Technology options for feeding 10 billion people

Options for Cutting Food Waste

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AUTHORS
Carmen Priefer, Project Leader (ITAS)
Juliane Jörissen (ITAS)
Klaus-Rainer Bräutigam (ITAS)

STOA RESEARCH ADMINISTRATOR
Lieve Van Woensel
Science and Technology Options Assessment (STOA)
Directorate for Impact Assessment and European Added Value
Directorate General for Internal Policies, European Parliament
Rue Wiertz 60 - RMD 00J012
B-1047 Brussels
E-mail: lieve.vanwoensel@ep.europa.eu

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This document is the Layman's summary of the STOA study 'Technology options for feeding 10 billion people - Options for Cutting Food Waste'. The full study and an Options Brief related to the topic are available on the STOA website.

Abstract of the study

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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LAYMAN'S SUMMARY

1. BACKGROUND AND MISSION OF THE STUDY

Although the assessment of global food losses along the supply 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, which amounts to approximately 1.3 billion tons per year. Food is lost or wasted throughout the entire supply chain, from initial agricultural production down to final household consumption. According to FAO the per capita food waste by consumers in Europe and North America is about 95 to 115 kg/year (Gustavsson et al. 2011). The European Parliament estimates that by 2020 food waste will increase by 40%, unless additional preventive actions or measures are taken (European Parliament 2012).

Given the fact that over one billion people suffer from malnutrition, wasting food is particularly an ethical issue. Although the question how consumer behavior 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 can 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. Rising population will exert increasing pressure on the global food supply.

The production of food, regardless of whether it is consumed or wasted, is connected with adverse environmental impacts. 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 a significant move away from a predominance of grain-based diets towards substantial consumption of animal-derived products. 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.

In addition to adverse environmental impacts food wastage causes significant monetary losses, both for the individual consumer as well as for the national economy. Similar 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.

Against this background, reducing the current level of food waste offers a significant opportunity for achieving global food security, diminishing environmental risks, conserving finite resources for other uses and avoiding financial losses. The implementation of prevention measures to combat food waste, however, requires a thorough analysis of the scale, pattern and impact of food wastage, which was one subject of this study. The main objective was to discuss which measures and instruments can help to prevent food waste, taking into account the experiences already gained in different countries. The focus was on approaches that are deemed in literature or in the current debate as particularly useful, easy to implement and able to achieve long-term gains. Based on this discussion, options for action were developed addressing European as well as national governments responsible for their implementation.
2. DEFINITION OF 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. In accordance with other relevant authors, it is suggested here to distinguish between ‘food loss’ and ‘food waste’. 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 needs to be made because 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. On the other hand, food that was originally intended for 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 can no longer be sold, but are recovered for human consumption, and thus remain in the food supply chain, are considered neither food loss nor food waste (for example the further processing of unsold bakery products into breadcrumbs).

In addition, to the difference between food waste and food loss, the scientific community makes a further distinction between ‘avoidable' and 'unavoidable' food waste. **Avoidable food waste** refers to products that are still fit for human consumption at the time of being discarded or products that would have been edible if they had been eaten in time. **Unavoidable food waste** refers to products or ingredients which are not suited for human consumption. This includes nonedible 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 third category, used in the current debate, ‘possibly/partially avoidable food waste’ refers to 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 should be abandoned because the respective quantities only play a minor role taking into consideration the total food being wasted.

3. CURRENT STATE OF RESEARCH

In January 2012 the European Parliament adopted the resolution ‘How to avoid food wastage: strategies for a more efficient food chain in the EU’, 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). With reference to these initiatives, in its ‘Roadmap for a Resource Efficient Europe’ the European Commission has set the target to halve the disposal of edible food in the EU by 2020 (European Commission 2011).

At the European level, quite a large number of studies on the scope, causes and impacts of food waste generation have been carried out. National surveys are available for the United Kingdom, the Netherlands, Denmark, Sweden, Finland and Norway, France, Italy, Portugal, Germany, Austria and Switzerland. Research activities as well as political initiatives mainly originate from Western, Central and Northern Europe and 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 the individual 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', the fixing of system boundaries, the design and scope of investigation as well as the methods used for data collection and analysis.

Until now there has only been 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. Several global 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.

