe Institute of Technology (KIT)/Germany. The aim of this survey was to investigate consumers’ attitudes and behaviour regarding the food they waste. The results of this survey can help to understand the reasons for food waste generation at household level and to highlight, as far as possible, any differences between Italy and Germany. In addition, the results of the survey can support the identification of measures and instruments to reduce food waste and increase public awareness on that issue.

The sample of the respondents was quite different at the three sites. While in Ispra and Karlsruhe the questionnaire was distributed only within the two scientific institutions JRC and KIT, the survey in Bologna was opened to the general public. As a consequence the socio-demographic characteristics of the respondents in Bologna are more diverse and reflect more likely the social stratification of the national population. Furthermore, the sample size in Bologna is about ten times higher than in Ispra and Karlsruhe and therefore hardly comparable. In order to carry out a meaningful and methodological correct evaluation of the survey results only the responses gathered in Ispra and Karlsruhe are taken into consideration for the comparison.

The survey results of Karlsruhe and Ispra are by no means representative for the inhabitants of the countries concerned. One reason is that the survey was limited to an academic environment at both locations. Another reason is that the share of Italians within the staff of the JRC is quite small, whereas the majority of employees are coming from other EU Member States. The third reason is that the questionnaire was sent via Internet to different institutes of the JRC and the KIT and it was up to the recipients to open the link or not. It can be assumed that mainly people with a distinct interest in environmental issues and sustainability were willing to spend their time on answering.

The respondents could choose between the original English version and an Italian respectively German translation of the questionnaire.

The questionnaire focuses on the following categories:

- General information about the household
- Shopping habits and attitudes
- Eating habits and attitudes
- Food waste generation
- Food waste prevention

The results of the survey are analysed especially with regard to the following questions:

1) Are there significant differences between Italy and Germany?

2) Are there significant deviations of our results from the results of other available studies?

The comparison with other studies is based on five surveys – two conducted by WRAP in the UK, one from Finland, one from Austria and one from Germany. Although the surveys differ in the methodologies used and the number of respondents, they deal with comparable questions.

Very comprehensive analyses are described in the WRAP-reports ‘The Food We Waste’ (Ventour 2008) and ‘Household Food and Drink Waste in the UK’ (Quested & Johnson 2009). The earlier report (Ventour 2008) refers to the results of a survey in which 2715 households within nine local authorities in England and two local authorities in Wales were interviewed and several weeks later the waste from 2138 of the
interviewed households was collected and analysed. The combination of methodologies (interview and waste analyses) enabled to calculate an average value for food waste generation per capita and identify correlations between waste amounts and attitudes as well as socio-demographic characteristics (ibid., p.13). In the later WRAP-survey households were asked to keep a diary on food waste generation (Quested & Johnson 2009). The analyses of bins does not cover the whole amount of food disposed of by households because surplus food is also composted, fed to animals or disposed of via sewer.

The Finnish survey (Katajajuuri et al. 2012) follows a similar approach. Household diaries on avoidable daily food waste were kept by 380 households (with 1054 people), for a period of two weeks. The study presents results on avoidable food waste within households and correlations with socio-demographic factors.

The Austrian survey (Selzer 2010) analysed food waste arisings in 30 households on the basis of diary entries over a period of four weeks. The collected data have been tested on correlations between waste rates and characteristics of households, bearing in mind that the results are not representative due to the small number of households taken into account.

In the German survey (Gusia 2012) 39 households of one local district in Southern Germany were asked to report waste rates as well as reasons for food waste generation via an online diary (Gusia (2012).

7.1 Socio-Demographic Characteristics of Respondent Households

In Karlsruhe the questionnaire was filled in by 455 persons (54.9% male, 43.5% female), in Ispra by 404 persons (44.6% male, 55.4% female). The numbers show that the groups have almost the same size. Nearly all persons who filled in the questionnaire in Karlsruhe are working at the Karlsruhe Institute of Technology (KIT), in Ispra nearly all persons are working for the European Commission or a related EU institution.

7.1.1 Age

Figure 10 shows a comparison of the distribution of different age groups in Karlsruhe and Ispra. As can be seen from the figure, there are only few persons younger than 18 years or older than 60 years that filled in the questionnaire. In Karlsruhe more than 40% of the persons are 18 to 30 years old, whereas in Ispra the focus of the age pattern lies in the range of 31 to 40 years (36%) and 41 to 50 years (29%). Nevertheless, it should be mentioned – and this is very important for the classification of the results in the following chapters – the age and sex is attributed to the person, who filled in the questionnaire, whereas data about shopping habits and especially about food waste generation are representative for the household with – in most cases – persons of different ages.
Figure 10: Comparison of different age groups between Karlsruhe and Ispra

7.1.2 Household Size

Figure 11 shows a comparison of household sizes (number of persons living in the household) between Karlsruhe and Ispra. In both countries households with two persons have the highest share. There are only slight differences between Karlsruhe and Ispra in the share of households with three or four persons. The share of households with five persons is relatively small in both countries, but it is more than twice as high in Ispra as in Karlsruhe.
7.1.3 Income

Regarding the yearly income (see figure 12) of the households, the share of households in the lower income groups (from less than €12,000 till €48,000) is higher in Karlsruhe than in Ispra. The share of the highest income group (more than €60,000) is 28% in Ispra and 11% in Karlsruhe.

![Figure 12: Comparison of yearly income between Karlsruhe and Ispra](image)

7.1.4 Education Level

The education level is slightly higher in Ispra than in Karlsruhe. The share of persons with a doctoral degree is higher in Ispra than in Karlsruhe, whereas the share of persons with a master/diploma-degree is higher in Karlsruhe than in Ispra (see figure 13).
7.2 Food Waste Generation

7.2.1 Types of Food Thrown Away

In a list of foods the respondents had to mark the ones that they consume and throw away often (once a week) or sometimes (once a month or less). Additional answers, which could be ticked, were: I do not consume and I consume, but never throw away.

Among the food groups listed in the questionnaire, the following ones are never consumed: red meat (19% in Karlsruhe and 15% in Ispra), poultry (15% in Karlsruhe as well as in Ispra), fish (17% in Karlsruhe, 11% in Ispra) and snacks (salty snacks: 29% in Ispra, 18% in Karlsruhe; sweet snacks: 29% in Ispra, 11% in Karlsruhe).

Figure 14 shows the results for foods, which are consumed and thrown away sometimes or often (the number of answers to these two options was summed up). In general, there are no large differences between Karlsruhe and Ispra. In both countries the highest percentage (more than 40%) for foods that are thrown away sometimes or often appears for cheese, vegetables, bread and fruits. The share of ‘sometimes’ and ‘often’ is a little bit higher in Ispra than in Karlsruhe. Higher percentages in Ispra appear for legumes/seeds, eggs, milk and vegetables, lower percentages mainly for bread.
7.2.2 Reasons that Lead to Food Being Wasted

With respect to the reasons that lead to food being wasted there are again no large differences between Karlsruhe and Ispra (see figure 15). Main reasons in both countries are ‘out of date’, ‘in fridge too long’, ‘smelted/tasted bad’, and ‘mouldy’. However, in Ispra ‘out of date’ is mentioned much more frequently (57% of respondents in Ispra compared to 32% in Karlsruhe), whereas in Karlsruhe ‘mouldy’ is marked much more often (78%) than in Ispra (37%). In all other cases less than 25% of all households marked the given reason for throwing food away, which means that these reasons are of minor importance.

An evaluation of the comment fields included in the questionnaire shows similar results: mouldy, especially for bread, is mentioned very often. In addition ‘wrong package sizes’ is also mentioned very often. In accordance with the analysis of the quantitative data ‘out of date’ is cited in the comment field in Ispra more often than in Karlsruhe.

The results of our survey are in good agreement with those of WRAP. Ventour (2008) identified the following main reasons for food being wasted in households: ‘left on the plate’, ‘passed its date’, ‘looked, smelt or tasted bad’, ‘went mouldy’ and ‘left over from cooking’. According to survey results of Gusia (2012) main reason for food being wasted in households are: ‘too long in fridge’, ‘wrong storage’ and ‘cooked too much’. Despite the category ‘too long in fridge’ there is no analogy to our results. However, the comparison is very limited due to discrepancy between the categories offered.
Intermediate Conclusions

As shown in the section above in both countries cheese, vegetables, bread and fruit are thrown away most often. The main reasons that lead to food being wasted are ‘out of date’, ‘in fridge too long’, ‘smelled/tasted bad’ and ‘mouldy’. This results lead to the conclusion that information campaigns on purchase planning, food date labelling and storage might help consumers to reduce food waste.

7.3 Analysis of Interrelations between Characteristics of Households and Food Waste Generation

In the following sections results of the analysis on interrelations between the amount of food waste per household respectively per person and special characteristics of the household will be presented in more detail. This analysis is based on the answers to the question: “Approximately, how much edible food does your household throw away a week?” Possible answers were: (1) I don’t throw away any edible food, (2) less than 250 g, (3) between 250 g and 500 g, (4) between 500 g and 1 kg, (5) between 1 kg and 2 kg, (6) more than 2 kg, (7) I don’t know. Compared to the results of other studies mentioned above, these predefined values are relatively low (especially the highest value of 2 kg per household and week). This fact may have misled households to underestimate their real amount of food waste.

In order to be able to calculate the amount of food thrown away per household and week, the following groups have been determined: (1) 0 g, (2) 125 g, (3) 375 g, (4) 750 g, (5) 1500 g and (6) 3000 g. To receive the amount of food thrown away per person and week, the quantities given in the questionnaire have been divided by the number of people living in the household and then assigned to the following groups: (1) 0 g, (2) 75 g, (3) 100 g, (4) 187.5 g, (5) 375 g and (6) 1 kg. On the basis of these data and the
number of households, which ticked one of the choices mentioned above, the amount of food thrown away per household respectively per household and person was calculated.

### 7.3.1 Household Size

In Karlsruhe as well as in Ispra (see figure 16) the absolute amount of food thrown away increases with the household size. However, in Ispra households with five persons show a very low waste rate. In this group, which consists of 29 households, eleven households reported that they do not throw away any edible food and 10 reported that they throw away less than 250 g per week.

Households with one person in average throw away 155 g per week (Karlsruhe) and 127 g per week (Ispra). Compared to results of the studies mentioned above (e.g. Ventour 2008; Selzer 2010), this quantity is only about 10% of the amount calculated in other studies. Selzer (2010) calculated about 6 kg of food waste in a four-week-period for a one-person-household. This quantity is about a factor 10 higher than the amount calculated in our survey. The same relation applies also to households with more than one person.

![Figure 16: Food thrown away (grams per household and week) in relation to household size](image)

Figure 17 shows the specific amount of food thrown away (grams per person and week) in relation to household sizes. As can be seen from the figure in both countries households with one person waste most (about 186 g per person and week in Karlsruhe and about 157 g per person and week in Ispra). This result is backed up by all other studies as well. Although large households waste most (in absolute amounts), on a per capita basis single households show higher waste rates. The amounts decrease for households with two and three persons in both countries. For households with more than 3 persons there is a slight increase in Karlsruhe whereas in Ispra no trend can be identified.

The average value of food waste is 107 g per person and week for Karlsruhe and 100 g per person and week for Ispra. An extrapolation of these data for the whole country results in 445,000 t food waste per year for Germany and 317,000 t per year for Italy. Compared to the quantities estimated in the BIOIS-study (7.7 Mio t per year for Germany, 2.7 Mio t per year for Italy), the amounts of food waste calculated...
on the basis of our survey, are very small. These differences cannot be explained adequately by the fact that the figures of BIOIS contain also the unavoidable parts of food waste. Other studies also report higher waste rates. However, the results vary greatly, between 211 g of food waste per person and week (Gusia 2012), 450 g (Katajajuuri et al. 2012), 820 g (Selzer 2010) and up to 1.3 kg (Ventour 2008). One reason for the low waste rates in our survey can be that the choices for food waste generation offered in the questionnaire were scheduled too low: ranging from throwing away nothing to more than 2 kg at the highest. Another reason could be that respondents in general underestimate the amounts of food they dispose of. Ventour (2008) reports that households testifying in the interview that they throw away nothing, actually generated 1.7 kg of avoidable food waste per week on average.

Figure 17: Per capita amount of food thrown away (grams per person and week) in relation to household size

The amount of food waste per capita shown in figure 17 was calculated by replacing the bandwidth specified in the questionnaire by an average value. Another possibility for analysing the influence of the household size on the specific amount of food thrown away is to differentiate between two groups:

(1) Households that throw away nothing or only a small amount of food. This group includes households which do not throw away anything or throw away less than 75 g per person and week.

(2) Households that throw away much; this group includes households throwing away more than 250 g per person and week.

The results of this evaluation are shown in table 13. For both countries and for all household sizes only a few people say that they throw away much food. This value is highest for households with only one person (25% in Karlsruhe and 12% in Ispra). This complies with the results given in figure 8 showing that households with only one person throw away the highest amount of food.
There is no clear trend for the correlation between the size of households and the answer that they are throwing away nothing or little, however there is a similar responsiveness in Karlsruhe and in Ispra.

### Table 13: Specific amount of food being wasted in relation to household sizes

<table>
<thead>
<tr>
<th>Persons per household</th>
<th>Karlsruhe</th>
<th>Throwing away</th>
<th>Ispra</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of households</td>
<td>Nothing or little</td>
<td>Much</td>
</tr>
<tr>
<td></td>
<td>Number of households</td>
<td>Nothing or little</td>
<td>Much</td>
</tr>
<tr>
<td>1</td>
<td>71</td>
<td>31.0%</td>
<td>25.4%</td>
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<tr>
<td>2</td>
<td>154</td>
<td>33.8%</td>
<td>4.5%</td>
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<td>81</td>
<td>65.4%</td>
<td>2.5%</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>54.5%</td>
<td>1.8%</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>72.7%</td>
<td>9.1%</td>
</tr>
<tr>
<td>&gt;=6</td>
<td>5</td>
<td>60.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>44.6%</td>
<td>12.0%</td>
</tr>
<tr>
<td></td>
<td>105</td>
<td>42.9%</td>
<td>4.8%</td>
</tr>
<tr>
<td></td>
<td>73</td>
<td>63.0%</td>
<td>2.7%</td>
</tr>
<tr>
<td></td>
<td>62</td>
<td>58.1%</td>
<td>8.1%</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>93.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>66.7%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

#### 7.3.2 Age

Until the age of 40 years there is a slight increase in the amount of food thrown away. In the following groups there is a slight decrease. Regarding the category ‘elder than 60 years’ there is a sharp increase (see figure 18). Due to the fact that this group consists of ‘only’ eight households in Karlsruhe and five households in Italy, the results are not meaningful. With regard to correlations between food waste generation and age there is no agreement in the literature under consideration. According to popular opinion, people ‘elder than 60 years’ waste less food, because of their experiences gained during the Second World War. In contrast, Ventour (2008) reports that the majority of singles, which waste the most on a per capita basis, are in the retirement age. Selzer (2010) found out there is no correlation between these age and food waste generation.

The amount of food thrown away per capita in relation to age groups is also evaluated for the two different groups described above (see table 14). Again only a few people say that they throw away much food; this share is higher in Karlsruhe than in Ispra. Whereas in Ispra there is nearly no difference between different age groups, in Karlsruhe people between 31 and 50 years more often say that they throw away much compared to the other age groups.

Again, with regard to the rubric ‘thrown away nothing or little’ there is a similar response behaviour in Karlsruhe and in Ispra and again no trend in relation to age group can be identified.
Figure 18: Per capita amount of food thrown away (grams per person and week) in relation to different age groups

Table 14: Specific amount of food being wasted in relation to age groups

<table>
<thead>
<tr>
<th>Age of respondents</th>
<th>Number of households</th>
<th>Throwing away</th>
<th></th>
<th></th>
<th>Number of households</th>
<th>Throwing away</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nothing or little</td>
<td>Much</td>
<td></td>
<td></td>
<td>Nothing or little</td>
<td>Much</td>
<td></td>
</tr>
<tr>
<td>&lt; 18 years</td>
<td>1</td>
<td>0.0%</td>
<td>0.0%</td>
<td></td>
<td>1</td>
<td>100.0%</td>
<td>0.0%</td>
<td></td>
</tr>
<tr>
<td>18 to 30 years</td>
<td>170</td>
<td>41.2%</td>
<td>7.1%</td>
<td></td>
<td>49</td>
<td>55.1%</td>
<td>6.1%</td>
<td></td>
</tr>
<tr>
<td>31 to 40 years</td>
<td>83</td>
<td>37.3%</td>
<td>12.0%</td>
<td></td>
<td>131</td>
<td>44.3%</td>
<td>7.6%</td>
<td></td>
</tr>
<tr>
<td>41 to 50 years</td>
<td>67</td>
<td>56.7%</td>
<td>14.9%</td>
<td></td>
<td>108</td>
<td>62.0%</td>
<td>6.5%</td>
<td></td>
</tr>
<tr>
<td>51 to 60 years</td>
<td>47</td>
<td>55.3%</td>
<td>4.3%</td>
<td></td>
<td>61</td>
<td>63.9%</td>
<td>3.3%</td>
<td></td>
</tr>
<tr>
<td>&gt; 60</td>
<td>8</td>
<td>25.0%</td>
<td>12.5%</td>
<td></td>
<td>5</td>
<td>20.0%</td>
<td>0.0%</td>
<td></td>
</tr>
</tbody>
</table>
7.3.3 Education Level

There is no trend observable in our responses (see figure 19). The large difference in the group ‘Less than high school’ between Karlsruhe and Ispra can be explained by the small number of respondents in Ispra (only five persons), compared to 25 persons in Karlsruhe. Selzer (2010) assumed that food waste rises with increasing level of education. However, this hypothesis could not be verified by the author’s investigations.

![Graph showing per capita amount of food thrown away (grams per person and week) in relation to the level of education](image)

Figure 19: Per capita amount of food thrown away (grams per person and week) in relation to the level of education

As can be seen from table 15 again there is nearly an identical responsiveness in Karlsruhe and in Ispra for the share of people throwing away much and no trend in the group of people which throw away nothing or little.

Table 15: Specific amount of food being wasted in relation to levels of education

<table>
<thead>
<tr>
<th>Level of education</th>
<th>Karlsruhe</th>
<th>Throwing away</th>
<th>Ispra</th>
<th>throwing away</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of</td>
<td>Nothing or</td>
<td>Number of</td>
<td>Nothing or</td>
</tr>
<tr>
<td></td>
<td>households</td>
<td>little</td>
<td>households</td>
<td>little</td>
</tr>
<tr>
<td>Less than high school</td>
<td>25</td>
<td>36.0%</td>
<td>5</td>
<td>80.0%</td>
</tr>
<tr>
<td>High school</td>
<td>47</td>
<td>51.1%</td>
<td>35</td>
<td>62.9%</td>
</tr>
</tbody>
</table>
### 7.3.4 Income

Based on a literature review, Selzer (2010) assumed that food waste rises with increasing income. However, this hypothesis could not be verified by her survey: instead the results show that the amount of food thrown away decreases with increasing income. Regarding the results of our questionnaire no trend can be identified. The reason for this might be that the yearly income of households – irrespective of how many people are living in the household – was taken as the basis for the evaluation.

In Karlsruhe as well as in Ispra the group with a yearly income less than €12,000 has the highest share in answering ‘throwing away nothing or little’ (see table 16). Regarding yearly incomes between €12,000 and 60,000 there is only a small variation in Karlsruhe (between 39% and 46%) and also in Ispra (with higher values between 45% and 55%). People with a yearly income above €60,000 in Karlsruhe rarely say that they throw away nothing or little (34%), whereas in Ispra this answer is given relatively often (60%) (see figure 20).

![Figure 20: Per capita amount of food thrown away (grams per person and week) in relation to yearly income](image)
Table 16: Specific amount of food being waste in relation to yearly income

<table>
<thead>
<tr>
<th>Yearly income</th>
<th>Karlsruhe</th>
<th></th>
<th>Ispra</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Throwing away</td>
<td></td>
<td>Throwing away</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of households</td>
<td>Nothing or little</td>
<td>Much</td>
<td>Number of households</td>
</tr>
<tr>
<td>&lt; 12,000 Euro</td>
<td>45</td>
<td>60.0%</td>
<td>11.1%</td>
<td>21</td>
</tr>
<tr>
<td>12,000 to 24,000 Euro</td>
<td>57</td>
<td>38.6%</td>
<td>12.3%</td>
<td>41</td>
</tr>
<tr>
<td>24,000 to 36,000 Euro</td>
<td>84</td>
<td>41.7%</td>
<td>7.1%</td>
<td>53</td>
</tr>
<tr>
<td>36,000 to 48,000 Euro</td>
<td>74</td>
<td>43.2%</td>
<td>8.1%</td>
<td>60</td>
</tr>
<tr>
<td>48,000 to 60,000 Euro</td>
<td>55</td>
<td>45.5%</td>
<td>7.3%</td>
<td>63</td>
</tr>
<tr>
<td>&gt; 60,000 Euro</td>
<td>38</td>
<td>34.2%</td>
<td>2.6%</td>
<td>106</td>
</tr>
</tbody>
</table>

7.3.5 Shopping Frequency

Possible answers to the question “How often do you shop for food?” were: (1) every day, (2) every second day, (3) twice per week, (4) every week, (5) every second week, (6) every month and (7) I don’t shop. In both countries answers (1) and (4) to (7) were marked altogether less than 7%. Therefore these answers are not taken into consideration for evaluation. In Karlsruhe as well as in Ispra most households shop for food twice a week (51% in Karlsruhe and 44% in Ispra). Figure 21 shows the specific amount of food thrown away (grams per person and week) in relation to the shopping frequency. In Karlsruhe there is a slight increase in food waste generation with decreasing frequency, whereas in Ispra the opposite can be observed.
Figure 21: Per capita amount of food thrown away (grams per person and week) in relation to the frequency of shopping for food

### 7.3.6 Money Spent on Food

The question was ‘How much money does your household spend on food per week?’ (please calculate the costs for your whole household and include both eating out and eating at home). In Karlsruhe and in Ispra most households spent on food about €50 to 100 per week (36% in Karlsruhe and 30% in Ispra) and €100 to 200 per week (36% in both countries). The share of households spending between €200 and 300 per week is higher in Ispra (15%) than in Karlsruhe (10%). The average amount of money spent for food is €129 per week and household in Karlsruhe and €139 per week and household in Ispra. As can be seen from figure 22, in Karlsruhe the amount of food thrown away slightly increases up to expenses between €100 and 300, but sharply decreases from 118 g per person and week to 75 g per person and week for households spending more than €300 per week for food (13 households). In Ispra the opposite can be observed: There is a decrease of food being wasted up to €200 expenses for food per week and an increase in food thrown away with a maximum of 150 g per person and week for households which spent more than €300 for food per week (16 households).
**7.3.7 Shopping Behaviour**

There is nearly no difference in shopping behaviour between Karlsruhe and Ispra. The mostly used shops are large retailer super markets (50% in Karlsruhe, 54% in Ispra), followed by small shops (27% in Karlsruhe and 20% in Ispra) and local markets (14% in Karlsruhe, 11% in Ispra). Own food production accounts for 7% in Karlsruhe and 8% in Ispra. Only a small number of households mainly shop for food online (8 in Karlsruhe, 27 in Ispra) or use home delivery (8 in Karlsruhe and 12 in Ispra). These options are therefore not shown in figure 23. The figure shows the relationship between shopping behaviour and amount of food thrown away per capita. As can be seen from the figure in both countries the amount of food thrown away per capita is highest when people frequently shop in large supermarkets, decreases when purchasing takes place in small shops and on local markets and is lowest when people grow their own food.

Figure 22: Per capita amount of food thrown away (grams per person and week) in relation to the amount of money spent on food.
7.4 Shopping Habits and Attitudes

In the following the responses to various questions with regard to shopping lists, special offers and sizes of pre-packed foods are summarised. In Karlsruhe as well as in Ispra 70% of households use a shopping list. When using a shopping list, the amount of food thrown away per capita is 99 g in Karlsruhe and 92 g in Ispra. This amount is clearly higher when no shopping list is used (124 g in Karlsruhe and 119 g in Ispra). The answers to the question “Do you think you are drawn to special offers? (Buy one get one free, 3 for 2, half price)” is shown in table 17. In Ispra households are more often drawn to special offers than in Karlsruhe.

Table 17: Share of households drawn to special offers

<table>
<thead>
<tr>
<th></th>
<th>Karlsruhe</th>
<th>Ispra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>18.9%</td>
<td>45.9%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>54.5%</td>
<td>37.7%</td>
</tr>
<tr>
<td>No</td>
<td>26.5%</td>
<td>16.4%</td>
</tr>
</tbody>
</table>

In Karlsruhe most households (55%) say that the size of pre-packed food meets their needs. In Ispra this share is only 40%. The share of households which answers ‘too small’ is less than 5% in both countries (see table 18).
Table 18: Consumer satisfaction with portion sizes of pre-packed foods

<table>
<thead>
<tr>
<th>Do portion sizes of pre-packed foods meet your needs?</th>
<th>Karlsruhe</th>
<th>Ispra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>54.6%</td>
<td>39.4%</td>
</tr>
<tr>
<td>Too big</td>
<td>16.5%</td>
<td>15.4%</td>
</tr>
<tr>
<td>Too small</td>
<td>3.2%</td>
<td>4.6%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>25.7%</td>
<td>40.6%</td>
</tr>
</tbody>
</table>

7.5 Technologies to Prevent Food Wastage

There are different technologies available, which might help reducing food waste in households. The following technologies were included in the questionnaire (it was possible to choose more than one technology):

- Extending shelf life of food
- Smart packaging: packaging with colour changing indicators that warn when food is spoiling/spoilt
- Smart fridges/cupboards that help planning the shopping list. For example, by scanning products in and out, these devices inform about what is at home and about expiry dates
- Smart interactive tools (online shopping websites or smartphone applications) with information on previous purchases, expiry dates etc.
- Fridges with temperature control
- Smart supermarket trolleys, which make shopping more efficient by planning the way through the supermarket based on the shopping list

The question was answered by 282 respondents in Karlsruhe (62%) and 270 respondents in Ispra (67%). In both countries the most preferred technology is smart packaging followed by smart fridges/cupboards. However, in both cases about 50% of the respondents say that such technologies would help reducing food waste. Fridges with temperature control, smart supermarket trolleys and smart interactive tools do not meet with much interest (less than 25% of persons say that these technologies would help reducing food waste. Again, the responsiveness is very similar between Karlsruhe and Ispra (see table 19).

Table 19: Rating of technologies which might help reducing food waste

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Karlsruhe</th>
<th>Ispra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart packaging</td>
<td>57.4%</td>
<td>51.9%</td>
</tr>
<tr>
<td>Smart fridges/cupboards</td>
<td>43.3%</td>
<td>49.3%</td>
</tr>
<tr>
<td>Extending shelf life</td>
<td>37.2%</td>
<td>28.1%</td>
</tr>
<tr>
<td>Fridge temperature controller</td>
<td>20.9%</td>
<td>21.1%</td>
</tr>
<tr>
<td>Smart supermarket trolleys</td>
<td>17.0%</td>
<td>24.8%</td>
</tr>
<tr>
<td>Smart interactive tools</td>
<td>13.8%</td>
<td>19.6%</td>
</tr>
</tbody>
</table>
7.6 Summary of Survey Results

The results presented in this chapter are based on a survey carried out in two different scientific institutions, the Joint Research Centre (JRC) in Ispra/Italy and the Karlsruhe Institute of Technology (KIT) in Karlsruhe/Germany. Due to the fact that the survey was limited to people working in scientific institutions, the results cannot be considered to be representative for the whole population in Germany or Italy. Nevertheless, they should give some insight into consumers’ attitudes related to the handling of food.

- One interesting result is that there are only little differences between the responses of households in Karlsruhe and in Ispra.
- The average amount of food thrown away per capita is 107 g per person and week in Karlsruhe and 100 g per person and week in Ispra. These values are far below those amounts of food waste in households calculated by other authors. This result confirms the presumption that people, who are asked to guess how much food they throw away, underestimate this amount by far.
- The amount of food waste (grams per household) increases with the size of households (number of persons living in the household). Regarding the amount of food thrown away per capita (grams per person and week) there is no trend identifiable.
- Regarding the correlation between the amount of food thrown away per capita and the age, the yearly income, the frequency of shopping and the money spent for food again no specific trend can be identified, neither in Italy nor in Germany.
- Referring to the shopping behaviour, the specific amount of food thrown away is highest when purchases take place in large supermarkets. Food waste generation decreases when people mainly purchase in small shops and local markets and is lowest when they grow food themselves.
- In Karlsruhe as well as in Ispra about 70% of households use a shopping list. When using a shopping list, the amount of food thrown away per capita is lower by about 20% in both countries.
- The most important foods thrown away sometimes or often are in both countries (in ascending order) cheese, vegetables, bread and fruit.
- Main reasons for food being wasted are ‘out of date’, ‘in fridge too long’, ‘smelled/tasted bad’ and ‘mouldy’.
- With regard to food waste prevention, there is no strong interest in the use of technologies. Only slightly more than the half of the respondents in Ispra and Karlsruhe answered to this question. Furthermore, a large amount of comments was added by the respondents which question the helpfulness of technologies to avoid food waste. The most preferred technologies are ‘smart packaging’ and ‘smart fridges/cupboards’. Relatively little interest is shown in ‘fridges with temperature control’, ‘smart supermarket trolleys’ and ‘smart interactive tools’.
- To the question if less food would be wasted when persons would be charged according to the amount of waste they produce, 51% of the respondents in Ispra and only 29% of the respondents in Karlsruhe gave a positive answer. This difference can be explained by the fact that in Germany a Pay-as-you-throw-system is already in place. However, the fee depends on the volume and not on the weight of the waste produced. The latter option is seen as more efficient with regard to the prevention of waste (see section 10.6.3).
8 IMPACTS OF FOOD WASTE GENERATION

Given the fact that over one billion people suffer from malnutrition, wasting food is mainly an ethical issue. Although the estimates of global losses along the food chain are based on highly uncertain data, there is no doubt that it comes to considerable amounts that would be sufficient, seen mathematically, to curb global hunger (Kreutzberger & Thurn 2011). Critics of such simple extrapolations argue that our unused food cannot be made available to the hungry. Thus, a reduction in the share of discarded food by one side will not automatically lead to equivalent supply on the other side. Critics further emphasize that people in poor countries suffer from hunger because they either do not produce food in sufficient quantity and quality or their purchasing power does not allow buying foodstuffs. Reducing food waste in rich countries will hardly modify these two roots of hunger (Koester 2012). These arguments might be justified. Nevertheless, it can be assumed, that the careless handling of food in rich countries will increase the demand for food, which can lead to higher prices on the world market. Higher food prices would further weaken the purchasing power of poor people in developing countries with the result that they can no longer take care of themselves.

Wasting food means losing not only life-supporting nutrition, but also scarce resources like land, water and energy. These losses will be exacerbated by future population growth combined with changing dietary habits shifting away from grain-based nutrition towards consumption of animal-derived products. Due to increasing prosperity in developing countries, the per capita caloric intake from meat consumption is set to rise 40% by mid-century (IMECHE 2013). The production of animal-derived products requires significantly more resources than the production of grain-based food. Against this background the reduction of food losses is seen as an important starting point for achieving global food security, freeing up finite resources for other uses and diminishing environmental risks (IMECHE 2013; Grethe et al. 2011; Gustavsson et al. 2011; The Government Office of Science 2011).

The wastage of food is associated not only with environmental burdens, but with economic losses along the whole food chain as well. The identification of the most relevant stages within the food chain and the most relevant food groups with regard to adverse environmental impacts and economic losses can provide additional hints for the prioritisation of prevention measures.

8.1 Environmental Impacts

Food production is one of the industries with the highest consumption of resources and a large emitter of pollutants. The agricultural sector is responsible for about 14% of global greenhouse gas emissions (Stern 2007). Adding to the direct emissions from agriculture also indirect effects through land use changes (e.g. deforestation of primary forests), this figure amounts to 30% (Chemnitz 2010). The direct emissions from agriculture occur particularly in the form of methane and nitrous oxide, whose climate change effect is much more pronounced than that of CO₂. In terms of greenhouse gas balances one ton of methane corresponds to the effect of 21 tons of CO₂, a ton of nitrous oxide has the same effect as 320 tons of CO₂ (ibid.). The main sources of greenhouse gas emissions from agriculture are the use of mineral fertilisers, animal husbandry and the cultivation of rice. Also the conversion of grassland to cropland can to a significant extent lead to the release of greenhouse gases (SRU 2012). Irrigated agriculture takes about 70% of global fresh water resources (UNESCO 2009). Depending on how food is produced in the future and on the validity of forecasts for demographic trends, the demand for water in food production could reach 10 to 13 trillion m³ a year by mid-century (IMECHE 2013). The application of fertilisers and pesticides as well as soil compaction caused by the use of heavy machinery burden soils and groundwater. The expansion of intensive agriculture, an increase in monocultures and the penetration of
agricultural production in environmentally sensitive areas result in a decline of biodiversity and a degradation of ecosystem services.\(^{22}\)

### 8.1.1 Increasing Amount of Bio-Waste

Among the environmental impacts of food waste are also methane emissions associated with the deposition of organic wastes and the need to expand the global landfill capacity (Monier et al. 2010; Hall et al. 2009). Large quantities of food waste from the household sector mean high costs for collection and transport as well as for separation and purification in waste treatment facilities. Biodegradable waste usually has high water contents and correspondingly low heating values that reduce the energy output of incineration plants. Thus, worldwide biogenic municipal wastes are mainly deposited in landfills. Outside of Europe, only a small portion of landfills are equipped with facilities for the collection and utilisation of the methane emitted.

In Europe, the deposition of untreated organic waste in landfills is restricted by legal provisions. The Landfill Directive (Council Directive 1999/31/EC of 26 April 1999) required Member States by 2006 at latest to limit the share of biodegradable municipal waste going to landfill to 75% (by weight) of the amount which was deposited in 1995. According to legally binding quotas specified in the directive the maximum amount of organic waste disposed of in landfills has to be reduced over time, to 50% (by weight) by 2009 and 35% (by weight) by 2016, as compared to 1995 (Directive 1999/31/EC, Article 5, Paragraph 2). Member States, which have been heavily reliant on landfill, such as Croatia, Czech Republic, Greece, Ireland, Poland, Portugal, Romania, Slovenia and the United Kingdom have an additional four years period to comply with the targets set in the directive (EEA 2013).

Between 118 and 138 million tons of biowaste are produced each year in EU-27, of which 88 million tons are estimated to be part of municipal waste (European Commission 2010). Various treatment options exist for biodegradable waste such as composting, anaerobic digestion, incineration, mechanical and biological treatment and landfilling. Disposal of waste in landfills is the least preferred option according to the EU ‘waste hierarchy’ as laid down in the EU Waste Framework Directive (Directive 2008/98/EC of 19 November 2008). There are considerable differences between the Member States in terms of treatment approaches (EEA 2009):

- Countries dependent on incineration, coupled with high material recovery rates and often advanced strategies promoting biological treatment of waste;
- Countries with a high level of material recovery rates and some of the highest composting rates in the EU, but very little incineration;
- Countries dependent on landfilling, where diversion of waste from landfills remains difficult due to a lack of alternatives.

A recent cross-country analysis, covering 32 European countries\(^{23}\) and carried out by the European Environmental Agency, shows that only eleven countries reduced per capita municipal waste generation between 2001 and 2010, whereas 21 countries produced even more municipal waste per capita in 2010 than in 2001. However, there are clear indications of a shift away from landfilling towards preferred waste management approaches, focusing on prevention, reuse, recycling and (energy) recovery. The number of countries landfilling more than 75% of their municipal waste decreased sharply, while the number of countries recycling more than a quarter of their municipal waste increased. Nevertheless, the majority of countries still landfilled more than 50% of their municipal waste in 2010 (EEA 2013).

\(^{22}\) Priefe & Jörissen (2012), p.32, translated by the authors

\(^{23}\) Including besides EU-27 Member States also Croatia, Iceland, Norway, Switzerland and Turkey
Figure 24 provides an overview of the percentages of municipal solid waste (MSW) landfilled, incinerated, recycled and composted in 2010 within in EU-27.

Figure 24: Treatment of MSW in different European countries in 2010

Source: own calculation based on EUROSTAT\textsuperscript{24}

Progress in enhancing recycling rates for municipal solid waste is primarily due to the recycling of materials, such as glass, paper, metals, plastics and textiles, whereas the recycling of bio-waste is lagging behind. According to European Commission (2010) on average 40% of bio-waste generated within EU-27 is still landfilled (up to 100% in some Member States). In 2009, eleven countries fulfilled the 50%-target. Seven countries (Austria, Belgium, Denmark, Germany, Luxembourg, the Netherlands and Sweden) already achieved the 2016 target of 35% by 2010 (EEA 2013). Bio-waste on average accounts for 37% of total municipal waste in Europe, but differs considerably between countries, from less than 20% in Lithuania, Norway and Slovenia up to more than 50% in Greece, Portugal, Slovakia and Malta. Due to the smaller proportion of bio-waste in total municipal waste, in most countries the potential of bio-waste recycling is lower than the potential of material recycling and thus not in the focus of interest. So, the increases of bio-waste recycling between 2001 and 2010 were much more modest than the material recycling performance. Only one country enhanced its bio-waste recycling rate by more than ten percentage points in the given period and six countries improved by five to ten percentage points (ibid). Figure 25 shows the percentages of bio-waste, which have been recycled in 2010.

8.1.2 Consumption of Resources

A more responsible and efficient use of the food produced would result in a saving of resources in terms of land, water, energy, equipment and labour. The freed up agricultural productive capacity could be made available for other uses. Engström & Carlson-Kanyama (2004) calculated that solely for the production of food discarded in the catering business of the EU-15 Member States an area of 1.5 million hectares is required. Using the same area for the cultivation of short-rotation coppice, 260,000 TJ could be produced by the combustion of the wood, which would be enough to supply annual heating energy for nearly three million households. According to calculations of Noleppa & von Witzke (2012) already a halving of the avoidable food losses in Germany might save 1.2 million hectares of agricultural land; a complete reduction of avoidable losses could release 2.4 million hectares for other uses. The land use for nutrition would be reduced from 2,300 m² to 2,000 m² per capita, which would correspond to a decrease in the German ‘land footprint’ of about 13%.25

An important issue in the consideration of land use and food production are indirect land use changes (ILUC). In a study of the WWF the influence of nutrition patterns on land use and the importance of food losses for land use competition and the release of greenhouse gas emissions were examined (Noleppa 2012). By importing food from emerging and developing countries to Europe, production sites are taken abroad. As the demand for agricultural products is continuously growing and the improvement of land productivity is limited, in other regions land conversions occur in terms of deforestation of tropical rain forests, crop cultivation instead of natural grasslands and extension of farmland at the expense of protected areas. Changes in dietary preferences such as higher consumption of meat products may increase land use changes in other parts of the world. Thus, for example due to altered eating patterns in Germany between 2009 and 2010 (more consumed grain products, dairy products and meat), the

25 Priefer & Jörissen (2012), p.33, translated by the authors
footprint abroad increased by more than 215,000 hectares (Noleppa 2012). This type of land conversion is accompanied by the release of CO₂, which was previously bound as carbon in the soil or in over-ground biomass.

Similarly, the prevention of food losses would reduce the ‘water footprint’. The water footprint that is recorded worldwide systematically for several years, is composed of the direct and indirect water use. The direct consumption regards the amount of water that is used for domestic purposes such as drinking, cooking, washing and cleaning. The indirect consumption refers to the amount of water that is used in the own country and in other countries for the production of goods consumed at national level. To indicate this hidden water in all kinds of products (food, clothing, paper, technical products) the term ‘virtual water’ is used. While the direct water consumption e.g. in Germany has declined steadily in recent years, from an average of 144 litres per person and day in 1991 to 124 litres per person and day in 2007 (Vereinigung Deutscher Gewässerschutz 2008), the indirect water consumption is many times higher. According to a study of the WWF (Sonnenberg et al. 2009) the total water consumption amounts to 5,288 litres per capita and day, of which 3,904 litres are consumed in the form of agricultural goods. About two thirds of the German indirect water consumption (71%) are caused by the production of arable crops, nearly one third (29%) by the production of animal-derived products.

The majority of arable crops consumed in Germany (about 59%) is imported and hence the water used for its cultivation and processing; that means the domestic water resources are saved at the expense of the producer countries. Germany leaves the largest water footprint in Brazil, the Ivory Coast, France, the Netherlands, the USA, Indonesia, Ghana, India, Turkey and Denmark (Sonnenberg et al. 2009). This is particularly problematic, because a certain share of imported products comes from arid areas with unfavourable hydrological conditions. To an increasing extent artificial irrigation is used for the cultivation of crops in arid areas. This practice stresses the natural water resources and provokes conflicts with other water users. Among the products with a very high water footprint are: cacao (27,000 l/kg), coffee (20,000 l/kg), beef (15,455 l/kg), rice (3,400 l/kg), wheat (1,300 l/kg), milk (1,000 l/kg) and apples (700 l/kg) (Wissenschaftsjahr 2012). A more conscious use of such products would relieve the water resources.

Complementary to the saving of resources an efficient handling of food would reduce agricultural emissions. According to estimates of BIOIS (Monier et al. 2010) the food wastage in Europe is responsible for the release of at least 170 million tons of CO₂-eq which is broadly equivalent to 1.9 tons of CO₂-eq per ton of food waste. These calculations include all stages of the life cycle of a food product; from cultivation through harvesting, processing, packaging, transportation, storage and sale, up to household consumption or final disposal.

The WWF study (Noleppa 2012) has calculated that in 2010 the German diet related direct greenhouse gas emissions accounted for 164 million tons CO₂-eq. The indirect diet related emissions, which are understood as emissions caused by indirect land use changes, amounted to 40 million tons CO₂-eq, which correspond to a share of about 20% of the total diet related greenhouse gas emissions. By inclusion of indirect land use changes, the diet related ‘climate footprint’ of a German citizen increases from 2,003 kg to 2,484 kg CO₂-eq. Noleppa (2012) calculated that by halving the food losses in Germany, 20 million tons CO₂-eq of direct and indirect greenhouse gas emissions could be avoided, and by a complete reduction of German food losses 40 million tons of CO₂-eq would be saved. This volume is comparable to the total greenhouse gas emissions from Slovenia or Israel.

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26 Priefer & Jörissen (2012), p.33-34, translated by the authors
27 Priefer & Jörissen (2012), p.34, translated by the authors
8.1.3 Environmental Impacts Broken Down to Stages and Product Groups

The environmental impacts inevitably add up along the supply chain; so one ton of food waste in the household (i.e. at the last stage of the chain) causes much higher environmental costs than one ton of food waste in the manufacturing sector. Beretta et al. (2013) illustrate this fact by the following example: Carrots remaining in the fields are ecologically less relevant than carrots wasted by households after being transported, stored, packaged and processed.

Following Lee & Willis (2010), the greenhouse gas emissions cumulate on the way from food processing to the final consumer from 2.4 tons to 3.8 tons of CO₂-eq per ton of food waste. Nevertheless, the processing sector is responsible for 73% of greenhouse gas emissions linked to the discarding of food in households. All in all, Monier et al. (2010) assume that at least three quarters of the environmental effects in terms of greenhouse gas emissions, acidification, photochemical oxidation and resource consumption occur before a product leaves the processing stage. Similar calculations have been performed by Lee & Willis (2010) for the UK, by Noleppa & von Witzke (2012) for Germany as well as by Hall et al. (2009) and Venkat (2011) for the United States.

In figure 26 the greenhouse gas arisings from food waste in the USA for the stages production, packaging, distribution/retail and disposal are shown, split by food types. It should be noted that the conditions in North America (e.g. extent of irrigation in agriculture, transport distances, dietary patterns, recycling/disposal routes) are different and therefore the results cannot be directly transferred to Europe. Nevertheless, the American calculations may provide a rough guide also for Europe.

As can be seen from the figure the production stage accounts for a high quantity of greenhouse gas emissions for most product groups. The highest emissions are caused by animal-derived products, of which beef comes by far in first place, followed by chicken and pork. This proves that meat has the
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highest environmental impact, although it is disposed of in rather small quantities - beef waste accounts for only about 2% of total avoidable food waste in the USA in 2009 (Venkat 2011). In contrast vegetables, fruit and grains (altogether almost 56% of total avoidable food waste in the USA in 2009 (ibid.)) cause much lower greenhouse gas emissions than beef, but higher emissions than pork and chicken. In case of fruit and vegetables the release of greenhouse gases relate to a relevant part to transport and waste disposal, while in the case of animal-derived products the overwhelming share of emissions is caused at the production stage. The importance of distribution/retail and disposal could be explained by the waste volume of fruit and vegetables as well as by the high perishableness.