Currently two EU-projects are dealing with food waste: In the project ‘Green Cook’ different countries such as France, Britain, the Netherlands, Belgium and Germany collaborate in order 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 implementation of an evaluation framework for food waste. In the European FP7-project FUSIONS (Food Use for Social Innovation by Optimising Waste Prevention Strategies) 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.

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 waste’ plays an important role in WRAP and is on the agenda for 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’.

4. ORIGINS AND REASONS FOR FOOD LOSSES ALONG THE FOOD CHAIN

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 and a growing demand for meat, fruit, vegetables and other easily perishable products. The increasing migration of population from rural to urban areas augments the distance between locations of production and consumption. This includes longer transports, longer cold chains and more intermediaries. Furthermore, the behaviour of city dwellers towards the handling of food is significantly different to that of country dwellers. Based on waste analyses, an Austrian study found out that the amount of food in the garbage bin of city dwellers is much higher than in rural areas (Obersteiner & Schneider 2006).

4.1 Losses in Primary Production

In industrialised countries losses in the area of primary production (agriculture, postharvest handling and storage) are relatively low, compared to developing and emerging countries. In industrialised countries one possible cause of losses is seen in the orientation of production towards the needs of the market, which may lead to supply exceeding demand. Also strict contract terms as well as rigorous quality standards set by large-scale distributors can result in surplus production.

Although plant breeding enables the use of plants with desired characteristics, farmers cannot predict exactly the yield of their harvest, not least because of varying weather conditions. On the other hand, a farmer has to supply the quantity agreed upon in perfect quality in order to receive the agreed price. This in turn has the effect that a considerable quantity of crops produced is left in the fields. However, it should be noted that farmers and processing companies generally search for alternative marketing channels for their surplus products.
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 legal limits set by European Law as a significant driver for the generation of food waste in primary production.

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’, surplus production cannot be excluded.

The food industry requires specific sizes and standards for the processing of products. Several selections during the different processing stages result in high waste rates. Vegetables and fruit, frequently sold in packages, are 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 damaged products it is too expensive to open the package and offer the remaining goods for sale. Food processing leads to residues which still could be used for human nutrition. These residues are sometimes used in other areas, but usually they are disposed of because this involves less efforts and expenses.

The production of different brands and certain trademarks of a product can also result in losses. Dairy products, for example, 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. In addition, producers of supermarket own brands cannot sell their over-production elsewhere.

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. Meat and sausages are highly perishable goods due to their microbial sensitivity. 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 products.

4.3 Losses in Distribution, Wholesale and Retail

By determining the quality standards for agricultural products, the trading sector has a strong influence on primary production leaving the rejected goods with the producers. Food gets lost, because the fixed standards in terms of size, shape, colour and appearance of 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.

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.
Moreover, losses or damages to goods or packaging may occur during transport because of improper transportation. 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.

Food waste in the wholesale/retail sector also emerges due to the reaching of expiry dates. It is not prohibited to re-label and sell products with expired best-before dates, so far as it is assured that there is no health risk. Due to liability reasons, it is simply not a common practice. Waarts et al. (2011) found 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. Also marketing strategies like ‘Buy One, Get One Free’ (BOGOF) are deemed to generate food waste at household level, as they encourage consumers to purchase unwanted products.

Although a number of reasons are given for the generation of food losses in the area of distribution, wholesale and retail, the quantities seem to be comparably low. According to the estimations of BIOIS and other studies, the trading sector only accounts for 5% of the total amount of food waste in the EU. However, this sector also represents the area where empirical data is particularly limited. Thus, more detailed research is strongly needed to gauge the generation of food waste more robustly.

4.4 Losses in the Hospitality Sector

For restaurants and other food service providers the amount of food waste is determined to a considerable extent by the portion sizes they offer. By increasing portion sizes – a trend that can be observed in recent years in America as well as in Europe – the number of customers that are unable to finish their meals rises. 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.

There are also logistical problems that foster food losses in the hospitality sector. A varying number of guests hinders the ability of management to purchase adequate amounts of food. Reservations facilitate estimations of the amounts needed, but they are not common in some types of restaurants, for example in cafeterias. If there is a buffet the demand can only be forecasted to a certain extent via reservation.

If food remains are going to be used or offered again, there need to be enough space for refrigeration. However, in stressful situations it is often easier to dispose of food than to package and freeze it. Furthermore, the re-use of remains is difficult since many operators fix their daily offers beforehand and are thus not very flexible to change their menu. In most facilities the food waste is not separately collected and weighed. This leaves the amount of food wasted invisible, i.e. there is no measurement and no reflection on possible improvements of the internal routines that could make the use of food more efficient.

Legal provisions also play an important role in the catering sector. Due to hygienic requirements the passing on of remains is only legal if the food has not left the kitchen. The two-hour guarantee on unrefrigerated products (part of the EU ‘food hygiene package’) leads to food waste, as caterers have to throw away products which normally need to be stored in refrigerators, if they are offered for sale longer than two hours. In addition Waarts et al. (2011) found that caterers, retailers and residual flow processors often apply stricter norms than imposed by law in order to avoid liability and damage to their reputation.
4.5 Losses in Private Households

Several studies reveal that the wastage of food tends to increase with rising prosperity. Even in countries with a low to medium average income the upper classes tend to be wasteful with food. In addition, the world market price for food has constantly decreased over the last century and in contrast has only slightly increased since the first decade of the new century. As a consequence, the amount spend on food represents an ever shrinking part of the families’ income. While an average household at the beginning of the 20th century had to spend more than half of its disposable income on food, the share is now between less than 10% and up to 20% across EU-27. Due to this development, the general appreciation of food has declined (Gerstberger & Yaneva 2013).

Also demographic change has an influence on the generation of food waste. The growing number of single households in industrialised countries increases 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. A third trend which has an impact on the handling of food is the increasing percentage of women in employment. 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. There is empirical evidence that persons with a full time job throw away more food.

Behavioural attitudes of households also play an important role for the arising of food waste. Consumers plan their daily shopping poorly and buy beyond their own needs. 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. Large product units minimise the need for packaging material and the amount of packaging waste. However, they often cannot be fully consumed whilst the food is still fresh. Small packaging sizes are much more expensive in comparison to large ones. Furthermore, consumers are often misinformed on the proper handling of food concerning storage and preservation.

According to the EU food labelling regulations the minimum durability of pre-packed products has to be indicated on the wrapping. There are mainly two important labels indicating expiry dates: the ‘best-before’ and ‘use-by’ date. 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. However, there is considerable confusion about the meaning of the labels, which results in further food waste. Different empirical studies on households’ behaviour within the EU found 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.

Table 1 gives a summary of the main contributory factors for the wastage of food on the different stages of the food chain


Table 1: 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>
</tr>
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| 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. This study excludes agricultural production, and does not consider different product groups. The SIK-study addresses the generation of food waste at all stages of the food chain, 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 the EU-27, Russia and other European countries, who are not members 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.

5.1 Calculations based on FAOSTAT-Data and SIK-Methodology

For the BIOIS-study a mixture of data was used, compounded of EUROSTAT, national studies and extrapolations by BIOIS. All figures presented by BIOIS have to be regarded 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. 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.

In order to subject the results of the BIOIS-study to a plausibility check, model-calculations based on FAOSTAT-data and the methodology provided by SIK (Gustavsson et al. 2013) have been carried out. These calculations were performed separately for different food groups and stages of the supply chain in each of the EU-27 countries. In order to allow a comparison with the results of the BIOIS-study the calculations were carried out with FAOSTAT-data for the year 2006.

The methodology used allows identifying ‘hotspots’ (e.g. country, type of food, stage of the supply 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 restrictions, which limit the liability of the results. The percentages of food losses for the individual stages of the supply chain provided by SIK are in most of the cases average values over all European countries and thus do not consider country-specific conditions. 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.

5.2 Results of the Calculations in Comparison with BIOIS’ Findings

Figure 1 shows the contributions of the individual stages of the supply chain to the total amount of food waste in EU-27. The figure demonstrates that the highest amounts of food waste are generated at the first and at the last stage of the supply chain. The finding, that agricultural production and postharvest
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handling and storage in EU-27 contribute to a considerable degree 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 in the primary production of industrialised countries are negligible.