Figure 27 demonstrates the material and carbon footprints of different food groups, referring to annual food waste in Germany. The material footprint is an input-based indicator for the consumption of resources, which represents the use of material (abiotic resources, biotic resources, erosion in agriculture and forestry) across the entire value chain of products in mass units (in kg resources). For this estimate Göbel et al. (2012) used data based on material intensity analyses for Germany, Finland and Italy. The carbon footprint is an output-based indicator, which describes climate change related emissions across the value chain of products in mass units (in kg CO2-eq). Here the above mentioned authors used data compiled by MTT Agrifood Research Finland. The calculations include the production of food and its transport to retail as well as transport from retail stores home. Packaging and storage (e.g. cooling) and further preparation at home (e.g. washing, cooking) are not included in the calculations. Besides these sources the authors took data on food consumption from the Statistical Yearbook 2011 of the Federal Ministry of Agriculture. The proportion of food waste for the different product groups was adopted from a national WWF study (Noleppa & von Witzke 2012). The category ‘others’ refer to data on fish, eggs, oils and fats, sugar and confectionery.

The pie charts illustrate that in Germany fruit and vegetables are disposed of most, followed with some distance by grain products. Although meat products are wasted least (about one quarter of wasted fruit and vegetables by weight), the material footprint for their production and transport is as high as for fruit and vegetables. Dairy products are connected to high resource consumption as well. Grain products show the lowest material footprint, even if wasted in higher rates than dairy products. Likewise production and transport of meat products cause the highest carbon footprint, followed with large distance by dairy products and fruit and vegetables. Grain products show the smallest carbon footprint, which is similar to the summarised one of all other food groups (whereas grain is wasted to a much smaller extent than the product groups in the category ‘others’).
8.2 Economic Impacts

In addition to negative environmental impacts food wastage causes significant monetary losses, both for the individual consumer as well as for the national economy. Analogous to the ecological impacts, economic losses accumulate along the food chain. Available data on economic losses primarily refer to households. The British WRAP-study ‘Waste arisings in the supply of food and drink to households’ (Lee & Willis 2010) estimates that the households in the UK throw away 5.3 million tons of food per year, corresponding to an economic value of £12 million (approximately €14.04 million\(^{28}\)) or £2,264 (€2,649) per ton of food waste. It is assumed that the avoidable costs in the field of food processing amount to about £500/t, of which £55/t relates to the disposal of waste; £1,088/t occur in distribution and £1,676/t at the retail level.\(^{29}\)

A differentiation of costs in British households according to the food groups wasted can be found in figure 28. The right chart shows that the economic impact is, analogous to the environmental impact, very high for animal-derived products like meat and fish (25% of total costs, or £2,470 million per year), although not wasted in high quantities (see left chart). This is due to the fact that meat products are more expensive. Fresh vegetables and salad correspond to a slightly lower proportion of costs (22% of total costs or £2,390 million per year), although they are wasted to a much higher extent. Bakery products amount to the third highest costs (17% of total costs or £1,100 million per year). Given the high economic losses due to wasting of meat and fish as well as fresh vegetables and salad these two food groups should be in the focus of prevention measures, at least in the UK.

![Figure 28: Proportion of different food groups on avoidable food waste in British households (left pie chart) and their proportion on the resulting economic losses (right pie chart)](image)

Source: own calculation based on Quested & Johnson 2009, p.32\(^ {30}\)

\(^{28}\) Exchange rate on 23/05/13: £1 corresponds to €1,1702

\(^{29}\) Priefert & Jörissen (2012), p.35, translated by the authors

\(^{30}\) The underlying main unit refers to total amount and costs of household food waste excluding the following categories: drink, meals, condiments, sauces, herbs and spices, staple foods, cake and desserts, confectionery and snacks and others. The calculation was limited to the most important and in literature frequently mentioned food groups.
Based on Austrian waste analyses, Bernhofer (2004) calculated that households in the province of Salzburg could save average costs amounting to €227 per year by avoiding the wastage of food, whereby nearly 40% of these costs can be attributed to the disposal of original packaged products. Households’ spending on food, which is discarded unused, accounts for around 6% of consumers’ spending in the nutrition sector. Meat products have the largest share of the expenses, followed by canned food, dairy products, eggs, sweets and bakery products. The product groups fruit, vegetables, bread and biscuits account for a relatively small proportion of the costs, although purely quantitative, they represent a third of the volume of avoidable food waste. For Germany Hafner et al. (2012) assume that food worth more than €234 per capita is disposed of annually.

As part of an online survey of 700 households (200 of them in the form of online diaries), conducted by the market research company ‘TheConsumerView’ on behalf of Cofresco Freshkeeping Products Europe, it was found out that in German households about 6.6 million tons of food per year or 21% of purchased food are discarded. This is equivalent to 80 kg of food waste per person and year with an economic value of €310 (TheConsumerView 2011). The study was carried out for various European countries. For France it was counted up that food amounting to €430 per capita and year is thrown away by households (Viel & Prigent 2011).

Buzby & Hyman (2012) estimated the total value of food loss in the United States and the value specified by food groups using ‘Loss-Adjusted Food Availability’ (LAFA) data from the US Department of Agriculture’s Economic Research Service. The results indicate that in 2008, the estimated total value of food loss at the retail and consumer level in the United States was $165.6 billion. On a per capita basis, the food loss is equivalent to 124 kg per year at an estimated retail price of $390/year. This is roughly 10% of the average amount spent on food per consumer in 2008 and more than 1% of the average disposable income. In 2008 three food groups were responsible for 78% of the total value of food loss at the consumer level. These groups are: meat, poultry and fish (41%); vegetables (17%) and dairy products (14%).

The figures on economic losses due to food being wasted are hardly comparable because there are significant differences in survey methods, underlying food prices and reference values. Nevertheless, these figures illustrate that food waste is accompanied by a considerable economic loss for the individual consumer. Current surveys refer primarily to the household level. Despite the lack of available data regarding the earlier stages of the food chain, it can be assumed that other players such as farmers, manufacturers, retailers and food service operators (e.g. hotels, restaurants, takeaways, caterers, hospitals, schools, public facilities) also experience financial losses. The assessment of the economic loss in present studies is mostly based on simple calculations, which multiply the volume of certain food groups in domestic waste with the retail prices of these products. Broader economic considerations, that take into account the economic costs of resource consumption, are largely missing. There are very few studies that hint to this deficit and carry out further assessments.

An example of a comprehensive economic analysis is provided by a study of the Barilla Centre for Food & Nutrition BCFN (BCFN 2011), which has been prepared in cooperation with the Universities of Bologna and Rome. The study is based on research of Segrè and Falasconi (inter alia Segrè & Falasconi 2011), who estimated the costs of the utilisation, degradation and pollution of the environment throughout the food supply chain in Italy. The results of the Barilla study suggest an annual economic impact of food waste in agriculture (i.e. on the first stage of the supply chain) equal to about €8 billion, if the calculation is set on production costs, and about nearly €10 billion, if the calculation is set on market prices, what is equivalent to €136 and €163 per person, respectively (the data refer to 2009). The economic impact based on market prices is higher, by about 16% compared to the production costs. If the negative consequences of food waste in terms of environmental damages are included, the estimate of the economic impact turns out to be higher than €10 billion, based on market prices. If the opportunity
costs\textsuperscript{31} of the land used for the production of food that is not consumed are valorised as well, the economic impact increases further by €30 billion.

The Barilla study has met considerable criticism when first published in Italy (Adragna 2012). Opponents pointed out that there would not exist any valid statistical basis that allows a sound assessment of the extent of food waste in Italy. According to Luca Falasconi, lecturer at the Faculty of Agriculture at Bologna and protagonist of the Italian initiative ‘Last Minute Market’, the available data fluctuate between 10 and 15\% of Italy’s total food production. In his opinion the agricultural sector is indeed one of the main sources of food loss due to inadequate harvesting of fruit and vegetables. According to the Italian statistics 8 million tons of fruit and vegetables remain in the fields, because they are too large, too small, or aesthetically deficient, which is similar to the amount of fruit and vegetables that is consumed in Italy (8.5 million tons). However, Falasconi stresses that for the rejected products there are other alternative marketing channels in the local area so that they could not be classified automatically as food waste (La Pira 2012). Apart from doubts about the reliability of the data used in the Barilla study, the monetary evaluation of environmental impacts has always been a highly controversial approach.

\\textsuperscript{31} The opportunity cost should correspond to a value at least equal to the best alternative use of the land, such as construction potential, which Segrè and Falasconi have quantified with €20,000 per hectare.
9 CONCLUSIONS FROM ITAS-CALCULATIONS AND DATA PROVIDED BY OTHER STUDIES

In this chapter we will draw initial conclusions from the discussion about the emergence of food waste, its causes and impacts, as presented in the previous chapters. The question is which kind of food losses, broken down by product groups, has the highest relevance in each individual Member State and thus should be in the centre of the development of prevention measures. The relevance depends first on the amount of avoidable waste generated at the various stages of the food chain and secondly on the negative environmental and economic impacts which are related to the provision of different food groups. Since the food groups that are discarded to a high extent are not identical with those that have the largest adverse impacts, it is important to consider both aspects. The identification of hotspots of wasting in the different Member States should be the starting point for the development of options for action in chapter 10.

Our own calculations based on the SIK-methodology, using FAO’s food balance sheets in combination with the results of many other studies presented here, lead to the following first insights that can help to identify hotspots in EU-27:

- ITAS-calculations demonstrate that the highest amounts of food waste are generated at the first and at the last stage of the food chain. The finding, that agricultural production in EU-27 contributes to a considerable extent to total food waste in Europe stands in a certain contradiction to the results of other studies. The prevailing opinion is that, in contrast to the developing countries, losses at the production stage in industrialised countries are negligible. High waste rates in agriculture can be found according to our calculations for the Southern European countries Cyprus, Spain, Greece and Italy as well as for the Netherlands and Belgium. This is due to the fact that these countries produce high amounts of agricultural goods, which are exported. Thus, agricultural production should be involved in the strategy to cut down on food waste in Europe.

- With regard to the manufacturing sector ITAS-calculations confirm that EUROSTAT-data overestimate the amount of food waste generated in this sector. This is particularly obvious for the Netherlands, Poland, Estonia, Hungary and Belgium. Thus, more detailed research is needed to assess the generation of food waste in this sector more robustly.

- In accordance with the results of other studies ITAS-calculations show that the household sector is responsible for the largest shares of food waste in comparison with all other stages of the food chain. Thus, the behaviour of the end-consumer should be in the focus for the development of prevention measures, but without neglecting the previous stages of the food chain.

- In all countries investigated by other studies, fresh fruit and vegetables represent the largest group in the composition of household food waste, followed by bakery products (see table 12). This result is backed by our calculations and our survey, carried out in cooperation with JRC in Ispra and the University of Bologna. According to research results of WRAP, these food types represent also the product groups with the highest absolute volumes of avoidable food waste (see figure 7). Thus, the wastage of fresh fruit, fresh vegetables and bakery products by households is certainly one of the hotspots that should be addressed in the context of prevention strategies.

- Looking at the food waste generation of households, differentiated by countries and food types in some more detail, the results of our calculations show the following picture (see figure 6): The highest waste rates for fruit and vegetables are apparent in Southern European countries like Cyprus, Italy, Greece, Spain, Malta and Portugal, but also in Luxembourg, France, Hungary and Romania. Waste rates for cereals are highest in Eastern European countries like Bulgaria, Slovakia and Czech Republic. Eastern European countries like Poland, Estonia, Latvia and
Lithuania, but also Denmark and the United Kingdom show the highest waste rates for roots and tubers. For milk and eggs the North European countries Sweden, Finland and the Netherlands and the Central European states Luxembourg and Germany, but also Lithuania have the highest waste rates. The waste rates for meat are similar across EU-27. The highest waste rates for fish can be found in South European countries like Portugal and Spain, but also in Northern, Central and Eastern European countries like Sweden, Finland, France and Lithuania. The wastage of oil crops and pulses is negligible in all Member States. All in all, the results of our calculations confirm the findings of analyses on the differences in dietary patterns across EU-27 (see section 6.3).

- A recent analysis on final household expenditure across EU-27 (see figure 9) shows that Southern and Eastern Member States generally spent a higher than average proportion of their income on food and non-alcoholic beverages in comparison to Western and Central European countries. The hypothesis that countries spending a relatively large proportion of household income on food will have a more careful and economical use of these goods, needs further research. It also might be that the high consumption of easily perishable products like fresh fruit and vegetables, red meat and fish in these countries overcompensate the potential saving effects.

- In addition to the scale of food waste, also the extent of environmental impacts in terms of harmful emissions and consumption of land and water caused by the provision of food plays a crucial role for the identification of hotspots. The provision of meat and meat products causes the greatest environmental impacts, although the wasted quantities are small compared to fruit, vegetables and bakery products. The reason is that the environmental impact of the production of one kilo of fruit and vegetables causes much less environmental impacts than the production of one kilo of meat (see figure 11).

- In connection with the wastage of fruit and vegetables not only the quantity but also the way of cultivation and the country of origin are of high relevance. Long transport distances as well as the production of fruit and vegetables in glasshouses and via irrigation in dry areas are particularly resource consuming and thus should find more attention in prevention strategies.

- Economic losses are highly associated with animal-derived products like meat and fish, dairy and eggs. Fresh vegetables, salad and fruit correspond to a similar proportion of costs due to their high waste rates.

We would like to emphasise that the interpretation of the quantitative results presented here should be handled with caution. As input data for the model calculations food group-specific waste percentages for the different stages of the food chain were used. These percentages, provided by SIK, are average values for Europe (including Russia and other Eastern European countries not belonging to EU-27). Thus, country-specific behaviours and technologies have not been taken into consideration. As a consequence, the results of the model calculation do not reflect the ‘real’ world. Given that restriction and the low reliability and comparability of the available data from other sources, it might be risky to identify hotspots of food wasting only based on quantitative findings. This may result in misleading recommendations. In today’s situation it seems more promising to address directly the main contributory factors to food being wasted at the different stages of the food chain (see table 2) as a starting point for the development of mitigation strategies.
10 APPROACHES TO REDUCE FOOD WASTE

In the current national and international debate there has been submitted, and partially already implemented, a wide range of approaches to encourage the different players along the supply chain to a sparing and responsible handling of food. These approaches can be grouped in persuasive, cooperative, regulatory, economic, organisational and technical measures. This chapter gives an overview of the measures and instruments under discussion taking into account the experiences already gained in different countries. The focus is on approaches that are considered in literature or in the current debate as particularly useful, easy to implement and able to achieve long-term gains and/or that have already proven their effectiveness in practice. Some instruments such as improving cold chain management or extending shelf life of products directly affect food, while others such as awareness campaigns indirectly affect food by influencing people’s consumption behaviour (Lipinski et al. 2013).

The approaches presented in this chapter are linked to the causes of food wastage illustrated in chapter 4 (see table 2). Thus, we organised the approaches following the stages of the food supply chain. Some approaches, however, such as improving data collection on food waste or extending food redistribution programmes, cut across multiple stages. These cross-cutting approaches are put together in a separate section (see 10.1).

10.1 Cross-Cutting Approaches

Some approaches to reduce food waste involve several stages of the food supply chain and therefore cannot be assigned to a certain stage. Among the cross-cutting strategies the following are of crucial importance:

10.1.1 Target Setting

There is general agreement that determining a quantitative, time-bound target for reducing food waste in EU-27 would build a basis for action in all Member States. Reduction targets are helpful instruments that could raise awareness, stimulate focused attention and mobilise resources towards reduction strategies. Furthermore, they are important for gauging progress and evaluating the effectiveness of different measures. This in turn requires a regular monitoring of food waste along the entire food chain.

In its roadmap for a resource efficient Europe the European Commission has set the target to halve avoidable food waste in the EU by 2020 (European Commission 2011). This requires the engagement of all EU-27 States.

Up to now, the efforts among Europe have been very disparate. A variety of private initiatives can be found nearly in all States, while the issue is not yet present on all political agendas. A stronger commitment of the individual Member states would be advisable. The BIOIS-study (Monier et al. 2010) recommends the setting of specific food waste prevention targets by each individual Member State, as part of the waste prevention programmes required by the EU Waste Framework Directive (Directive 2008/98/EC of 19 November 2008). The directive puts waste prevention at the top of the ‘waste hierarchy’ and obliges Member States to establish National Waste Prevention Programmes by December 2013, which shall set out waste prevention objectives. According to Article 22 of the directive Member States are further required to encourage the separate collection of bio-waste with a view to its composting or anaerobic digestion. Member States shall determine appropriate specific qualitative or quantitative benchmarks for waste prevention measures adopted in order to monitor and assess the progress of the measures (Article 29).
The World Recourses Institute (Lipinsky et al. 2013) suggests targets on food waste prevention to be adopted across a range of geographic scales; from global, national to sub-national level, which includes provinces and cities. New York City for instance is currently pursuing the target of reducing food waste by 50% by 2030 and Hong Kong by 10% between 2013 and 2016.

Referring to the individual stakeholders the question arises whether statutory or voluntary obligations are more suitable to tackle the problem on the different stages of the food chain. Voluntary obligations are broadly accepted, while statutory duties are seen critically, especially by the food industry and the retail sector. They argue that intense competition would automatically lead to a strict cost management and avoidance of food wastage (BVE 2012; BVL 2012). One example for voluntary commitments is the one set by Arla Food, Europe’s second largest company for dairy products, to reduce food loss and waste in the company and its supply chains by 50% by 2020 compared to 2010 levels. Another example is the Courtauld Commitment, a voluntary agreement on the reduction of food and packaging waste in the UK with more than 40 signatories, including manufacturers, retailers and brands like Nestlé, Tesco and Unilever (Lipinsky et al. 2013). The agreement is funded by the Westminster, Scottish, Welsh and Northern Ireland governments and arranged by WRAP. The Commitment was launched in 2005 and until now 2.3 million tons of waste, equivalent to £3.5 million (product waste as well as packaging waste) could be saved (Goodwin 2013). In the current third Courtauld Commitment, which runs from 2013 to 2015, the following targets are pursued (WRAP 2013):

- Reduction of household food and drink waste by 5% by 2015 from a 2012 baseline.
- Reduction of traditional grocery ingredient, product and packaging waste in the grocery supply chain by 3% by 2015 from a 2012 baseline.
- Improvement of packaging design throughout the supply chain in order to improve recyclability and to reduce food waste by enhancing product protection, while ensuring that there is no increase in carbon footprint of packaging by 2015, from a 2012 baseline.

Activities to reach these goals include e.g. targeted food waste reduction initiatives, for example the ‘Love Food Hate Waste’ campaign, clearer product labelling and improved packaging design.

### 10.1.2 Improvement of the Data Basis

All available studies revealed the deficient data basis as a main obstacle to the development and implementation of measures to reduce food waste. Without reliable data neither a robust estimate of the magnitude of food waste generation on the individual stages of the food supply chain nor a comparison between different countries will be feasible.

Under EUROSTAT, data which are relevant to assess the generation of food waste along the food supply chain are given in the waste category W09 - animal and vegetal waste. This category includes all types of animal and vegetal wastes, but does not provide a special subsector for data on food waste. Consequently no differentiation is made between food waste, which would have been avoidable, by-products and the non-edible parts of raw products. According to the NACE-classification (Nomenclature statistique des activités économiques dans la Communauté européenne) data for animal and vegetal waste are available for different economic activities. Sectors which are relevant in the present context are the ‘agricultural, forestry and fishery sector’ (not taken into consideration by many recent studies), the ‘manufacturing sector’ and the ‘household sector’. For other economic sectors generating high amounts of food waste such as the ‘wholesale/retail’ and the ‘food services/catering’ sector, there does not exist an individual category within the NACE-classification. Whether data from the NACE-category ‘Services’ – including a lot of subcategories, which are not relevant in the given context – can serve as a source of data for the ‘wholesale/retail’-and the ‘food services/catering’ sector has not been checked so far.
Starting with the reference year 2004, Regulation (EC) No 2150/2002 on waste statistics requires EU Member States to provide data on the generation, recovery and disposal of waste every two years. However, as stated in the explanatory text of the EUROSTAT database on waste generation and treatment, the Member States are free to decide on the methods used for data collection. Possible options are: surveys, administrative sources, statistical estimates or any combination of methods. That means that there is no compulsory instruction how data have to be collected. As a result, it is difficult to judge how reliable data provided by various governmental authorities are and whether data from different countries or even from different years for the same country are comparable.

Given this situation, there are three key requirements for improving the data basis (BIOIS 2011; Monier et al. 2010):

1. Development of an agreed and binding definition of the term ‘food waste’ on European level, which differentiate between unavoidable food waste (referring to the non-edible parts of raw products), by-products and food waste that would have been avoidable.

2. Standardisation of the methods used for the collection and calculation of data on food waste generation in Europe related to all stages of the food chain. This implies an extension of the NACE-classification of the previous missing sectors ‘wholesale/retail’ and ‘food services/catering’.

3. Separate collection and measurement of food waste generation at all stages of the food chain, whether voluntarily or mandatorily, in order to enhance transparency and foster awareness of the problem among all players involved.

It is among the tasks of the ongoing FUSIONS-project to elaborate recommendations concerning these issues, which can be expected in the end of the year.

In order to check the plausibility of statistical data, but also to estimate the impact of different prevention measures or of specific scenarios, mathematical models (e.g. the model of SIK used for ITAS-calculations in the present study) should be further developed.

10.1.3 Integrated Food Supply Chain Management

Reducing food waste demands action from a plurality of players: farmers, food companies, retailers, consumers and policymakers. It also requires changes in technologies, practices, behaviour and policy. These conditions suggest that no individual group can sufficiently tackle the problem, but that cooperation is strongly needed (Lipinsky et al. 2013).

Due to the ever-increasing degree of processing the food supply chain has become more complex. There is a strong division of labour, so that the individual operations are not known at all preceding and subsequent stages of the chain. Carried by this mutual lack of knowledge waste is generated, particularly at interfaces. Furthermore, many technical and/or organisational solutions can be effective only when all parts of the food supply chain cooperate in mutual agreement. For example, if retailers use poor forecasting techniques with the result that food orders later have to be cancelled, they contribute to wipe out efficiency gains made in the food industry. Thus, the information flow across the chain should be encouraged and supported with appropriate tools. Progress in reducing food waste will require an Integrated Food Supply Chain Management (Lipinsky et al. 2013; Göbel et al. 2012).

In 2006, the Dutch food industry committed to address food waste issues. To fulfil this commitment, Wageningen University & Research centre (Wageningen UR) has cooperated with representatives of government and business in order to optimise supply chain management for private companies, using a

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procedure of factual survey, monitoring, modelling, scenario analysis and business model integration. Wageningen University, among other research organisations, provides expertise to foster entrepreneurs’ understanding of the primary opportunities for waste reduction in their supply chain and to incorporate long-term changes in their production processes (Monier et al. 2010, p.98). Following this example, the establishment of networks, round tables, discussion forums or information pools might be useful, that aim at bringing together key stakeholders, experts and representatives of public authorities and civil society organisations, in order to tackle the challenge of preventing food waste along the entire food chain.

10.1.4 Taxes and Fees on Waste Treatment

Taxes and fees on waste treatment can be seen as an economic incentive to stimulate waste prevention as they escalate the total costs of waste handling, so that the financial benefits of avoiding treatment increase (Watkins et al. 2012; Marthinsen et al. 2012). Although economic instruments such as landfill or incineration taxes are introduced primarily with the intention to move waste management away from landfill towards recovery and recycling, they might also help, by proper configuration, cutting down on food waste.

In 18 European Member States (or regions within Member States) taxes on waste sent to landfills are in place. In the Netherlands the tax has been eliminated from January 2012 due to decreasing revenues. The majority of countries have a tax level exceeding €30 per ton of waste and some countries are increasing the rate, so that it reaches or will soon reach a level between €50 and €70 per ton of waste (EEA 2103).

More important than the level of the pure tax are the total landfill costs composed of the tax (charged by a public authority for the disposal of waste) and the gate fee (charged by the operator of the landfill for the provision of the service). A study carried out by the Bio Intelligence Service on behalf of the European Commission (DG ENV), regarding the use of economic instruments and waste management performances in EU-27 (Watkins et al. 2012), suggests that there is a clear relationship between the total costs of landfilling and the percentage of municipal waste recycled and composted: the higher the total costs of landfilling are, the more municipal waste is pushed up the waste hierarchy towards recycling and composting. Member States appear much more likely to meet a 50%-recycling target once landfill charges approach €100 per ton.

The study identified six Member States that have incineration taxes in place. The total charge for incineration (i.e. the tax plus the charge required by the operator for the service) in EU is ranging from €46 in the Czech Republic to €174 in Germany (ibid). All Member States that have incineration taxes, also have landfill taxes, and in every case the landfill tax is higher than the incineration tax. Analogous to the landfill case it can be assumed that higher incineration charges are associated with higher percentages of municipal waste being recycled or composted. However, due to the lack of data on the change of the tax level over time, there is no empirical evidence to support this hypothesis. In addition, it should be noted that in view of considerable overcapacities in incinera tors the gate fees are declining in various EU countries (Marthinsen et al. 2012).

The study of BIOIS (Watkins et al. 2012) as well as the cross-country analysis of the European Environmental Agency (2013) further reveals that countries using a broad range of instruments are more successful in reducing municipal waste disposal than countries using only few instruments. Such national and regional instruments include regulatory provisions like bans on disposing untreated biodegradable municipal waste in landfills or mandatory separate collection of different waste fractions, economic instruments like waste collection fees, landfill and incineration taxes or financial support to build up recycling infrastructure. Germany for example, has achieved one of the highest recycling rates of municipal waste in Europe, without using taxes but with a combination of all the other instruments mentioned above (EEA 2013). In the UK the landfill tax was coupled with the introduction of the Landfill Allowances Trading Scheme (LATS) in 2005. Within this scheme for each local authority a quantitative
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limit for the disposal of biodegradable waste in landfills was set with the possibility to trade unused potentials. These limits were reduced year by year and a fine of £150 per ton was enforced for those who exceeded their allowance, thereby encouraging authorities to move away from landfill towards alternative waste treatments (Tudor et al. 2011).

The experiences gained in different European countries indicate that taxes on waste treatment are in principle a good instrument for pushing waste management further up the waste hierarchy towards recycling, reuse and recovery. However, it seems that taxes have not been set at rates which enable a complete shift away from landfill (Watkins et al. 2012). Whether this instrument is likely to reach the top of the hierarchy, i.e. prevention of waste, depends on its configuration. When using taxes on waste treatment as a tool to prevent food waste, certain requirements have to be met:

- Firstly, a mandatory separate collection of food waste, both in households and in commercial enterprises (mainly in the retail and hospitality sector) should be introduced; the latter is currently stipulated only in Ireland.

- Secondly, the tax rate must be high enough to create a sufficiently strong incentive for waste minimisation as well as for the donation of surplus food to charities. However, high taxes can equally generate an additional stimulus for illegal activity, so regulatory measures need to be developed in parallel (Watkins et al. 2012).

- Thirdly, the existing regulations to promote and subsidise the use of renewable energies in Europe should be reviewed in order to identify incentives that run counter to the objective of food waste prevention.

Several European countries (Austria, Belgium, Finland, Germany, Hungary, the Netherlands, Poland and the United Kingdom) offer financial support for waste-to-energy plants with CHP (Combined Heat and Power) or provide a special feed-in tariff for energy produced from waste incineration and/or anaerobic digestion (Watkins et al. 2012). It may lead to conflicting incentives, if national legislators on the one hand would impose high taxes for the treatment of food waste and on the other hand subsidise the production of energy from waste.

10.1.5 Food Redistribution

Food redistribution programmes pursue a twofold objective: to prevent food waste and to alleviate food scarcity of economically deprived people. Charitable institutions like ‘FareShare’ in the UK, ‘Fondazione Banco Alimentare’ in Italy or ‘Die Tafeln’ in Germany and Switzerland collect food, voluntarily given away by producers, processors, retailers or food service operators that would otherwise be lost or discarded, and distribute it to the needy. This strategy can apply to different stages of the food chain: at agricultural production (for fruit and vegetables that are rejected by retail, produced in abundance or not placed on the market in order to keep prices stable), at manufacturing (for damaged or overproduced goods), at wholesale/retail (for products near to their expiry date, seasonal or surplus goods) and at the food services/catering sector (for fresh-cooked meals that are unsold in the end of the day) (Lipinsky et al. 2013). Some institutions distribute groceries free of charge to their clients, while others demand a symbolic price, which may be up to a third of the normal retail price. The collection of a financial contribution follows the intention to dismiss consumers from the role of a beggar and to assign a certain value to each food item (BMELV 2012a). Several European countries (e.g. Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Norway, Sweden, Spain and the United Kingdom) have successfully implemented food redistribution programmes, in which excess food is transported from donors to people in need.

Following Lipinsky et al. (2013) the main obstacles to food redistribution are related to economic and legal constraints. Especially in rural areas the network of food rescue organisations often is not tight enough to organise the transport of surplus food from the point of origin to the food bank in an
economically feasible way. Furthermore, charity organisations outside major cities are not always equipped with refrigerated vehicles. In cases where market prices for certain products do not justify the expenses for harvest, it seems unlikely that the farmer will invest labour, logistics and transportation costs to donate the goods.

To overcome the economic barriers, Lipinsky et al. (2013) suggest the introduction of tax incentives for food donations following the example of the United States. California, Arizona, Oregon and Colorado have passed laws providing tax credits for food redistribution to food banks (Van Zuiden 2012). Martthinsen et al. (2012) stress that there is a need for an improved infrastructure in order to utilise all food better. Similar to recycling stations for packaging, food banks should be a natural part of society’s infrastructure. The authors suggest that retailers as well as food business operators with a certain predictable amount of food waste should be obliged to finance and use these food banks.

Charity organisations that redistribute food as well as the prospective food donors might be concerned about the legal consequences in case that somebody will be injured by a defective product. To address the legal obstacles, the United States in 1996 enacted the Bill Emerson ‘Good Samaritan Act’ which limits the liability of donors. The law protects food donors from civil and criminal liability in the case that the product they gave in good faith to a charitable organisation should harm a recipient. In addition to granting legal protection to donors, the law may also be seen as an endorsement of redistribution activities (Lipinsky et al. 2013; Van Zuiden 2012; Morenoff 2002).

In Europe there does not exist any similar regulation. Only Italy has developed a statutory provision (L. 155/2003) that protects donors and charity organisations collecting surplus food for redistribution, acknowledging the latter ones as ‘final consumers’. This legal construction prevents recipients of food from food banks from filing a lawsuit against the donor, because the charity organisation is seen as the final link in the food chain (Planchenstainer 2013). Whether the European food law mandatory requires an amendment in line with the Good Samaritan Act is controversial.

In the opinion of the German Ministry of Food, Agriculture and Consumer Protection (BMELV) the provisions of the European food law, especially those about food safety and food hygiene, also apply to the transfer of food to charitable institutions (BMELV 2012a). Following this legal interpretation, social organisations that receive food by donors and pass it on to other social organisations or directly to needy persons act as a ‘food business operator’. Under the General Food Law (Regulation (EC) 178/2002) food business operators are responsible for the safety of food within the business under their control. Responsibility implies liability. The General Food Law also contains the principle of ‘traceability’ which is defined as the ability to trace a product and its ingredients forwards and backwards in the supply chain from harvest up to final consumption. The obligation of traceability at least refers to the immediate preceding and subsequent stage in the food chain (Schroeder 2006; Van der Vorst 2006). Furthermore, food business operators have to adhere to the hygiene rules imposed by Regulation (EC) 852/2004 (see section 10.5.1). According to BMELV, charity organisations which distribute food are also subject to these rules, regardless of whether the food products are distributed free of charge or in exchange for money.

In contrast to the German Ministry of Food, Agriculture and Consumer Protection, Planchenstainer (2013) who carried out a thorough examination of European food law and the prevailing legal practice, calls into question if charity organisations collecting surplus food have in fact to be seen as ‘food business operators’. He argues that the European regulations grant some flexibility, allowing a preferential treatment of such organisations by the national authorities. So, Regulation (EC) No 852/2004 provides for certain exceptions. The provisions should not apply to the preparation, handling and storage of food for private domestic consumption. Furthermore, they should only apply to undertakings which imply a certain continuity of activities and a certain degree of organisation. In the view of

Planchenstainer food banks and charity organisations could be associated with one or the other of these categories, enjoying the same status and facing less burdensome requirements.

Nevertheless, the author pleads for the introduction of a provision analogous to the Good Samaritan Act, mainly because without any modification of the European food law, donors may be discouraged to give their surplus food to charity organisations. Under the applicable law, they may be driven to discard non-marketable goods in order to avoid liability (similar Lipinsky et al. 2013; BIOIS 2011). Following Planchenstainer’s suggestion, a common European standard for the liability of charity organisations that redistribute food and their donors should be implemented by amending Regulation (EC) 178/2002.

**For-Profit-Enterprises**

Apart from the redistribution of food by charity organisations there are also profit-oriented companies that collect non-marketable products from retailers and resell them in discount stores or via internet. One example is the online-shop ‘Approved Food & Drink Company’, founded 1990 in the UK, which distributes groceries at favourable prices. The product range is limited and includes products that are damaged, near or past the expiry date and de-identified (products where the brand name has been removed). Besides everyday food stuff, the company offers dietary products and non-food items. Usually, the products listed on the website of the company are available only for a very short time.

The commercial resale of non-marketable products, which represents according to the BIOIS-study (Monier et al., p.93) “an innovative private-sector approach to avoid food waste and the related adverse environmental impacts”, has pros and cons. Its advantage is that they can educate consumers about the difference between ‘best-before’ and ‘use-by’ dates and to convince them that even products beyond their ‘best-before’ date are completely fit for human consumption. The downside is that the sale of large packages at bargain prices further undermines the estimation of food and makes it easy for customers to throw away the food purchased in excess. Furthermore, it evokes additional transport. Up to now, there is no empirical research on the impacts of this marketing concept on consumers’ behaviour and the generation of food waste.

**10.2 Agricultural Production**

According to ITAS-calculations (see section 5.2) agricultural production in EU-27 contributes to a considerable extent to total food waste in Europe. High waste rates can be found especially for the Southern European countries Cyprus, Spain, Greece and Italy as well as for the Netherlands and Belgium. This is due to the fact that all these countries produce high amounts of agricultural goods that are exported.

In contrast to the estimates of Gustavsson et al. (2011) and ITAS-calculations a recent German study carried out by the Johann Heinrich von Thünen Institute in cooperation with the Max Rubner Institute and the Julius Kühn Institute (Peter et al. 2013) comes to the conclusion that food losses in primary production are relatively small. The study exemplarily examined four products: wheat, potatoes, apples and carrots. The product-related loss rates were estimated using existing research results, backed up by supplementary expert interviews. The study was strongly criticised because the authors assume a ‘loss’ only if an agricultural product was not directed to alternative uses. For wheat and potatoes also the energy use was considered as a recovery alternative, for fruit and vegetables also the further processing into animal feed. Thus, the estimate was limited to storage losses. This explains why the study shows relative small food losses in primary production, ranging from 3% for wheat to 11% for apples, whereas the loss rates estimated by Gustavsson are between 2% and 20% (see table 4). According to our definition (see chapter 2), food items that were originally dedicated to human consumption, but are removed from the supply chain due to different reasons are considered to be food waste, even if they are brought to a non-food use.
Contributory factors leading to food wastage in the primary production are food safety standards imposed by law as well as rigorous quality standards set up by retailers, supply agreements with large scale distributors, crop damages and prices that do not justify the expense of harvesting. In the following, existing obstacles and approaches to reduce food waste in the agricultural sector will be described.

10.2.1 Review of EU-Legislation on Contamination of Food

The societal objective of preventing risks to consumers’ life and health, which is anchored in various EU regulations and directives, may come into conflict with the ambition of avoiding food waste. A study of Wageningen UR (Waarts et al. 2011), commissioned by the Dutch Ministry of Economic Affairs, Agriculture and Innovation, identified strict norms for contaminants and Maximum Residue Levels for pesticides and veterinarian medicines in foods as significant legal drivers promoting food waste in the primary production. The study was carried out in 2010 and involved via interviews and workshops more than fifty stakeholders representing all stages of the food chain and all areas of food production (horticultural, agricultural, meat, dairy and fisheries sector).

Current Regulatory Framework

There is a variety of laws and regulations dealing with food safety. A distinction should be made between contamination of food occurring during production, residues of pesticides on crops and residues of veterinarian medicines in foodstuffs of animal origin. For all these types of contamination maximum concentrations limits have been set on European level.

The basic principles of EU-legislation on contaminants of food, laid down in Council Regulation 315/93/EEC of 8 February 1993, require that:

- food containing contaminants to an amount unacceptable for human health and in particular at a toxicological level, shall not be placed on the market
- contaminant levels shall be kept as low as reasonably achievable following recommended good working practices (ALARA-principle)
- the Commission may establish the maximum tolerance for certain contaminants that can threaten public health

Maximum levels for certain contaminants in food are set in Commission Regulation (EC) No 1881/2006, which entered into force on 1 March 2007. The annex of the directive lists hundreds of foods with the associated maximum concentration of contaminants, such as nitrate, mycotoxins (aflatoxins, ochratoxin A, patulin, deoxynivalenol, zearalenone, fumonisins), metals (lead, cadmium, mercury, inorganic tin), 3-MCPD, dioxins and dioxin-like PCBs and polycyclic aromatic hydrocarbons. For some contaminants a ‘zero tolerance’ policy is applied. According to Article 3 of the regulation it is prohibited to use foodstuff exceeding the maximum values as ingredients of food dedicated to human consumption, to mix it in order to reduce the contamination level or to detoxify it by chemical treatment. Regulation 1881/2006 has been substantially amended many times, taking into account new information and developments.

The use of pesticides is governed by Regulation (EC) No 1107/2009 of 21 October 2009, which repealed and replaced Council Directive 91/414/EEC and came into force on 14 June 2011. The regulation aims to harmonise the overall arrangement for the approval of plant protection products in the EU, laying down rules for their authorisation and their placing on the market. According to these rules, Member States can only authorise the marketing and use of plant protection products after any contained active substance has been shown to be without unacceptable risk to people or the environment and added to the list of approved active substances. The list of approved active substances is contained in the Commission
Implementing Regulation (EU) No 540/2011 of 25 May 2011. Inclusion is for a maximum period of 15 years, but it is renewable and can be subjected to conditions and reviewed at any time.

A possible consequence of the approval of plant protection products may be the presence of pesticide residues in food. To ensure that these residues do not reach levels which may cause harm, statutory Maximum Residue Levels (MRLs) are set. Regulation (EC) No 396/2005 provides a harmonised system of MRLs setting, and applies to all foods treated with pesticides after 1 September 2008. The annexes to this regulation specify the MRLs and the food commodities to which they apply. All substances acting as pesticides are subject to these regulations, whether or not they have authorised uses within the EU. Farmers, importers, distributors and retailers are responsible to ensure that marketed food complies with all statutory MRLs set. National authorities are responsible for control and enforcement of the MRLs.

Residues of veterinarian medicines are governed by Regulation (EC) No 470/2009 of 6 May 2009, laying down uniform procedures for the establishment of maximum concentrations for residues of pharmacologically active substances in foodstuffs of animal origin, which repealed Regulation (EEC) No 2377/90 of 26 June 1990. Aim of the legislative amendment was to improve consumer health protection and the functioning of the Single Market by providing clear references for the control of residues of veterinarian medicines in food, to clarify uniform procedures for the establishment of residue limits by ensuring consistency with international standards and to simplify existing legislation.

Perceived Legal Barriers

The above mentioned study of Wageningen UR identified various legal obstacles with regard to the current legislation on food contamination, promoting the discarding of edible food (Waarts et al. 2001, p.29 et seqq.):

- Setting of always lower limits for pesticide residues in fruit and vegetables leads to reduced use of plant protection products and increases losses in storage.
- Following the precaution principle, some norms are stricter than necessary to exclude risks for public health: in some cases MRLs are based on what is the technically feasible minimum. Rejecting foodstuff that fails to comply with the feasibility norm, but meets the public health norm, means to destroy food that is perfectly suitable for human consumption.
- ‘Zero tolerance’ policy for certain substances in combination with always improved measuring methods enabling even the smallest traces of pollution to be detected: theoretically, the proof of a single molecule of a prohibited substance may result in the destruction of the entire batch.
- Lack of MRLs for certain substances and long procedures to get authorisation.
- Inconsistency of current legal provision: authorisation of certain plant protection products only for one type of fruit, but not for similar types. For example, if residues of an individual pesticide permitted for apples are found in pears, the pears will be rejected and destroyed.
- Strict prohibition of mixing and chemical or physical treatment of food in order to reduce the contamination level.

Proposals to Overcome Perceived Legal Barriers

Although the fixing of strict concentration limits for contaminants seems to be preferable from the viewpoint of food safety, there is no denying that it is a significant cause of food losses in the primary production. In the light of even more precise methods of measurement, the current practice of setting maximum levels according to the precautionary principle should be reviewed in order to assess whether they are really justified from the perspective of human health. Waarts et al. (2011, p.71) suggest taking an inventory of MRLs that seem to lie below the standard of human health and lead to unnecessary food
waste in practice. Further research is required to decide where concentration limits may be increased without running a risk for food safety.

However, the question, whether the setting of less stringent standards would actually result in a reduction of food waste, is controversial. Some argue that fruit producers, wholesalers and supermarkets would not adopt toned down standards in practice. In the past the affected parties often adhere to stricter concentration limits than required by law, as a result of the ‘naming and shaming’ of retailers by telecasts and NGOs in the context of food contamination scandals. In the workshops organised by Wageningen UR, a public dialogue between government, producers, retailers and civil society organisations was proposed that might help to reduce the negative publicity and contribute to a more objective debate on the fixing of maximum residue levels (Waarts et al. 2011, p.32, 78).

### 10.2.2 Amendment of European Marketing Standards

By Regulation (EC) No 1221/2008 of 5 December 2008 the number of specific European marketing standards for fresh fruit and vegetables was cut back from 36 to ten. The intentions pursued with this amendment were to increase product choices for the consumer and to reduce waste. The reduction of waste was expected to have also positive impacts on food prices (Milzow 2009). Under the new regime, fruit and vegetables not covered by a specific marketing standard shall conform to the **general marketing standard** set out in detail in Part A of Appendix I of the Regulation. Minimum requirements are that the products are intact, clean, free from pests and damages caused by pests, free from abnormal extern moisture, free from any foreign smell or taste and in such condition that they can withstand transport and handling. Furthermore, the products must be sufficiently developed and display satisfactory ripeness. Community requirements in terms of shape, size and colour are no longer provided.

For ten types of fruit and vegetables (apples, citrus fruit, kiwifruit, lettuces, peaches & nectarines, pears, strawberries, sweet peppers, table grapes and tomatoes) **specific marketing standards** remain in place. The reason for this different treatment of individual product groups by the European legislator is – according to the preamble of the regulation – the relevance they have for intra-and extra-community trade. The ten products, for which the EU maintains specific standards, constitute 75% of trade in value terms (Tobler 2010). However, Member States may exempt even these products from the specific marketing standards, if they are presented for retail sale to consumers and appropriate labelled as ‘products intended for processing’ or any equivalent wording. Four Member States – Cyprus, Denmark, Germany (apples and pears) and the United Kingdom – have made use of this provision (freshfel Europe 2012).

Whether the European legislator should adopt regulations that do not concern consumers’ life and health, but the shape, size and colour of agricultural products, remains a controversial issue. The repealing of the specific marketing standards in 2009 was supported by most consumer associations and environmental groups, primary in view of the intentions pursued: reduction of waste, increase of consumer choices and decrease in prices. Among producers, wholesalers and retailers there were, however, also many voices in favour of the standards. In particular, farmer unions from producing countries like France, Germany Italy, Poland and Spain opposed the revision, warning that it would become more difficult for consumers to compare quality and prices across EU. Fears of price drops were articulated as well, particular clearly in France. German retailers like Aldi and Kaiser’s also pleaded for maintaining the status quo. In contrast, British producers and retailers favoured the revoking of the standards. The different positions of British and other European farmers’ associations can be partly attributed to structural differences within the agricultural sector. Whereas large farming enterprises have adjusted their production to the standards, smaller producers would more likely benefit from the change (Milzow 2009).
Criticism of the reform, however, came not only from parties concerned, but also from others. Legal experts criticise the inconsistent treatment of individual product groups that cannot be justified by compelling reasons (Tobler 2010). Protagonists of a fundamental restructuring of food production argue that the European legislator should set another type of standards, not relating to the external appearance of a product, but to its quality for human consumption in terms of taste, natural purity, nutrition value, ingredients, growing conditions etc. (Kreutzberger 2012; Stuart 2009).