![Figure 1: Share of the different stages of the food chain on total food waste generation in EU-27 (ITAS-calculations)](image)

According to the calculations high waste rates can be found for the Southern European countries Cyprus, Spain, Greece and Italy as well as for the Netherlands, Belgium and Poland. All of these countries have an extensive agricultural production sector, meaning that a large portion of food produced is exported and therefore not consumed in the country. This result suggests that the agricultural sector should be involved in an European strategy to reduce food waste. In accordance with the findings of other studies ITAS-calculations show that the household sector is responsible for the largest share of food waste in comparison to 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.

Figure 2 presents the amount of food waste in kg per capita for the year 2006, sorted in descending order based on the performed calculations. Due to the fact that the BIOIS-study excludes the first two stages of the supply chain (agricultural production and postharvest handling and storage) and refers only to the downstream stages, the calculations carried out in the present study use the same frame of reference. The figure demonstrates that the compliance of the results is relatively good. Exceptions are the Netherlands, Belgium and Poland where the figures of BIOIS, based on EUROSTAT-data, are not plausible as they cannot be explained by technological inefficiencies or the scale of food industry in those countries.
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). One reason for these discrepancies might be, that the data used by BIOIS had been extrapolated from the results of other countries, due to the lack of empirical evidence. Another reason might be that the percentages provided by SIK for the different stages of the supply chain 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 3 illustrates the generation of food waste on households’ level. 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 a ‘minimum scenario’. For all these countries the specific amount of food waste (kg per capita) estimated by BIOIS is much lower than the figures calculated by ITAS. The reason might be that the value chosen by BIOIS for the minimum scenario is too low.
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Figure 3: Per capita food waste generation at household level – comparison of ITAS-calculations and BIOIS-results for EU-27 in 2006

For countries on the right side of figure 3 data from national studies or from EUROSTAT have been used in the BIOIS-study. 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 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.

6. WASTAGE BEHAVIOUR OF HOUSEHOLDS

There are significant differences in the disposal behaviour of households related to individual food groups, which can be studied with various methodological approaches. The available national studies used household surveys, sometimes combined with household diaries, or waste composition analyses. 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 errors. Experience also teaches that consumers substantially underestimate their losses when self-reporting. 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; this applies even more since the topic of ‘wasting food’ is associated with emotional and moral judgements. 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.
The vast majority of the available studies applies the second approach and specifies the amount of waste as a percentage of household waste. Table 2 gives an overview of households’ waste composition in different European countries.

Table 2: 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>UK(^1)</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>Netherlands(^2)</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>Sweden(^3)</td>
<td>10</td>
<td>3</td>
<td>38</td>
<td>15</td>
<td>27</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Norway(^4)</td>
<td>10</td>
<td>6</td>
<td>31</td>
<td>27</td>
<td>15</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Finland(^5)</td>
<td>7</td>
<td>17</td>
<td>19</td>
<td>13</td>
<td>13</td>
<td>18</td>
<td>6</td>
</tr>
<tr>
<td>Austria(^6)</td>
<td>12</td>
<td>15</td>
<td>13</td>
<td>8</td>
<td>13</td>
<td>15</td>
<td>24</td>
</tr>
<tr>
<td>Germany(^7)</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>

\(^1\)(Johnson & Quested 2009), \(^2\)(van Westerhoven & Steenhuisen 2010), \(^3\)(Andersson 2012), \(^4\)(Syversen & Marthinsen 2010), \(^5\)(Silvennoinen et al. 2012), \(^6\)(Schneider 2008), \(^7\)(Hafner et al. 2012)

The table demonstrates that in all countries studied fresh fruit and vegetables represent the largest group in the composition of household food waste, followed by bakery products and meals. These results are backed by the calculations carried out in the present study. Figure 4 shows the percentages of different types of food to total food waste generation in the household sector for different countries. 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.
Looking at the food waste generation of households, differentiated by countries and food types in some more detail, the results of the calculations carried out in the present study show the following picture: 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.

The results of the calculations are also in line with the findings of studies on the differences in dietary patterns across EU-27. 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 Mediterranean countries have strongly increased their meat consumption and now appear to surpass the Central/Nordic countries in the availability of red meat. Similarly, 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). Despite the harmonisation of eating habits, there are still significant differences. For example Mediterranean 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.
7. IMPACTS OF FOOD WASTE GENERATION

Food production is one of the industries with the highest consumption of resources and a large emitter of pollutants. 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 CO\textsubscript{2}. 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. Irrigated agriculture takes about 70\% of global