In practice, the impacts of revoking the specific marketing standards remained quite small. The expectation that the sale of products with deviant shape, size and colour to consumers would significantly increase was not fulfilled. One reason is that the 26 types of fruit and vegetables covered by the repealed norms account for only 25% of all fruit and vegetables marketed in the EU. The more important reason is that especially the trading sector has an interest in maintaining the standards, providing an objective yardstick, which facilitates business relationships between producers, manufacturers and retailers (BVL 2012). Furthermore, the logistic processes in storage, packaging and distribution are geared to standardised products and cannot handle goods with irregular size and shape (Waarts et al. 2011, p.12). Thus, the original statutory standards are further used by different food companies in form of private norms.

**Proposals to Overcome Perceived Barriers**

There are no legal obstacles for the marketing of fruit and vegetables that do not meet the standards; however, due to the market power of large retailers this option only plays a minor role in practice. Very few supermarkets offer products of a second quality class to a reduced price. One positive example provides the British supermarket chain Waitrose, which recently introduced a new range of ‘not perfect’ fruit and vegetables (Stuart 2009).

Usually it is left to the producers themselves to seek alternative distribution channels and to develop innovative marketing strategies for second class goods. Possible solutions are:

- **Fruit and vegetables that were rejected by trade or produced in abundance can be further processed into fruit juices, jams or canned products.** Up to now, there are no data available to what extent this type of secondary recovery path is used. It seems important that the producers find bulk buyers for processing fruit and vegetables and negotiate fixed purchase contracts with them.

- **In the context of direct marketing, producers should offer products already processed on the farm (e.g. sales of lettuce hearts as a strategy to recover lettuces that are wilted or surplus)** (WWF 2012).

- **Supermarkets seem to be convinced that consumers will not buy fruit and vegetables with deviate shape, size and colour.** Surveys, however, show that consumers are willing to buy aesthetically imperfect products as long as the taste is not affected (Stuart 2009). According to Gustavsson et al. (2011) consumers have the power to influence the quality standards set by retailers and the range of products offered in stores. They should make use of this power.

### 10.2.3 Promotion of Direct Marketing Systems

Direct marketing of agricultural products offers an opportunity to bypass the ‘middlemen’ in the food supply chain and to establish a closer link between producers and consumers. Due to a growing interest in sourcing local food and an increasing concern about the adverse impacts of an industrialised agro-food business, decentralised direct marketing schemes have significantly augmented in recent years. A close partnership between producers and consumers offers many benefits. It provides consumers with an improved access to fresh, healthy, locally grown foodstuff at affordable prices, from sources that they know and trust. Produce that is sold directly does not require additives which are used to extent the
shelf life of a product or to keep it fresh during transport. By avoiding long distant transport, direct marketing has also positive impacts on the environment. For producers it offers the opportunity to build a customer base, obtain better prices and try out new product lines without taking too much risk (Oberholtzer & Grow 2003; Trobe 2001).

Among the many types of direct marketing systems, the most known are: Farm shops and farmers’ markets, delivery of vegetable boxes by subscription, mail-orders, producer co-operatives, solidarity purchasing groups and Community Supported Agriculture (CSA). The different models are more or less popular in individual countries. Vecchio (2009) found that CSA has gained increasing importance in the American food system, while solidarity purchasing groups (association of consumers who buy directly from selected producers) flourish in Italy. In Spain producer co-operatives have been successful, while in Germany the concept of subscribed vegetable boxes is quite widespread.

In the last decade a renaissance of farmers’ markets can be observed across European as well as North American States. In the USA the number of farmers’ markets has grown by 150% between 1994 and 2006 (Brown & Miller 2008). Several case studies, carried out both in rural and urban areas of Europe and the United States, suggest that farmers’ markets are a ‘keystone’ for rebuilding local food systems. By making local food more visible, they educate consumers on the potentials and seasonal limits of local food production. Furthermore, farmers’ markets foster the production of a greater diversity of food products and have positive economic impacts for local business (Gillespie 2007; Oberholtzer & Crow 2003). Given the popularity of farmers’ markets, even supermarket chains like Asda and Tesco jump on the bandwagon by holding farmers’ markets in their car parks and foyers (Trobe 2001).

Community Supported Agriculture is a contractual agreement between a farm and a group of consumers who pledge financial support to a local smallholder. The involved consumers, called ‘members’, ‘shareholders’ or ‘subscribers’, commit themselves to cover the anticipated operative costs of the farm, containing an appropriate reward for the farmer. In return, they receive shares of the harvested crops throughout the growing season. Depending on the output of the farm, the shares could comprise other products, such as eggs, poultry, honey, cheese, bread and flowers. Some farms provide ‘winter shares’ of root vegetables for storage in November and December. Members also bear the risks together, including poor harvests due to unfavourable weather or pests. By direct sales to community members who have provided the farmer with working capital in advance, growers receive better prices for their crops, gain some financial security, and are relieved of some burden of marketing. The CSA-concept was first developed in the 1960s in Japan and called teikei which can be translated into ‘food with the farmer’s face on it’. European farmers adapted the teikei-concept during the 1970s and brought it 1985 to the United States (Brown & Miller 2008; Adam 2006, Wilkinson 2001; Cone & Myhre 2000). Besides the United States, CSA-systems are practiced in Austria, Belgium, Croatia, France, Germany, Italy, Norway, Portugal, Romania, and the United Kingdom. All these different models are represented in the international network ‘Urgenci’.

The original idea of direct marketing was not avoiding food waste, but to foster community, to preserve local food production, to revitalise rural economies and to protect the environment (Adam 2006). Nevertheless, for various reasons circumventing the middlemen in the food supply chain can contribute significantly to the prevention of food waste. Direct marketing shortens transport distances between producers and consumers, thereby reducing the risk of spoilage. By making food production and its natural and seasonal limits more visible, it encourages customers to a sparing and responsible handling of food. Furthermore, losses caused by wholesale/retail, e.g. by means of supply agreements forcing farmers towards overproduction or rejecting products that do not meet the standards, are avoided.

Despite the sharp growth of direct marketing approaches in recent years throughout Europe, they still represent only a small part of the food system (Vecchio 2009; Brown & Miller 2008). Whether in the future direct marketing can be more than a niche for consumers with high environmental and food quality awareness remains to be seen. With regard to an efficient use of food, this concept can bring advantages and should be stimulated (similar Stuart 2009; Gustavsson et al. 2011). On the other hand,
due to seasonal restraints, direct marketing systems can never replace the weekly supermarket for most people (Trobe 2001). Another limitation is that there is little empiric research on the impact of direct marketing systems on food waste generation. Some concepts like for example subscribed vegetable boxes might produce even more food waste than normal supermarket purchasing, due to the fact that consumers may be supplied with food items they do not like or do not know how to cook. Further research is needed to assess the impacts of direct marketing systems on food waste generation.

### 10.2.4 Plant Breeding and Genetic Engineering

In the field of agriculture, plant breeding can be used to create robust and durable species which withstand transport and have long shelf lives. Cultivation of fruit and vegetables with such attributes is already widespread today. Moreover, there have been attempts to achieve special properties via genetic modification. An example of a genetically modified product with extended shelf life is the FlavrSavr tomato, which is known for its long shelf life without getting overripe. This tomato was introduced on the US market in 1994 and was removed three years later due to various reasons. Key drivers were lacking acceptance by consumers and not satisfactory cultivation results (lacking resistance to environmental conditions and low yields). Plant breeding, including genetic engineering may provide effective strategies to combat food waste. However, due to the risks associated with these technologies their use requires further research and a careful weighing up of the pros and cons.

Table 20 gives an overview on the different approaches to reduce food waste generation in agricultural production.
Table 20: Approaches to reduce food waste in agricultural production

<table>
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<tr>
<th>Instrument</th>
<th>Approaches</th>
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| **Cooperative Instruments** | - Initiation of a dialogue between government, producers, retailers and civil society organisations about the fixing of maximum residue levels  
- Exercising of consumers’ pressure on retailers to introduce a new range of fruit and vegetables with aesthetical deficiencies not affecting quality and taste |
| **Regulatory Instruments**  | - Review of EU-legislation on contamination of food  
- Taking an inventory of maximum residue levels that seem to lie below the standard required to protect human health  
- Elimination of inconsistencies in the current law concerning the approval of plant protection products  
- Abandoning private norms set by retailers that are more stringent than general marketing standards  
- Setting another type of European marketing standards, not relating to the external features of a product, but to its quality for human consumption |
| **Organisational Instruments** | - Opening alternative marketing channels for fruit and vegetables rejected by retail or produced in abundance  
- Developing innovative marketing strategies for second class goods  
- Promotion of direct marketing systems in order to create a closer link between producers and consumers |
| **Economic Instruments**     | - Tax incentives for food donations from the agricultural sector |
| **Technical Instruments**    | - Use of plant breeding to create robust species which withstand transport and promise long shelf life |

10.3 Manufacturing

The manufacturing sector accounts for 39% of total food waste in Europe pursuant to the BIOIS-study (Monier et al. 2010) and 12% based on own calculations. According to ITAS-calculations, processing and packaging food waste is highest in Eastern, Northern and Central European countries like Czech Republic, Slovakia, Estonia, the United Kingdom, Denmark, Ireland, Germany and Luxembourg. This can be explained by the fact that on the one hand there is a high concentration of food processing companies in these countries and on the other hand in Eastern countries production efficiencies may be not fully exploited yet. Main causes for food waste generation in this sector are: surplus production due to short-term cancellations and returns by retail, selection processes based on aesthetic criteria, surpluses due to production for specific brands, failure to comply with food safety and hygiene rules, damaged packaging or incorrect labelling, seasonality of products, limited storage capacities and high storage costs. In the following paragraph approaches for preventing food waste generation in the manufacturing sector (inclusively packaging) will be outlined.
10.3.1 Improving Workflows

There are different possibilities for the improvement of workflows, most of them relate to organisational and logistical optimisations. The WWF-study on food waste generation in Switzerland (WWF 2012) specifies the following measures as most relevant:

- Use of production equipment according to the actual state of technology, which causes little residues and rejections
- Monitoring of rejections and regular inspection of equipment
- Arranging production lines in a way that containers have to be minimally cleaned, e.g. preparation of fillings in the following order: from bright to dark, mild to piquant, organic to conventional products, vegetarian to meaty etc.
- Reintegration of fallen out goods in the production process
- Intensifying staff training on right handling of food and possibilities to avoid wastage during the entire production process
- Coordination with retailers to come up with an agreement on the range of goods and required amounts in order to avoid surplus production
- Cooperation with charitable organisations for redistribution of surplus food

Stuart (2009) reports on ways how manufacturers can cope with imprecise orders by supermarkets. He explains that a lot of products contain identical ingredients (like tomato sauce), although they are produced for a certain brand. Instead of mixing all ingredients in different production streams, processing industry should hold the ingredients back until the supermarkets confirm their orders and not till then start the final production process. Manufacturers who tested this approach declared that enormous amounts of food and up to 20% of production costs could be saved (Stuart 2009).

In the UK programmes like ‘Envirowise’ (financed by the government) or the ‘Food Processing Faraday Partnership’ have helped plenty of manufacturing companies to improve the efficiency of resource use, reduce waste generation and costs. These programmes are primarily focussed on supporting business by providing information, guidance and advice that allows companies to implement improved practices. The Envirowise programme offers advice through a helpline, website, events, publications and site visits. The Faraday Partnership also runs the ‘Food Processing Knowledge Transfer Network (KTN)’, which facilitates the introduction of new techniques and equipment.

10.3.2 Extending Shelf Life by means of Active Packaging

As a response to consumer demands (less time spent on shopping and cooking), industrial production trends (mildly preserved, fresh, tasty and convenient products with prolonged shelf life and controlled quality) and changes in retail practices (market globalisation resulting in longer distribution chains) the development of new and improved packaging has increased. Active Packaging can be used to extend shelf life, but also to improve quality and safety of products. Depending on product groups, different functions can be applied to packaging, like for example oxygen scavenging, oxygen permeation, moisture absorption, humidity regulating or antimicrobial characteristics of materials. The main application area for active packaging concerns perishable food items like meat, sausage, dairy products, fruit and vegetables (Müller 2013). While moisture regulating films are most adequate for dry products and meat, anti-fogging and gas permeable films are recommended for fresh fruit, vegetables and ready-to-eat-salads (Restuccia et al. 2010).

There are different activities in the area of active packaging. One example is the ongoing project Safe Pack (2012-2015) on antimicrobial plastics for extending shelf life of meat products, funded by the
Federal Ministry of Food, Agriculture and Consumer Protection in Germany (BMELV). Aim of the project is the development of antimicrobial plastics for the self-service field of supermarkets, which cause an improvement in the quality, durability and food safety of meat and meat products. In the focus of the project are in addition to the technological development, investigations of the different products in pilot studies and the economic assessment of packaging solutions for different applications. Another example is the application of the preservation ingredient natamycin, an antimicrobial agent which prevents the growth of moulds and yeasts. It is used for various foods such as cheese, sausages, yoghurts and do not pose any risk to humans. Moreover, a packaging product called ‘Pack-Age’ was developed which allows cheese to ripen naturally in a film with an optimum taste and texture. Both products are developed by the Dutch company DSM (Segrè & Gaiani 2012).

Active packaging must comply with European Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food and with the new Regulation (EC) No 450/2009 on active and intelligent materials and articles intended to come into contact with food. The Regulation No 1935/2004/EC offered for the first time the opportunity for active packaging to be used in Europe by allowing the application of materials with agents that could migrate into foods. The new regulation which lays down additional rules for active and intelligent materials and articles is seen as a reaction to the lack of penetration of active and intelligent packaging in the European market compared to Japan, USA and Australia (Restuccia et al. 2010). This amendment has been critically commented as an attempt to promote commercial interests (without taking public interest into account) and not made with the intention to fill a regulatory gap. To guarantee the conformity of the used materials, all active and intelligent packaging systems initially need to be evaluated by the European Food Safety Authority, based on toxicological data.

Although not yet widely spread, nanocomposite packages are predicted to make up a significant portion of the food and beverages packaging market in the near future. Some of the applications associated with nanotechnology are antimicrobial nano silver, carbon nanotubes, which improve the mechanical properties of the packaging, and nano-sensors used to detect chemicals, pathogens and toxins in food. Exposure to nanoparticles is likely due to dermal contact with the packaging material, ingestion due to leakage to foodstuff and inhalation of particles. Data on the toxicity of nanoparticles are currently very limited and it is not clear which effects on human health and the environment can be expected. Nanoparticles have unique chemical and physical properties. Their large surface for instance allows a greater contact with cellular membranes, as well as greater absorption and migration capacities. According to the regulations, nanotechnologies cannot be applied without further assessment, even when direct contact with the product is not intended or impossible. They should be assessed on a case-by-case basis, until more information is known about this new technology (Restuccia et al. 2010).

Although a new legal basis for the correct use, safety and marketing of active and intelligent packaging was set in order to increase their expansion on the EU market, there are still some obstacles for their implementation. The costs as well as deficient acceptance by retail, food industry and consumers are considered as main obstacles for the introduction. It is the question whether consumers will be willing to pay for the technology and if the different stakeholders perceive it as a strong benefit. While studies on acceptance by brand owners and packaging converters showed that existing materials were considered to already meet the market needs, research on consumers’ attitudes indicated that the majority is open to such innovations, providing that the material is safe and the information is comprehensible for the user. Furthermore, consumers are demanding food-packaging materials that are more natural and recyclable or even biodegradable (Restuccia et al. 2010).

Table 21 gives an overview on the approaches to reduce food waste in food manufacturing.
Table 21: Approaches to reduce food waste in manufacturing

<table>
<thead>
<tr>
<th>Persuasive Instruments</th>
<th>➢ Staff training on right handling of food and possibilities to avoid wastage during the entire production process</th>
</tr>
</thead>
</table>
| Cooperative Instruments | ➢ Seeking an agreement on the range of goods and required amounts in order to avoid surplus production  
➢ Cooperation with charitable organisations for redistribution of surplus food |
| Organisational Instruments | ➢ Checking of possibilities to reintegrate deficient products in the production process  
➢ Avoidance of cleaning losses (e.g. preparation of fillings in the following order: from bright to dark, mild to piquant, organic to conventional products, vegetarian to meaty etc.)  
➢ Starting the mixing of ingredients as late as possible  
➢ Improving visual presentation of expiry dates (e.g. bigger font sizes, different coloration) ⇒ see section 10.4.2  
➢ Simplifying food labelling (reducing the number of labels) ⇒ see section 10.4.2 |
| Economic Instruments | ➢ Tax incentives for food donations from the manufacturing sector  
➢ Taxes on waste treatment |
| Technical Instruments | ➢ Adapting the production equipment to the actual state of technology  
➢ Regular inspection of equipment and monitoring of deficient products  
➢ Applying active packaging in order to increase shelf life of products |

10.4 Distribution, Wholesale and Retail

According to the estimates of BIOIS (Monier et al. 2010) and our own calculations (see section 5.2) the wholesale/retail sector generates the smallest portion of food waste, only about 5% on average of total food waste in the EU Member States. Here however, two restrictions have to be observed: The one is that the wholesale/retail sector represents also the area where empirical studies are particularly scarce. The available data are mostly based on extrapolations. Secondly, it can be assumed that large retailers have a strong influence on the generation of food waste in the upstream and downstream stages of the food chain (see section 4.3). By setting quality standards for agricultural products, for example, retailers leave the rejected goods with the producers. Marketing strategies like ‘buy one get one free’ in order to address overstocking problems shift the responsibility from retail to households. The statistical recording of waste by EUROSTAT and FAOSTAT register only foods that are discarded directly by supermarkets and do not consider the food wastage induced by activities of the wholesale/retail sector on the preceding and subsequent stages. Thus, the amount of food waste generated by this sector may be generally underestimated. Primary reasons for the creation of food waste in retail are inaccurate ordering and overstocking, reaching of expiry dates, lack of cold storage, interruption of the cold chain and product damages. The most discussed approaches to prevent food waste at retail and wholesale are presented below, including those that refer to the upstream and downstream stages.
10.4.1 Monitoring during Distribution

Smart wireless temperature monitoring microsystems such as Radio Frequency Identification (RFID) systems in combination with shelf life prediction tools can be used to control the status of products. They are only applicable from production to retail; the consumer stage is not integrated in this concept. The company ‘Fresh Test’ for instance developed technologies to monitor the status of food shipments and deliveries which also measures humidity and pH-value. An integrated alarm system warns customers when critical limits are exceeded (Segrè & Gaiani 2012).

Mathematical models to predict microbiological growth and thus to estimate shelf life of certain product groups can be used. They can help in specific situations of decision making, for example by optimising the storage management from the ‘First In First Out’ (FIFO) to the ‘Least Shelf life, First Out’ (LSFO) concept (Bruckner et al. 2013). In frame of the EU-project FRISBEE (Food Refrigeration Innovations for Safety, consumers’ Benefit, Environmental impact and Energy optimisation along the cold chain in Europe) new tools, concepts and solutions for improving refrigeration technologies along the European food cold chain will be provided. Structured quality management systems based on prevention by monitoring, controlling and recording of critical parameters throughout the product’s life cycle will be developed. This will include new innovative mathematical modelling tools that combine food quality and safety together with energy, environmental and economic aspects in order to predict and control food quality and safety in the cold chain.

In frame of the project ‘Intelligent Container’, funded by the German Ministry of Education and Research (BMBF) a shipping container was developed and tested in cooperation with the fruit and vegetables producer DOLE. The container is equipped with wireless sensors. During shipment the container and its cooling unit can be online monitored and configured via satellite connection. The container was tested for shipment of bananas from Costa Rica to Europe. It is also possible to adapt the logistics to the actual status of the products via dynamic route planning. The temperature data are evaluated by a product-specific shelf life model. The various available means of transportation are represented by software agents. In case of quality problems, the agents get into contact with each other in order to find another transport possibility or unloading point. It remains to be seen if the distribution and retail sector will be interested in this technology at all.

Although monitoring technology can help identifying vulnerabilities and optimising the cold chain, it can also lead to an increase of food waste generation as it reveals all weak points and enables stricter controls. It is important that the technology design includes possibilities for intervention in order to prevent food wastage and that the pros, the cons and possible alternatives are weighed up carefully before implementation.

10.4.2 Streamlining Food Date Labelling

The influence of expiry dates on food waste generation is discussed very controversially. Purpose and content of expiry dates are defined in the EU Directive 2000/13/EC on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs. On national level country-specific translations of the ‘best-before’ and ‘use-by’ date are implemented. While the use-by date is the latest date recommended for the use of a product from a food safety perspective (e.g. for minced meat, raw fish), the best-before date does not refer to food safety. It can be seen as a warranty of liability by the producer and groceries should be safe to eat after this date. The best-before dates are not set by law, they are normally determined by manufacturers on the basis of laboratory studies (Waarts et al. 2011).

In addition to the legally required dates mentioned above, retailers can use other labels such as ‘display-until’ dates, which are used for commercial purposes and aim to help shop staff with stock control. These have no legal basis and are not aimed at consumers (DEFRA 2011).
Different empirical studies on households’ behaviour within the EU found out that expired best-before dates are an important cause for the disposal of food in households as consumers connect both terms with spoilage and inedibility of the products (Gusia 2012; Katajajuuri et al. 2012; Barabosz 2011; Glanz 2008; Ventour 2008). This assumption is confirmed by our survey, too. It is mainly the question if a lack of knowledge on the meaning of these food date labels or confusion due to different notions result in increased waste generation on household level and how this could be avoided. There is a debate about whether a change of the terms, a simplified labelling or rather consumer information campaigns would be more successful in addressing the problem.

Researchers and also many stakeholders question the sense of a change in terminology as they expect same difficulties also for another wording. The German retail and food industry assumes information campaigns on expiry dates to be useful measures, like initiated by the Ministry of Food, Agriculture and Consumer Protection (BMELV) together with the retail and food industry (BVE 2012; BVL 2012). Lipinski et al. (2011) suggest retailers to post in-store displays, provide leaflets or print messages on grocery bags that define the various food date labels and explain their differences. Thurn (2012) argues for a better visual presentation of the best-before and use-by dates. He criticises that the labels are barely readable due to small font sizes while the dates are in large letters. This would direct consumers’ attention to the dates and the difference between the labels would not be noticed. He recommends bigger letters and a different coloration of the best-before and use-by labels.

A pilot experiment of Tesco, one of the largest worldwide operating retail companies, showed that reductions in food waste for items with only a single date code could be realised. Tesco has piloted the use of a single code on meat (use-by), fruit and vegetables (best-before) in UK stores. Additionally, ‘display-until’ dates were removed from these items (Lipinski et al. 2013).

It is not prohibited to re-label and sell products with expired best-before dates, so far as it is assured that they are not harmful to human health. Due to liability reasons, it is simply not a common practice. Waarts et al. (2011) investigated legislative obstacles for the reduction of food waste in the Netherlands and found out that producers set best-before dates very conservatively in order to limit their risk in terms of product liability and potential damage to reputation. For the same reason retailers decide to not re-label products which have passed their best-before dates. The involved stakeholders of the food chain argue for setting new best-before dates according to true shelf life and the abolition of expiry dates for stable foods like salt, sugar, rice or dried beans. Also consumer representatives like the German Rural Women's Association recommend the cancellation of expiry dates for certain product groups and the development of guidelines for more realistic best-before dates (dlv 2012).

Within these different considerations it should always be kept in mind that food wastage due to expired best-before dates is also linked to a non-optimal food supply on the different stages of the food chain and that this point has to be addressed as well. Measures like writing shopping lists at household level as well as optimisation and further development of intelligent ordering systems at retail need to be further discussed.

10.4.3 Intelligent Labels

One possibility to control the temperature history of a product from the packaging process to the consumption is the implementation of Time-Temperature-Indicators (TTIs). Time-Temperature-Indicators (TTI) monitor and record the temperature along the whole cold chain. The principle is based on enzymatic, chemical, mechanical, electrochemical or microbiological reactions which result in a color change of the label in a rate that is temperature dependent. A high temperature leads to a fast colour change, a low temperature to a slow discoloration process in the labels. TTIs can be especially applied for the last stage of the chain, on the way from retailer to consumer (Kreyenschmidt et al. 2010).
The European research project FRESHLABEL (2005-2008) aimed at the development of the first generation of commercially available and applied Time-Temperature-Indicators (TTIs) for fresh chilled products (primary meat and fish products). The project showed that there are still many unexploited application areas for intelligent labels.

In the subsequent EU-project IQ-Freshlabel (2010-2014) novel intelligent labels to monitor temperature abuse of frozen foods and oxygen content in modified atmosphere packaged products are developed. These labels will show a colour change when the modified atmosphere is changing, which has in most cases a high level of carbon dioxide and a low level of oxygen. The focus of research is presently on meat, meat products and fish as quickly perishable products. Other areas of application could be milk, drinks, as well as the pharmaceutical industry. There is also research on labels indicating the perishableness during consumption when the packaging is already opened. Partners from Finland, France, Germany, Greece, Italy, Norway and Poland are participating in this project.

In addition to technological development, a flexible online tool has been developed to calculate the costs and benefits for the implementation of intelligent labels in different parts of the food chain. Furthermore, investigations on expectations and concerns of consumers, retailers and the food industry in different Member States were conducted. The results of the interviews are not published yet. In personal contact with one of the project partners it was reported that several TTI-systems are already available, but up to now they are not widely spread due to different reasons.

Retail fears that consumers could not understand the labels and that this would lead to numerous customer complaints. Moreover, it is assumed that labels would have the same effect as expiry dates and that customers could select products with best coloration and leave others in the shelves. Retail also considers the implementation to be too expensive as the costs have to be added to the product price. This seems to be a difficult issue in light of high competition in the retail sector. According to operators in retail, the application of intelligent labels would also not be lucrative for products with low prices. It was mentioned that the food industry would be willing to implement such labels, also for internal uses, but that such action would particularly require the demand of retail as product labelling is always suited to the need of retail.

Interviews with consumers in Germany showed that they are rather open and positive towards the TTI-technology. Focus group discussions with Finnish consumers lead to similar results. Consumers considered intelligent labels to be innovative, reassuring and impressive, to improve safety, transparency and reliability in the cold chain, to assist in choosing products in store and to enhance consumers’ behaviour regarding food safety and monitoring. But also doubts were mentioned, regarding manipulation and removal of labels by retail, outsourcing consumers’ personal responsibility, increasing food waste, insufficient information and confusion about the technology and other labels and increased prices of the products (Pennanen et al. 2013).

Göbel et al. (2012) conclude that up to now there has not been any clear evidence that food waste generation can be reduced by using TTIs. The authors base their statement on an expert’s report of researchers at the University of Bonn who are partners in the European projects mentioned above. Nevertheless, Göbel et al. assume that these labels can improve the flow of information and enable a better decision making regarding the status of highly perishable products.

### 10.4.4 Adapting Packaging Sizes and Special Offers

The debate on packaging sizes and special offers is mainly about offering large quantities at low prices. It is argued that this marketing strategy would lead to consumers purchasing more than they actually

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34 Personal communication by Sonja Rossaint, partner in the IQ-Freshlabel-project, 26/06/13
need. Opponents of this argumentation like the Federal Association of the German Food Industry point out that on average consumers can choose between 7.4 different packaging sizes per commodity group and that the often mentioned trend towards ‘XXL-packages’ would not exist. It is argued that the strong competition on the side of producers and retailers would ensure that the product supply conforms to the demand (BVE 2012). The food industry, however, ignores that large packaging sizes are often much cheaper than smaller ones and so consumers are driven to buy bigger units.

Special offers like ‘Buy One, Get One Free’ (BOGOF) are considered to encourage non need-based shopping and the generation of food waste at household level. The World Resource Institute (Lipinsky et al. 2013) report on a British supermarket operator called ‘Co-operative Group’ which shifted away from ‘buy one, get one free’ promotions for perishable goods, using price reduction promotions for such goods instead.

In 2009 the British grocery retailer Tesco launched the initiative ‘Buy One Get One Free Later’ that allows customers to take advantage of BOGOF-deals by picking up their free item at a later date, if they don’t need it right now. The new arrangement works with a voucher system: A coupon will be issued to customers if they have not redeemed both items, offering the opportunity to claim the second product at another time. Products included in the programme are those with short sell dates like yoghurts, salad, lettuce, fruit, vegetables and cheese. The initiative addresses much-voiced concerns that BOGOF-promotions encourage customers to buy too much and lead to wastage. Mainly one- or two-person households may not be able to consume the products before they perish. The initiative was introduced by Tesco as a ‘green consumer revolution’ to cut down on food waste (Gray 2009). However, the question who benefits more from the initiative, the consumer or the company, is highly controversial (Baker 2009).

Price reductions are also considered useful for products which soon reach their best-before date (Silvennoinen et al. 2012). Thurn (2012) suggests to integrate expiry dates in the barcode, enabling automatic price reductions at the checkout. The price reduction could be applied to individual items or entire product groups like ‘two days before reaching the expiry date 30% discount on dairy products, a day before expiry 50%’. This procedure would reduce efforts for wrapping the items with new price tags, not devaluate products as extraordinary items, attract people to buy foods with shortest expiry dates and avoid social stigmatisation due to purchasing of price-reduced labelled products.

Although the retail sector affirms that price-reduced offers due to short expiry dates would be common practice (BVL 2012; EHI 2011), the implementation seems to be very different among supermarkets. This relates mainly to the fact that retail chains themselves can determine to what extent and in what form they would like to offer products close to the expiry date. Furthermore, organisational and economic considerations like regularly checking of shelves and input of labour for such activities as well as questions on presentation and placement of such products may prevent retailers from using this option more often.

### 10.4.5 Intelligent Ordering Systems

In order to counteract surpluses due to miscalculations, intelligent ordering systems can be used. These systems analyse sales data for each individual product, make forecasts for future demand (taking into account seasonal variations in sales, public holidays, weather conditions) and reorder the products according to the results. For retail such systems mean temporal discharge of staff, reduction of ordering and logistics costs caused by the flow of goods between headquarters and branch office and the prevention of sales shortfall due to non-existent or unnecessary goods. Providers of these forecasting systems include forseason (D), SAF (CH) or Teradata DCM (USA). Intelligent ordering systems are very common in retail; their penetration in German retail is about 45% (Buck 2008). Expansion and extension of these systems to special functions for preventing food waste would be imaginable, for example by an
automatic linking of data on expiry dates and short-term re-use opportunities in other stores, supermarkets and factories.

Table 22 gives an overview on the different approaches to reduce food waste generation in the wholesale and retail sector.

**Table 22: Approaches to reduce food waste in distribution, wholesale and retail**

| Persuasive Instruments | ➢ Awareness campaigns for customers on food date labelling and the right handling of food  
➢ Staff training on ordering, storage, handling and monitoring of products |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| Cooperative Instruments | ➢ Initiation of a dialogue with food industry on urgent issues like food date labelling, packaging sizes, pricing etc.  
➢ Cooperation with charitable organisations for redistribution of surplus food |
| Regulatory Instruments | ➢ Amendment of European food law in order to limit the liability of food donors  
➢ Review of EU-legislation on food date labelling  
➢ Abandoning food safety standards that are more stringent than the statutory ones |
| Organisational Instruments | ➢ Avoiding inaccurate ordering and overstocking  
➢ Reducing the range of products and the supply quantities, mainly for perishable goods  
➢ Widening the offer of package sizes  
➢ Reducing prizes for small packages  
➢ Giving up promotion strategies which encourage non-need based shopping  
➢ Integrating expiry dates into barcodes and enabling automatic price reductions at the checkout |
| Economic Instruments | ➢ Tax incentives for food donations from the wholesale and retail sector  
➢ Taxes on waste treatment |
| Technical Instruments | ➢ Application of intelligent monitoring systems for cold chain management  
➢ Application of intelligent ordering systems  
➢ Application of intelligent labels for certain products like meat and fish |
10.5 Hospitality Industry and Catering

According to the estimates of WRAP (Williams et al. 2011) the hospitality sector in UK (hotels, restaurants, pubs and quick service restaurants) threw away 600,000 tons of food waste in 2009. Two-thirds of the food discarded is regarded to be avoidable, that means could have been eaten if it had been better portioned, managed, stored or prepared. The project ‘Foodspill’ carried out between 2010-2012, estimates that Finnish restaurants throw away 19% of all food produced and served (Silvennoinen et al. 2012). Reasons for the high food waste rates in this sector are strict hygiene rules imposed by law or industrial bodies, oversized portions, self-service buffets at fixed prices and difficulties in assessing the demand.

10.5.1 Food Hygiene Regime

As already mentioned, there exists a considerable tension between food safety and prevention of food waste. Some hygiene rules, for example regarding food storage and cooling have also a positive impact on reducing food waste (Waarts et al. 2011). However, in other cases it may be difficult to reconcile hygienic requirements imposed in order to protect consumers’ health and the targets for avoiding food wastage. A survey in the Nordic hospitality sector carried out by ‘Nordic Co-operation’ with financial support by the Nordic Council of Ministers (Marthinsen 2012) revealed some frustration in view of a lack of flexibility when applying legislative rules and disparities in the practice of food inspections in different parts of the country. Many companies feel obliged by law and by internal routines to waste too much food. Thus, the food hygiene rules should be reviewed in order to identify possible improvements without undermining the ambitions on food safety.

Current Regulatory Framework

The current regime of hygiene rules was adopted in April 2004 by the European Parliament and the Council and became operational on 1 January 2006. This legal framework, often referred to as ‘food hygiene package’ aims to ensure the hygiene of foodstuffs at all stages of the food chain, from the primary production up to the supply of food to the final consumer. The responsibility for adopting appropriate measures in order to guarantee the safety of their products lies with the food business operators. The package comprises three basic Acts: Regulation (EC) No 852/2004 (hygiene of food stuff general), Regulation (EC) 853/2004 (hygiene of food of animal origin), and Regulation (EC) No 854/2004 (official controls on products of animal origin intended for human consumption), along with Regulation (EC) No 882/2004 (official controls performed to ensure the verification of compliance with feed and food law). The clear objective of the legal amendment was to simplify the existing legal corpus on food hygiene, make it more coherent by separating the different disciplines (public health, animal health and official controls) and specify the requirements to be met by food business operators (European Commission 2009).

Regulation (EC) No 852/2004 stipulates that food business operators shall apply the principles of the HACCP (Hazard Analysis and Critical Control Points)-system, introduced by the Codex Alimentarius (code of international food standards drawn up by the United Nations Food and Agriculture Organisation). These principles prescribe a number of requirements to be met throughout the cycle of production, processing and distribution of food, which can be grouped into three elements: hazard analysis (principle 1), measures for hazard control (principles 2-5), verification and documentation of the system (principles 6-7). The measures for hazard control include: identify Critical Control Points (CCPs), establish critical limits for each CCP beyond which intervention is necessary, implement an effective monitoring system and establish corrective action when monitoring indicates that critical limits are exceeded. Exemptions of the obligation to implement a HACCP-system can be made in the case of traditional production methods or restrictions related to the construction, design and equipment of
facilities. Large companies normally have food safety systems based on the HACCP. For smaller companies, the procedures are generally translated into hygiene codes developed by industry bodies. These codes have to be approved by the national food administration (European Commission 2012).

**Perceived Legal Barriers**

The study of Wageningen UR mentioned above identified various legal barriers with regard to the hygiene rules promoting the discarding of edible food by companies, retailers and caterers (Waarts et al. 2001, p. 43 et seqq.):

- Very large safety margins
- Short deadlines (maximum three days) for storing opened packaging and self-prepared products
- Two-hour guarantee on unrefrigerated products (products which normally need to be stored refrigerated may be offered for sale for a maximum of two hours and have to be thrown away afterwards, whether packaged or unpackaged)
- Obligation of throwing away products once supplied (out-of-home-sector) if they have not been eaten or sold (this also applies e.g. for closed containers of self-prepared crudities, salad etc.)
- Obligation to meet the standards of HACCP or another approved quality system when residual flows are reused for food
- Product liability (producers/retailers/caterers are legally responsible for the product until delivery)
- Reluctance of companies to run the risk of possible damage to their image if not supplying high-quality products; this may result in hygiene codes, agreed on by the food industry, that are even stricter than the statutory regulations they are based on
- Differences in evaluation by enforcers depending on sector, company size and code

**Proposals to Overcome Perceived Legal Barriers**

The HACCP principles constitute a very ambitious system of food safety, originally developed in the early 1960s in the USA in order to produce safe food for the space programme (Untermann 1999). Against this background, one may ask if it is necessary to make food as safe as possible if it is already safe. In other words, it should be considered whether and in which cases safety margins could be reduced. In the workshops organised by Wageningen UR with representatives of the food industry, further proposals to overcome the above listed legal obstacles have been submitted (Waarts et al. 2011, p. 45 et seqq.):

- Extension of the two-hour guarantee for certain products, mainly for less perishable food e.g. with high fat/sugar content and low water activity (a_w)
- Easing the legal provision of throwing away products after supply or after storing for three days
- Revision of approved hygiene codes containing requirements beyond those imposed by legislation
- Better coordination of inspections by the national food control authorities: standardisation of enforcement instead of enforcing stricter standards in individual companies

However, a prerequisite for any weakening of the strict food safety standards in force today is that further research will be established in order to exclude microbiological and chemical risks for consumers’ health. Exemptions should be regulated centrally on European and/or national level, not by means of inspections per company.
10.5.2 Management Guidelines for the Hospitality Sector

Several guides and handbooks have been created by public authorities, industry associations and NGOs that should help specific sectors preventing food waste. They exemplify good practices for households, retailers, hotels, cafeterias, pubs and commercial kitchens. The following initiatives are directly related to the food services/catering sector, to name just a few:

- ‘Menu Dose Certa’ (Portugal 2008)\(^{35}\): The project, which was initiated by Porto waste management company LIPOR, aims to support restaurants to serve balanced meals in reasonable quantities in order to prevent food waste.

- ‘Al la carte menu for hospitals’ (Denmark 2008)\(^{36}\): Hvidovre Hospital offers anytime ‘a la carte’ order options to patients. The aim was to change the previously rigid patient catering system, while remaining within budget limitations.

- ‘Less Food Waste More Profit’: A guide to minimising food waste in the catering sector’ (Ireland 2010)\(^{37}\): The guide was launched by the National Waste Prevention Programme of the Irish Environmental Protection Agency, providing a step-by-step approach on how to eliminate, reduce, recycle, recover and dispose food waste in the catering sector.

- ‘Lutter contre le gaspillage alimentaire’ (Belgium 2010)\(^{38}\): The brochure offers a collection of good practices to reduce food waste for caterers and restaurants, edited by UCM Environment and FED Horeca Wallonie Asbl.

- ‘Sustainable catering’ (the Netherlands 2011)\(^{39}\): The famous Dutch online restaurant guide ‘IENS’, the information organisation Milieu Centraal and CREM, united in a pilot project work together towards a healthier and more sustainable catering industry.

- ‘La reduction des déchets’ (France 2011)\(^{40}\): The guide published by GESPER (GEStion de Proximité des l’Environnement en Région) gives advices on the prevention of food waste in educational establishments for the region Alpes-de-Haute-Provence.

- ‘Biodéchets en restaurant, gestion, prevention…’ (France 2013)\(^{41}\): The guide published by ADEME (Agence des l’Environnement et de la Maîtrise de l’Energie) gives advices on prevention, treatment and recovery of waste in the hospitality and retail sector.

Some of these initiatives have already shown positive impacts. However, most of them have started recently and until now no results have been reported.

Marthinsen et al. (2012) recommend the integration of the food waste prevention issue into the common standards and eco-labels that are applied in the hospitality sector. As many leading companies are certified, this might be an efficient strategy to anchor reduction targets in the routines of food service operators.

\(^{35}\) http://ec.europa.eu/environment/waste/prevention/pdf/MenuDoseCerta_Factsheet.pdf

\(^{36}\) http://ec.europa.eu/food/food/sustainability/good_practices_en.htm

\(^{37}\) http://www.epa.ie/pubs/reports/waste/wpp/lessfoodwastemoreprofit.html


\(^{39}\) http://www.crem.nl/eng/projects/view/dd

\(^{40}\) http://www.gesper.eu/media/ressources/publications/guide%20dechet%20scolaire%20WEB%20BAT.pdf

\(^{41}\) http://ademe.typepad.fr/files/ademevous_61_dossier.pdf
10.5.3 Adaption of Portion Sizes to Costumers’ Real Needs

For restaurants and other food service providers the amount of food waste is determined to a considerable extent by the portion sizes they offer. US-American studies suggest that portion sizes in restaurants have been increased since the 1970s (Nielsen & Popkin 2003). It can be assumed that the same trend towards larger portion sizes would be evident in Europe as well. By enlarging portion sizes, the number of customers that are unable to finish their meals rises. Thus, the adaption of portion sizes to costumers’ real needs would be a simple, but effective approach to reduce food waste in the hospitality sector (Lipinsky et al. 2013; Marthinsen et al. 2012; Silvennoinen et al. 2012; Monier et al. 2010; Stuart 2009).

To avoid dissatisfaction of clients, ‘à la carte’-restaurants could offer a choice of portion sizes to graded prices. To further refine this approach, restaurants could examine how much and what types of food tend to be left over on customers’ plates and modify their dishes according to the insights gained by this examination (Lipinsky et al. 2013; EPA 2010).

The Finnish project ‘Foodspill’ found out that the amount of food waste in restaurants is influenced by the business model. According to Silvennoinen et al. (2012) there is a clear difference between ‘à la carte’- and ‘buffet style’-restaurants. With regard to buffet style-restaurants the majority of waste is generated by cooking too much food that cannot be stored or served as a different dish later. One reason is that customers often expect that nothing will run out, particularly in the upscale market, forcing operators to prepare substantially more food than will be consumed (Monier et al. 2010). Although in buffet style-restaurants customers serve themselves, thereby determining the size of their meal, food service operators have means to influence consumers’ behaviour.

One option is to post information signs reminding customers to take only as much food as they can eat. Another option is to replace dinner trays by portion size plates. Under this system customers can return to the buffet to take more, but are limited at each trip to the amount of food they can carry on a plate. A pilot study at cafeterias of US-American universities suggests that by operating tray-less buffets, the emergence of food waste could be reduced by 25 to 30% (Lipinsky et al. 2013). The Irish Environmental Protection Agency recommends in its ‘Guide to Minimizing Food Waste in the Catering Sector’ the use of smaller containers for the buffet and replenishing them more often (EPA 2010). A third option is to remove ‘all you can eat’-buffets and replace them by ‘pay by weight’-systems (Lipinsky et al. 2013; Monier et al. 2010). This approach would give the customer an economic incentive not to take more than necessary. The same strategy to reduce food waste by setting economic incentives is also followed by some restaurants in London. Stuart (2009) reports that guests of the Nigerian restaurant ‘Obalenda Suya Express’ have to donate £2.50 to Oxfam if they don’t finish their meals.

The examples indicate that there are different ways to reduce food waste in the hospitality sector. Restaurants and other food service providers should have the opportunity to test different options of adapting portion sizes to consumers’ real needs. If it turns out that food service operators do not use any of the available possibilities, national legislators should consider the introduction of a statutory obligation to do so.

10.5.4 Logistical and Organisational Improvements

The above mentioned survey within the Nordic hospitality sector (Marthinsen et al. 2012) revealed that an improvement of the internal routines for purchasing, storing and freezing is considered to be important for limiting food waste (similar EPA 2010). A careful menu planning, including clearly defined rules for the ordering and cancelling of meals in advance, also got a rather high ranking. Some of the interviewed restaurants, for example McDonalds, have advanced planning tools that can forecast the demand of different food and beverages based on historical consumption data, weather conditions and other key parameters. Another approach to minimise food waste, applied for example by Fazer Food
Service in Finland, is the use of batch production. Differences between the individual dishes are generated by adding sauces and special ingredients just immediately before serving.

The relevance of a careful menu planning and a good estimate of the required demand are confirmed by other studies. According to Silvennoinen et al. (2012) the knowledge of the clientele and interacting with them may offer a solution as well as cooking in stages. The latter option however, may be difficult to organise due to limited manpower and requires motivation and commitment of the staff. All studies related to the hospitality sector agree that training of staff is crucial for reducing food waste. Eurest in Denmark highlights that especially training of the chefs and the sandwich makers is important. Also the Danish Diet & Nutrition Company stresses the relevance of training, including the exchange of expertise concerning lean-production, quality management, use of raw materials and seasonal offerings (Marthinsen et al. 2012).

High significance is finally attributed to the collection and documentation of food waste data which can help to identify restaurants’ food waste sources and form the basis for finding solutions. Regular weighing allows to identify the changes in food waste composition and to detect the most vulnerable points in each restaurant (Silvennoinen et al. 2012; BIOIS 2011). The company LeanPath developed a software for food waste tracking called ‘WasteLOGGER’, which helps food services to avoid pre-consumer food waste (due to overproduction, spoilage, expired best-before dates, trim waste). The software runs on computers and does not require specialised tracking equipment. Pilot studies on eight American college campuses were carried out. Canteen employees entered data about what they are throwing away and why. The experiments showed that great reductions could be achieved (Segrè & Gaiani 2012).

Table 23 shows the different approaches to avoid food waste generation in the hospitality sector at a glance.
### Table 23: Approaches to reduce food waste in the hospitality sector

<table>
<thead>
<tr>
<th>Instrument Type</th>
<th>Approaches</th>
</tr>
</thead>
</table>
| **Persuasive Instruments** | - Awareness campaigns in canteens, cafeterias and take-aways  
                          | - Staff training on right ordering, storage, handling and monitoring of products  
                          | - Compiling a good practice guide for the hospitality industry |
| **Cooperative Instruments** | - Cooperation with charitable organisations for redistribution of surplus food |
| **Regulatory Instruments** | - Review of the current hygiene rules regime  
                          | - Extension of the two-hour guarantee for certain products  
                          | - Revision of approved hygiene codes containing requirements beyond those imposed by legislation  
                          | - Standardisation of inspections by the national food control authorities  
                          | - Amendment of European food law in order to limit the liability of food donors |
| **Organisational Instruments** | - Careful menu planning and a good estimate of the required demand  
                          | - Offering of a choice of different portion sizes in ‘a la carte-restaurants’  
                          | - Replacing ‘all you can eat-buffets’ by ‘pay by weight-systems’  
                          | - Avoiding pre-mixing of ingredients  
                          | - Providing sufficient possibilities for storing and cooling of surplus food  
                          | - Examination of leftovers in order to optimise the composition of meals |
| **Economic Instruments** | - Tax incentives for food donations from the hospitality industry  
                          | - Taxes on waste treatment |
| **Technical Instruments** | - Application of software for monitoring food waste generation |
10.6 Households

Consumers play an important role for the reduction of food waste, not only because a large proportion of waste occurs at household level, but also because all activities along the food chain are targeted to the end-consumer. In the following different approaches to address consumer-related waste generation are presented.

10.6.1 Awareness Campaigns

All available studies agree on the fact that consumer information and education are crucial measures helping influence consumers’ behaviour. Meanwhile there is a wide variety of awareness campaigns throughout Europe, aiming to draw consumers’ attention to the issue of food wastage and to increase their respect for food. This includes information and tips on shopping, shelf life, storage, preparation and recovery of food. Because of their direct interaction with consumers, the retail and hospitality industry play an important role for the provision of information and should therefore be integrated in consumer-focused initiatives.

One of the most famous and successful campaigns in Europe is certainly the British ‘Love Food Hate Waste’ campaign, supported by the government and operated by WRAP (Waste & Resources Action Programme), which provides simple tips and tools to help consumers waste less food. As part of this, WRAP funds local authorities and waste partnerships across the country to undertake local ‘Love Food Hate Waste’ communication campaigns. The campaign was launched in 2007 and claimed two years later to have already helped two million households to reduce their food waste, amounting to savings of almost £300 million and preventing 137,000 tons of food waste (Environmental Data Interactive Exchange 2009).

Meanwhile, there are similar initiatives in different European countries; to name just a few:

- The Danish initiative ‘Stop Spild Af Mad’ (Stop Wasting Food), the largest private consumer movement in the country, seeks to raise public awareness creating campaigns in schools, public lectures, and seminars, but primarily through information and communication mediums. A series of cookbooks, that explain how to reuse leftovers, was released.
- The German initiative ‘Zu gut für die Tonne’ (Too good for the bin), which was launched by the German Ministry of Food, Agriculture and Consumer Protection (BMELV), provides consumer information and practical advice on food purchasing, management and preparation. Schools and consumer organisations as well as retail and food industry are integrated into the activities. Furthermore, an exchange between the stages of the food chain was stimulated. A smart phone app with a food lexicon, shopping planner and leftover recipes is available to consumers.
- The French initiative ‘Pacte national contre le gaspillage alimentaire’ (National pact against food wastage) aims at halving food waste in France by 2025, on the basis of eleven measures to be implemented. The campaign integrates all stakeholders of the food chain, but main focus is on households. The French Ministry for Agriculture, Food Industry and Forestry launched an online-campaign in 2012 with funny slogans such as ‘Who throws out an egg, throws out a cow’ to raise awareness among the French population. With the help of playful web performances and local actions, the campaign seeks to make the struggle against food waste to a part of citizens’ everyday life.
- The Catalan initiative ‘De menjar, no en llençem ni mica’ (Of a meal do not even waste a tiny bit) started by Associació Espai Ambiental (Environmental Space Association) in Barcelona. In this context, a number of workshops have been designed, including purchase planning, cooking without excess, conserving food and cooking with leftovers.
The Portuguese initiative ‘Movimento Zero Desperdício’ (Zero Waste Movement) can be seen as a mix of awareness campaign and food donation programme. A model for food donation was developed, which was implemented in cities like Lisboa, Loures, Cascais and Sintra. The initiative is linked to DariACordar, a non-profit and volunteer membership organisation, dedicated to the prevention of all types of waste, with a focus on food waste.

In the meantime, education campaigns to combat food waste are starting to bear first results. In the UK avoidable household food waste has been reduced by 18% in five years, primarily due to public awareness campaigns (Quested & Parry 2011). In Worcester (England) a three-month campaign to reduce food waste has been started by the council, including partnerships with local business, community organisations and schools. Samples of household waste before and after the campaign showed that food waste had declined by about 15% (Lipinsky et al. 2013). The experience gained shows that persuasive measures are quite promising instruments to reduce food waste.

Hanss & Böhm (2013) investigated how consumers can be encouraged by informational campaigns to purchase sustainable groceries. 150 participants were asked to purchase groceries with various sustainable attributes via an internet platform and to take part in a follow-up six months later in order to investigate whether the effects of the intervention had diminished over time or not. The authors found that sustainable consumption can be promoted by providing information about how individuals can reduce their environmental and social footprint through everyday purchasing decisions and about how individuals’ decisions to consume sustainably encourage other people to join it. The findings also indicated that the effects of the intervention on purchasing intentions did not diminish over time.

Hanss & Böhm conclude that informational campaigns can promote sustainable behaviours and supplement structural strategies like subsidies or taxes. The authors point out that providing information however does not suffice for strengthening consumers’ self-efficacy beliefs. This would require also feedback systems as an opportunity to actually experience that one’s own behaviour makes a difference. The authors state that information campaigns should embed the information in a format that attracts, involves and entertains consumers, such as an educational game (e.g. a multiplayer online game). In their opinion a promising strategy may be to address primarily those consumers who already have an interest in sustainability topics and who may later serve as opinion leaders. The experience gained with consumers’ behaviour towards sustainable purchasing can be easily transferred also to a sparing and efficient handling of food in order to avoid food waste.

### 10.6.2 Early Childhood Education

Various authors emphasize that consumer education has to start at infancy and that the topic thus should be integrated into curricula. Education can guide to a responsible handling of food and support sharpening our senses to detect spoiled food, favouring seasonal and locally produced goods and recovering leftovers. School education would also not only affect children; indirect effects are expected for the parent generation as well. The German Rural Women’s Association argues that food preparation has become less important in households (mostly due to time restrictions of working women) and calls for a mandatory school subject to impart everyday skills. Furthermore, the association points to the special role of women as multipliers in society (dlv 2012).

Engstrom & Carlson Kanyama (2004) propose to integrate the topic as permanent lessons and to carry out educational lunches. Authors see self-efficacy promoted playfully through actions such as the weighing of own plate waste with subsequent presentation of results. The integration of nutrition issues in early childhood education appears to be a promising approach which could lead to significant positive effects on consumers’ behaviour, using simple instruments without great additional expenses.
Moreover, schools are places where food waste may occur. Due to an increasing employment of mothers, a large share of children eats lunch at school. Different factors play an important role for food waste generation at school canteens: ready-made portion sizes that do not meet children’s often fluctuating hunger, limited budgets and a lack of motivation of service providers to offer high-quality meals with the effect that children do not like the food as well as bad timing of lunch or lack of break times so that children want to play rather than concentrating on lunch (Monier et al. 2010; Engström & Carlson-Kanyama 2004; Bergman et al. 2003).

Several Member States have already developed materials for schools in order to attract children to this issue, including lesson plans, factsheets, joint activities, films and teacher guidelines (BIOIS 2011). The Netherlands have developed a two year curriculum across all levels of education, schools in the UK have carried out test series in which pupils weigh the quantity of the food they waste and schools in France have designed specific food waste prevention plans (ibid).

10.6.3 Economic Incentives

There is broad agreement that undervaluing of food arises from low market values. The world market prices for food constantly decreased over the last century and only slightly increased again in the first decade of the new century. Furthermore, the wastage of food tends to augment with rising prosperity. Both factors contribute to a careless handling of food (Grethe et al. 2011; Parfitt et al. 2010; Monier et al. 2010; Stuart 2009). While an average household at the beginning of the 20th century had to spend more than half of its disposable income for food, the share is now between less than 10% and up to 20% across EU-27 (see figure 9). Due to this development, the general appreciation of food has declined. Against this background, many experts consider economic incentives as particularly suitable to recuperate the social esteem of food.

The Swiss WWF complains that food today is heavily subsidised in many countries inside and outside of Europe (WWF 2012). The organisation advocates the abolishment of all subsidies for food and the introduction of cost-covering prices. Following Marthinsen et al. (2012) the tax regulations, mainly the Value Added Tax (VAT) Regulations in EU Member States should be reviewed in order to remove all incentives that may encourage the generation of food waste. In order to make food affordable for consumers, reduced VAT-rates on food apply in many European countries. In Britain there is a zero rate on staple foods, whereas the standard rate has to be paid for luxury goods such as sweets, crisps and ice cream (Stuart 2009).

Some experts like the German Scientific Committee on Agricultural Policy (Bauhus et al. 2012) call for the elimination of the reduced VAT-rate on food, representing an indirect food subsidisation. Any social hardships caused by tax harmonisation should be offset by targeted governmental income support, which could be financed from additional tax revenue. Other experts, especially from environmental groups, suggest imposing different VAT-rates according to the environmental impacts of food items. High tax rates e.g. on meat, dairy products and convenience food could be compensated by reduced tax rates on less environmentally damaging products such as fruit and vegetables. In contrast, Stuart (2009) highlights that not the consumption of food should be taxed but rather its wastage.

South Korea has proved this approach to be possible. The Korean government has imposed an obligation to households and business to separate food waste and collect it into specially labelled bags that are available for purchase. SK Telecom, Korea’s largest wireless carrier, has designed food waste bins equipped with devices that weigh the waste. Using radio frequency identification (RFID) technology, the bins calculate the disposal fee based on the exact weight, which will then be debited from the user’s public transportation card or processed for payment on a linked credit card. So, the more one wastes the more he pays. Anyone who fails to separate his waste and discards food scraps with the municipal garbage risks a fine. According to Stuart (2009) these fines have hardly ever become matured because the rules are almost universally observed.
This technological development and its success are much affected by cultural factors. Food waste has increased dramatically in Korea as the country has experienced a long economic boom. Also the Korean food tradition with its variety of tiny side dishes contributes to the high generation of food waste. In a country with little landfill capacity, the government has decided to take more drastic measures. Korea’s education ministry has been tasked to push for a minimum 20% reduction in food waste. In Korea, technology traditionally plays an important role and social control to adhere to statutory rules is very strong (Kaye 2012). It is questionable if such ‘intelligent bins’ would be suitable for European conditions. The implementation is associated with huge financial expenses and the need of strict rules in order to prevent negative effects like illegal dumping of waste. However, the basic idea of collecting food waste in separate bins and paying fees according to one’s waste generation could be transferred with less technical effort.

Intelligent bins can be seen as a special manifestation of Pay-as-you-throw (PAYT) schemes, which are already in place in different European countries. Member States apply PAYT-schemes in form of fees according to the weight of municipal waste, the size of the waste bin or the frequency of its emptying. Countries using PAYT schemes have mostly a better waste management performance, in terms of decreasing waste generation and increasing recycling, than countries where waste collection fees are based on the property value, the number of square meters of housing, the household size or similar indicators. With regard to waste prevention, weight-based PAYT-schemes tend to be the most successful (EEA 2013; Watkins et al. 2012).

When using waste fees as an economic instrument to prevent food waste, certain requirements have to be met. Following the Korean example, an obligation to households for the separate collection of food waste and a payment according to its weight should be introduced. The level of the fee must be high enough to encourage reflection by households on their waste behaviour. At the same time, there are arguments for not setting charges such high that they offer an incentive for illegal dumping or burning of waste (Watkins et al. 2012).

### 10.6.4 Sharing Networks for Surplus Food

The idea of giving surplus food to people who have use for it can also be found in the private sector. Different internet platforms to donate, share and exchange food have been established in Europe.

One example is the German internet platform ‘foodsharing.de’ which enables consumers, as well as retailers and producers to offer and collect foods for free. The project was initiated by the film producer Valentin Thurn and has been financed by crowdfunding. Meanwhile, it was transformed into an association which is financed by membership fees (per year €60 for private persons and €150 for institutions). The platform is also available via a smartphone application. The activities are based on rules all members have to comply with. It is prohibited to donate products with a use-by date, raw fish and meat products, products which contain raw eggs, prepared meals and non-foods (like clothes, cosmetics, toys etc.). Products with exceeded expiry dates can be provided. The users have to register as members, list the products they want to donate and appoint a time for picking them up. When logging in, offered foods in one’s vicinity are shown, which then can be collected.

Aim of the project is not only to provide the needed infrastructure for food sharing, but also to inform the users about right transport, cooling and storage of different products, the meaning of expiry dates and how one’s senses can be used to check the spoilage of products. Single food items as well as food baskets can be shared. It is also possible to arrange a meeting for joint cooking via the food-sharing community. Foods have to be collected at individual households and companies (the platform includes a route planner function), but collection points can be established by single members as well.
The association established the same platform for Austria; the domain is called ‘myfoodsharing.at’. The German platform has actually been joined by 22,000, the Austrian one by 1,500 members. Both websites inform about their successes by counting members, the number of passed on food baskets and the amount of food saved (in kg) since the beginning. This action can help to positively affect the self-efficacy of the users. The German platform specifies that since its establishment in December 2012 (seven months ago) about 8 tons of food could be saved (www.foodsharing.de 2013).

Other examples for food sharing activities are (see inter alia Pelatelli 2013):

- The platform ‘Ifoodshare.org’ in Italy, originated by four young Sicilians.
- The website ‘casserole-club.com’ initiated by Future Gov, a company that aims to support social projects by the use of digital technologies. The idea is to bring people who are willing to cook an extra portion together with those in their neighbourhood who need it.
- The French project ‘Discosoupe’, a session of collective cooking hosted in various French cities where, to the rhythm of music, participants are invited to prepare and eat soups and salads made from unsold vegetables gathered from markets. Dates are announced via facebook.
- The Finnish initiative ‘Saa syödä’ (license to eat) which is supported by the Ministry of Environment. The initiative established a food sharing collection point in Helsinki where the local population can deposit ready-made meals, vegetables and unopened products whose expiry date is imminent. The project can be reached by its website.
- The American initiative ‘AmpelHarvest.org’ which strives to connect home gardeners who have surplus produce with registered food pantries, reducing food waste and feeding families in need.
- The internet platform ‘freecycle.org’ which is operating as a worldwide non-profit network of people who are giving (and getting) stuff for free, which would end up in the landfill. This includes things that are no longer needed like furniture, electronics or toys, but food can be advertised as well. The membership is free. The movement is organised in local groups which are moderated by volunteers. There are actually about 5,000 groups with nearly 9,500,000 members around the world (freecycle 2013).

Although such initiatives are very much appreciated by stakeholders and policymakers, it is not evident how effective they are. The number of members as well as the level of local penetration show that only a certain part of the population is addressed. The initiatives match to interested, mainly young people who are used to communicate via internet and smart phones. For others they are hardly accessible and may also appear too time-consuming and expensive (if membership fees are required). Nevertheless, such initiatives can be seen as valuable and should thus be developed further and carried forward. It should be considered to scientifically accompany such instruments in order to measure and improve their effectiveness.

**Last Minute Market**

Another example of a food recovery system with a slightly different character is the Last Minute Market (LMM), an academic spin-off established in 2001 and supported by the University of Bologna. LMM offers assistance to donors during the entire recovery process. The project is designed as a supply of services to commercial companies, charities and other non-profit organisations, public institutions and waste removal companies. The areas of activity are foods, harvest, seeds, catering as well as books and pharmaceuticals. The project usually starts in supermarkets where a special area is reserved for the storage of products which can no longer be sold, but are still usable. Supermarket staff, trained by LMM, check, sort and catalogue the products. LMM dictates the best interpretation and application of regulations to ensure maximum safety (Hazard Analysis and Critical Control Points (HACCP) protocols
are used), sanitary, fiscal and administrative solutions. Then boxes for distribution are prepared, according to the quantities the recipient charities require. LMM staff periodically visits the charitable organisations and make sure that the food is properly stored and cooked.

In 2008 nearly 170 tons of edible foods were recovered from supermarkets in Bologna, with a value of €646,000. It was possible to provide 365,000 meals with the help of these donations. The initiators of LMM assume that food worth nearly one billion euros, corresponding to about 580 million meals could be recovered every year, if the concept would be adopted nationwide by supermarkets, small shops and outlets.

Challenges for LMM have been a general lack of trust in the success and effectiveness of the project, a complicated bureaucracy and the need to demonstrate to the local health authority that the food recovered is without health-related risks (Segrè & Gaiani 2012).

10.6.5 Intelligent Devices to Encourage Responsible Consumer Behaviour

There are various intelligent systems available which directly apply to consumers and their purchasing, storage and consumption behaviour. Intelligent refrigerators have been developed which analyse their own content, create shopping lists according to the needs of their users and the availability of products and share information (e.g. via message on smart phone), if certain products are close to the expiry date. There are several systems under development. Companies like LG (Smart-ThinQ-Technology-series), Elektrolux (Screenfridge) and Mediacenter (prototyp KIKs) are working on placing intelligent fridges on the market. Intelligent supermarket trolleys offer the possibility to plan the way through the supermarket based on the shopping list. This device could help avoiding ‘incorrect’ purchases. There a different research activities relating to this field, one example is the intelligent supermarket trolley ‘SmartCart’ by the Innovative Retail Laboratory (IRL), an application-oriented research laboratory of the German Research Center for Artificial Intelligence (DFKI). The French company ‘Oxel’ develops and manufactures innovative solutions to help consumers saving money by reducing food, water and energy wastage. For each element the company offers effective tools to fight wastage. The first step is to detect and quantify waste and find out solutions to reduce it. The second step will be to educate and make people aware to the need of environmental protection (Oxel 2013).

There are different smart phone applications on the market, which aim to support consumers optimising their food use. The app ‘My Food Reminder’ helps consumers to set reminders when food items are about to expire. Foods can be listed by groupings based on best-before date or food types. The ‘Food Waste Diary’-app encourages consumers to document their wastage behaviour and reflect on possibilities for avoiding food waste. Reasons that led to the discarding can be indicated and information on food type, price, a photo and a comment can be added. Entries allow then to understand where and why something was thrown away. The apps ‘Key Ingredient’, ‘Recipes by Ingredients’ and the website ‘The Reverse Cook Book’ enable consumers to search for recipes starting from the ingredients and residues that they have at home.

Until now little is known about positive and negative effects of such intelligent devices. Furthermore, it is not clear if consumers and retailers would accept these technologies and be willing to pay for it. The survey carried out at JRC in Ispra (IT) and KIT in Karlsruhe (GER) showed that consumers do not pay much attention to technologies and consider other measures like awareness campaigns to be more important for cutting down on food waste. Nevertheless, research on human-technology-interactions, positive and negative impacts, acceptance and obstacles is strongly needed.

Although services like smart phone apps are very appreciated by users, it is not evident whether they come to use and turn out to be helpful and practicable in everyday life. The impacts of such apps as well as obstacles experienced need to be further assessed in pilot projects and consumer surveys.
Table 24 gives an overview on the different approaches to reduce food waste generation in households.

**Table 24: Approaches to reduce food waste in households**

<table>
<thead>
<tr>
<th>Instruments</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persuasive Instruments</td>
<td>- Awareness campaigns in order to draw consumers’ attention to the issue of food wastage</td>
</tr>
<tr>
<td></td>
<td>- Educating consumers on optimising purchasing, storing, preparation and recovery of food</td>
</tr>
<tr>
<td></td>
<td>- Starting consumer education at infancy and integrating the topic into curricular</td>
</tr>
<tr>
<td>Cooperative Instruments</td>
<td>- Supporting private food sharing networks</td>
</tr>
<tr>
<td>Organisational Instruments</td>
<td>- Improving lunch and break times at schools, so that children can concentrate on lunch</td>
</tr>
<tr>
<td>Economic Instruments</td>
<td>- Amendment of the national Value Added Tax Regulations</td>
</tr>
<tr>
<td></td>
<td>- Introduction of weight-based PAYT-schemes for food waste</td>
</tr>
<tr>
<td>Technical Instruments</td>
<td>- Application of intelligent devices such as intelligent refrigerators, supermarket trolley and smart phone applications</td>
</tr>
</tbody>
</table>
11 OPTIONS FOR ACTION

In the following options for action on European and national level are presented, based on the discussion of possible approaches to reduce food waste in the previous chapter. These policy recommendations are considered urgent to promote the already existing efforts to reach the European Commission’s goal of halving food waste generation by 2020.

Option 1: Target Setting

The national governments should be obliged to set targets for food waste reduction to be reached within a given time and to establish a systematic monitoring in order to review progress. Local authorities should break down the national targets to their area of influence. Individual sectors like manufacturing, retail and hospitality should agree to voluntary commitments on food waste reduction.

Quantitative reduction targets are helpful instruments for raising awareness and mobilising resources towards strategies to combat food waste. The European Commission has set the target to halve disposal of edible food in the EU by 2020. Under the Waste Framework Directive of the EU, Member States are obliged to develop waste prevention plans by 2013. As part of these plans Member States should set mandatory reduction targets for food waste. Regions and cities should break down the national targets to their local area of influence. For gauging progress and evaluating the effectiveness of different measures, a regular monitoring of food waste along the entire food chain should be established in all EU-27 States. Individual sectors like manufacturing, retail and hospitality should agree to voluntary commitments on food waste reduction.

Option 2: Improvement of the Data Basis

Within the EUROSTAT-framework an agreed and binding definition of the term ‘food waste’ as well as a standardisation of the methods used by the Member States for the collection of data on the generation of food waste should be introduced. Furthermore, the separate collection of food waste at all stages of the food chain should be stipulated, whether voluntarily or mandatorily.

All available studies revealed the lack of reliable data as main obstacle to the development and implementation of measures to reduce food waste. Under EUROSTAT, data which are relevant to assess the generation of food waste along the food supply chain, are given in the waste category W09 – animal and vegetal waste. This category includes all types of animal and vegetal wastes, but does not provide for a special subsector with data on food waste.

According to the NACE-classification data for animal and vegetal waste are available for different economic activities, including the ‘agricultural, forestry and fishery sector’, the ‘manufacturing sector’ and the ‘household sector’. For other sectors producing high amounts of food waste such as the ‘wholesale/retail’ and the ‘food services/catering’ sector there exist no individual category within the NACE-classification. Starting with the reference year 2004, EU Member States are obliged to provide data on the generation, recovery and disposal of waste every two years. However, they are free to decide on the methods used for data collection.

Given this situation there are three key requirements for improving the data basis:

1. Development of an agreed and binding definition of the term ‘food waste’ on European level, which differentiates between unavoidable food waste (referring to the non-edible parts of raw products), by-products and food waste that would have been avoidable.

2. Standardisation of the methods used for the collection and calculation of data on food waste generation in Europe related to all stages of the food chain. This implies an extension of the
NACE-classification of the previous missing sectors ‘wholesale/retail’ and ‘food services/catering’.

(3) Separate collection and measurement of food waste generated at all stages of the food chain, whether voluntarily or mandatorily, in order to enhance transparency and foster awareness of the problem among all players involved.

It is among the tasks of the ongoing FUSIONS-project to elaborate recommendations concerning these two issues, which can be expected in the end of the year.

Option 3: Reviewing EU Legislation on Food Safety

| The current regime of food safety regulations should be reviewed in order to identify norms that are not mandatory to protect human life, but lead to unnecessary food waste. Further research is required to decide where limits may be revised without running a risk for food safety. |

The societal objective of preventing risks to consumers’ life and health, which is anchored in various EU regulations and directives, may come into conflict with the ambition of avoiding food waste. With regard to current legislation on food contamination and food hygiene requirements, various barriers have been identified. Mainly strict norms for contamination, Maximum Residual Levels for pesticides and veterinarian medicines in food as well as hygienic rules concerning the packaging and storage of food are seen as significant legal drivers promoting the discarding of edible food.

Surveys have shown that producers, retailers and food service providers feel obliged by law and by internal routines to waste too much food. The current regime of food safety regulations should be reviewed in order to identify possible improvements without undermining the ambitions on food safety. In the light of even more precise methods of measurement, the setting of maximum levels according to the precautionary principle should be checked in order to assess if they are really justified from the perspective of health protection. It was recommended to take an inventory of norms going beyond the standard of human health protection, and thus leading to unnecessary food waste in practice. However, a prerequisite for any weakening of the strict food safety standards in force is that further research will be performed in order to exclude microbiological and chemical risks to consumers’ health.

Option 4: Amendment of European Marketing Standards

| The European legislator may consider to replace the current system of general and specific marketing standards for fruit and vegetables by another type of standards, not relating to the external appearance of a product, but to its quality for human consumption in terms of taste, natural purity, nutrition value and growing conditions. |

In 2009 the number of specific European marketing standards for fruit and vegetables was cut back from 36 to ten. Under the new regime, fruit and vegetables not covered by a specific marketing standard shall conform to the general marketing standards. For ten types of fruit and vegetables specific marketing standards remain in place. The intentions pursued with this amendment were to increase consumers’ choices and to reduce food waste.

In practice the impact of the reform remained quite small. The expectation that the sale of products with deviant shape, size and colour to consumers would significantly increase, was not fulfilled. The main reason is that especially the trading sector has an interest in maintaining the standards because the logistic processes in storage, packaging and distribution are geared to standardised products. Thus, the original statutory standards are further used by various food companies in form of private norms.

Whether the European legislator should adopt regulations not concerning consumers’ life and health, but the shape, size and colour of agricultural products, was and remains a controversial issue. Given the
fact that the repealing of marketing standards in 2009 did not reach the desired objectives – reducing food waste and increasing consumers’ choice – the European legislator should consider to abandon the current system entirely. Critics demand the setting of another type of standard not related to the external appearance of a product, but to its quality for human consumption in terms of taste, natural purity, nutrition value and growing conditions. How this new system should look like, raises a number of difficult questions that should be solved in close cooperation with producers, retailers, civil society organisations and scientific experts.

Option 5: Opening of Alternative Marketing Channels for Agricultural Products

To reduce the amount of food waste in the primary sector, alternative marketing strategies such as direct marketing should be stimulated. Further research is needed to assess the pros and cons of this approach in some more detail, including possible rebound effects.

There are no legal obstacles for the marketing of fruit and vegetables that do not meet the European marketing standards. However, due to the market power of large retailers this option only plays a minor role in practice. Very few supermarkets offer products of a second quality class at reduced prices. Usually, it is left to producers to seek for alternative distribution channels and develop innovative marketing strategies for products that are rejected by trade or produced in abundance. To reduce the amount of food waste in the primary sector alternative marketing strategies should be pushed forward.

One possibility is the further processing of surplus fruit and vegetables into juice, jams or canned products. Another possibility is the use of decentralised direct marketing systems in form of farm shops, farmers’ markets, delivery of vegetable boxes by subscription, producer co-operatives, solidarity purchasing groups and Community Supported Agriculture. The different models are more or less popular in individual European countries.

The original idea of direct marketing systems was not to avoid food waste, but to establish a closer link between producers and consumers, to foster community, to preserve local food production, to revitalise rural economies and to protect the environment. Nevertheless, circumventing the middlemen in the food supply chain can contribute significantly to the prevention of food waste for various reasons. Direct marketing shortens transport distances between producers and consumers, thereby reducing the risk of spoilage. By making food production and its natural and seasonal limits more visible, it encourages customers to a sparing and responsible handling of food. Thirdly, losses caused by wholesale, e.g. by means of supply agreements forcing farmers towards overproduction or rejecting products that do not meet the standards, are avoided.

Despite the sharp growth of direct marketing approaches in recent years throughout Europe, they still represent not more than a niche for consumers with high environmental and food quality awareness. Although direct marketing cannot replace supermarkets due to seasonal restraints, this concept can contribute to an efficient use of food and should be stimulated. Further research is needed to assess the pros and cons of this approach in some more detail, including possible rebound effects.

Option 6: Streamlining Food Date Labelling

The European legislator should revise existing regulations on food date labelling in order to improve the visual presentation of expiration dates. In addition legal possibilities for setting new best-before dates according to true shelf life of products and the abolition of expiration dates for stable foods should be considered. Information campaigns on labelling should be initiated by national governments and the retail sector. The retail sector in cooperation with the food industry should prove to abandon additional labels like ‘display-until’ and to introduce price reductions for products close to the expiry date.
Consumer surveys in various Member States have shown that knowledge on the meaning of expiration dates is rather rare among consumers and that the differences between the ‘best-before’ and ‘use-by’ date are often unknown. Researchers and also many stakeholders question the sense of a change in terminology as they expect the same confusion also for another wording. Instead of changing terminology, consumers should be informed about the meaning of the existing labelling. The retail sector, playing a key role in the interaction with consumers, should be integrated in consumer-focused initiatives and may even be obliged to provide information.

Today labels are barely readable due to small font sizes and consumers are overextended due to a variety of different labels. The European legislator should consider revising existing regulations in order to improve visual presentation of expiration dates (e.g. increase font sizes of text, introduce different coloration). Furthermore, the retail sector in cooperation with the processing and packaging industry should consider to abandon additional labels like ‘display-until’ in order to create more clarity for the costumers. Changes in the graphical presentation should be designed with the involvement of consumers and be tested in pilot studies before being rolled out nationally. National governments could announce research projects, which develop and test new graphical designs and attend their implementation.

Retail should apply price reductions for products close to the expiry date. An innovative suggestion is to integrate information on best-before dates in the barcodes, enabling automatic price reductions at the checkout. Intelligent labels (like Time-Temperature-Indicators) which show edibility of products via color change should be further studied in pilot projects as well. On the one hand they could help preventing food wastage by indicating real perishableness; on the other hand food waste rate could be increased by allowing precise auditability of cold chain interruptions.

In interviews with various food chain operators it was found out that food producers set best-before dates very conservatively and retailers decide to not sell products which have passed their best-before date in order to limit their risk in terms of product liability and potential damage to reputation. The European legislator should investigate ways to relieve producers and retailers from the anxiety of liability and reputation damage. Furthermore, it should be proved if setting new best-before dates according to true shelf life of products and the abolition of expiration dates for stable foods like salt, sugar, rice or dried beans would be feasible and helpful measures for avoiding food waste.

**Option 7: Improving Workflows and Supply Chain Management**

| The manufacturing industry should improve organisational workflows. Food companies should seek, together with retailers, for an agreement on the range of products and the required amounts. Governments should support these efforts by establishing special advising programmes. The aim should be an Integrated Supply Chain Management. |

Improving workflows within food manufacturing is an important approach for a sparing use of raw materials. There are different possibilities to ensure efficient workflows. On the one hand manufacturers should use production equipment according to the actual state of technology that should be regularly inspected. Residuals should be monitored and fallen out goods should be reintegrated in the production process. Furthermore production should be arranged in a way that containers have to be minimally cleaned and mixing of ingredients should be started as late as possible. Food companies should aim at increasing coordination with retailers to come up with an agreement on the range of products and required amounts. The improvement of organisational processes as well as the intensification of dialogue with retailers may be supported by government-financed programmes, which provide information, guidance and advice on improved practices.
Option 8: Awareness Campaigns

National governments should initiate consumer awareness campaigns, involving the retail and hospitality industry. The latter should provide in-store information on urgent issues like expiration dates and portion sizes. Campaigns should be suited for different target groups, be presented in a way that attracts and involves consumers and should contain feedback elements. Consumer education has to start at infancy and the topic of food wastage should be integrated into curricula in all Member States.

All available studies agree on the fact that consumer information and education are crucial measures to influence consumers’ behaviour. Awareness campaigns aim to draw consumers’ attention to the issue of food wastage and increase their respect for food. Information and tips on shopping, shelf life, storage, preparation and recovery of groceries instruct consumers to a more efficient handling of food. National ministries should initiate such campaigns, using various channels for reaching different target groups. Because of their direct interaction with costumers, the retail and hospitality sector should be integrated in consumer-focused initiatives.

These initiatives should contain feedback elements on the achieved results in order to strengthen behaviour changes in the long term. Information campaigns should embed the information in a way that attracts and involves consumers. Consumer education has to start at infancy and the topic of food wastage thus should be integrated into curricula in all Member States. School education would also not only affect children, indirect effects are expected for the parent generation as well.

Option 9: Combating Food Waste in the Hospitality Sector

The adaption of portion sizes to costumers’ real needs would be a simple, but effective approach to reduce food waste in the hospitality sector. If it turns out that restaurant and food service providers do not use voluntarily any of the available possibilities, national legislators should consider the introduction of a statutory obligation to do so.

For restaurants and other food service providers the amount of food waste is determined to a considerable extent by the portion sizes they offer. Thus, the adaption of portion sizes to costumers’ real needs would be a simple, but effective approach to reduce food waste in the hospitality sector. A la carte-restaurants could offer a choice of portion sizes to graded prices. To further refine this approach, restaurants could examine how much and what types of food tend to be left over on customers’ plates and modify their dishes according to the insights gained by this examination. In buffet style-restaurants customers serve themselves, thereby determining the size of their meal. Nevertheless, food service operators have means to influence consumers’ behaviour. One option is to post information signs reminding customers to take only as much food as they can eat. Another option is to replace dinner trays by portion size plates. Under this system customers can return to the buffet to take more, but are limited at each trip to the amount of food they can carry on a plate. A third option is to remove ‘all you can eat’-buffets and replace them by ‘pay by weight’-systems. This approach would give the costumer an economic incentive not to take more than necessary.

The examples indicate that there are different ways to adapt portion sizes to consumers’ real needs. Restaurants and other food service providers should have the opportunity to test different options for a certain period of time. If it turns out that they do not use voluntarily any of the available possibilities, national legislators should consider the introduction of a statutory obligation to do so.

Besides the adaption of portion sizes to consumers’ real needs, different surveys agree that training of staff as well as an improvement of the internal routines for purchasing, storing and freezing is crucial for reducing food waste in the hospitality sector. Also a careful menu planning by using, whenever possible,
advanced tools that can forecast the demand based on historical consumption data, weather conditions and other key parameters are considered to be important. High relevance is finally attributed to the collection and documentation of food waste data, which can help to identify the changes in food waste composition and to detect the most vulnerable points in each restaurant. It was further recommended to integrate food waste prevention issues into certification standards and eco-labels that are applied in the hospitality sector.

**Option 10: Economic Incentives**

The EU Member States should review their tax regulations, mainly the Value Added Tax (VAT) Regulation, in order to remove all incentives that may encourage the generation of food waste. It should be considered to eliminate the reduced VAT-rate on food or to introduce different VAT-rates according to the environmental impacts of food items. As an alternative to the taxation of food consumption also the taxation of food wastage may be suitable.

There is broad agreement that undervaluing of food resources arises from its low market value. The world market prices for food decreased over the last century constantly and only slightly increased again in the first decade of the new century. Furthermore, the wastage of food tends to augment with rising prosperity. Both factors contribute to a careless handling of food. Given this situation, many experts consider economic instruments as particularly promising to recuperate the social esteem of food.

A thorough review of tax regulations, mainly of the Value Added Tax (VAT) Regulation in all EU Member States is seen as necessary in order to remove all incentives that may encourage the generation of food waste. Some experts advocate for the elimination of the reduced VAT-rate on food, representing an indirect subsidisation. Any social hardships caused by tax harmonisation should be offset by targeted governmental income support, which could be financed from additional tax revenue. Other experts, especially from environmental groups, suggest the imposing of different VAT-rates according to the environmental impacts of food items. High tax rates e.g. on meat, dairy products and convenience food could be compensated by reduced tax rates on less environmentally damaging products such as fruit and vegetables.

A third group of experts highlights that not the consumption of food should be taxed, but rather its wastage. South Korea has proved the feasibility of this approach by introducing special bins for the collection of food waste. Using radio frequency identification (RFID) technology, the bins calculate the disposal fee based on the exact weight, which will then be debited from the user’s public transportation card or will be processed for payment on a linked credit card. It is questionable if such ‘intelligent bins’ would be suitable under European conditions. However, the basic idea of collecting food waste in separate bins and paying fees according to one’s waste generation could be transferred also with less technical effort.

Intelligent bins can be seen as a special manifestation of Pay-as-you-throw (PAYT) schemes that are already in place in different European countries in form of fees according to the weight of municipal waste, the size of the waste bin or the frequency of its emptying. With regard to waste prevention, weight-based PAYT-schemes have shown to be most successful. Following the Korean example, an obligation to households for the separate collection of food waste and a payment according to its weight might be introduced. The level of the fee must be high enough to encourage reflection by households on their waste behaviour. At the same time, there are arguments for not making charges so high that they give an incentive for illegal dumping or burning of waste.
**Option 11: Taxes and Fees on Waste Treatment**

With the intention to stimulate waste prevention in the business sector national governments should consider the introduction or increase of taxes and fees on waste treatment. The existing regulations to foster the use of renewable energies in Europe should be reviewed in order to eliminate incentives that run contrary to the objective of food waste prevention.

Taxes and fees on waste treatment can be seen as an economic incentive to stimulate waste prevention in the business sector as they escalate the total costs of waste handling, so that the financial benefits of avoiding treatment increase. Although economic instruments such as landfill or incineration taxes are introduced primarily with the intention to move waste management away from landfill towards recovery and recycling, they might also help cutting down on food waste. Whether this instrument is likely to reach the top of the ‘waste hierarchy’, i.e. prevention of waste, depends on its configuration. When using taxes on waste treatment as a tool to prevent food waste, certain requirements have to be met:

- Firstly, a mandatory separate collection of food waste, both in households and in commercial enterprises (mainly in the retail and hospitality sector) should be introduced; the latter is currently stipulated only in Ireland.
- Secondly, the tax rate must be high enough to create a sufficiently strong incentive for waste minimisation as well as for the donation of surplus food to charities. However, high taxes can equally generate an additional stimulus for illegal activity, so regulatory measures need to be developed in parallel.
- Thirdly, the existing regulations to promote and subsidise the use of renewable energies in Europe should be reviewed in order to identify incentives that run counter to the objective of food waste prevention.

Several European countries provide financial support for the production of energy from waste. It may lead to conflicting incentives, if national legislators on the one hand would impose high taxes for the treatment of food waste and on the other hand subsidise the production of energy from waste.

**Option 12: Promotion of Food Redistribution Programmes**

It should be checked if the European food law needs an amendment in line with the US American ‘Good Samaritan Act’ in order to limit the liability of donors and charity organisations that redistribute surplus food. It should be further assessed if financial incentives are required to stimulate the further development of the European food bank system.

Even if all possibilities to combat food waste would be exploited, a certain amount of surplus food would persist. Food redistribution programmes are a proven tool to use this surplus in an efficient way and to the benefit of economically deprived people. Charitable institutions like ‘FareShare’ in the UK, ‘Fondazione Banco Alimentare’ in Italy or ‘Die Tafeln’ in Germany and Switzerland collect food, voluntarily given away by producers, processors, retailers and food service providers, that would otherwise be discarded, and distribute it to the needy. Several European countries (e.g. Austria, Denmark, Germany, Italy, Norway, Sweden, Spain and UK) have successfully implemented food redistribution programmes. The main barriers to food redistribution are related to a lack of infrastructure as well as economic and legal constraints.

To overcome the economic obstacles, the introduction of tax credits for food donations following the example of the United States is proposed. Other authors stress the need to improve the infrastructure for food distribution. They suggest that retailers as well as food business operators with a certain predictable amount of food waste should be obliged to finance and use an enlarged system of food banks.
Donors of surplus food as well as charity organisations that redistribute it may be concerned about the legal consequences in case that somebody will be harmed by a defective product. To address this legal obstacle the United States in 1996 enacted the Bill Emerson ‘Good Samaritan Act’, which limits the liability of donors. With the exception of Italy, in Europe there does not exist any similar regulation up to now. Whether the European food law requires an amendment comparable to the Good Samaritan Act is controversial. Proponents of an amendment point out that under current law donors may be discouraged to give their surplus food to charity organisations. Without any amendment to European food law they may be driven to discard non-marketable goods in order to avoid liability. Thus, it should be considered to introduce a common European standard for the liability of donors and charity organisations that redistribute food. This could be implemented by amending Regulation (EC) 178/2002.

Option 13: Sharing Networks for Surplus Food

The national governments should consider to support the further development of food sharing initiatives by providing financial aid and smoothing bureaucratic obstacles. Research projects that accompany the work of food sharing-networks should be initiated in order to measure and improve effectiveness.

Giving away surplus food free of charge to people who have use for it is a reasonable approach to save food from disposal and to make it available for human nutrition – both on company and private level. The goal of consumer-aided networks is not only to provide the infrastructure for food sharing, but also to inform the users about the right handling of food. Experienced barriers are a general lack of trust in the success and effectiveness of these projects, a complicated bureaucracy and the need to demonstrate to health authorities that the food recovered is without any risks for recipients’ health. Governments should support food sharing initiatives by smoothing bureaucratic obstacles. Many networks felt impelled to set membership-fees in order to be able to self-finance the activities and are therefore not very attractive to consumers. Governments should consider providing financial support for the establishment of such networks. Food industry and retailers could also act as sponsors. The work of food sharing initiatives should be accompanied scientifically in order to measure and improve their effectiveness.

Option 14: Assessment of Technological Developments

European as well as national policy makers should initiate research programmes for evaluating the different technological options for cutting down on food waste, taking into account country-specific conditions and integrating all affected stakeholders of the food supply chain.

For the different stages of the food supply chain technological developments, which aim at avoiding food waste, are available. While intelligent ordering systems for retail or RFID-technology to collect data during distribution (e.g. temperature data during transport) are widely used today, various inventions like intelligent labels on packaging, intelligent refrigerators, intelligent supermarket trolleys or intelligent waste bins are highly new technologies. Even if these innovative technologies promise improvements and comfort at same time, it is not sure if they can really contribute to a reduction of food waste. Monitoring of the cold chain for instance can on the one hand help identifying and dispelling vulnerabilities in the cooling process. But on the other hand it can also enable rejection of products if the temperature once fell below a specified value and result in stricter controls.

Furthermore, quite little is known about their implementation in real life. Expectations, misgivings and advocacy of the target groups are studied far little. Literature review and results of a survey carried out jointly by the University of Bologna, the JRC in Ispra and KIT in Karlsruhe showed that technologies are assumed to play a much smaller role than awareness campaigns to combat food waste.
Moreover, it is not clear which human-technology-interactions could result from the implementation of such technologies, which effect they will have on society and what side effects and rebound-effects have to be expected. The use of technologies like nanotechnology (in case of active packaging) and genetic engineering (in case of plant breeding) is highly controversial due to the related risks and possible impacts on human health and the environment. As all these technological innovations are still in the development phase, there is considerable need for accompanying research and a careful weighing up of the pros and cons.

The European Parliament as well as national governments and ministries should initiate research programmes for evaluating the different technologies. This should also include pilot studies in which the devices are experimentally tested. The considerations have to be performed country-and region-specific, since the cultural, legal and structural conditions are very different between and within the Member States. The research activities should integrate all affected stakeholders and mediate a dialogue between them in order to obtain a comprehensive picture.
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A summary of the study is also available.

The STOA studies can be found at: http://www.europarl.europa.eu/stoa/cms/studies
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In addition, a short Options brief is also accessible through the STOA studies website via this QR code: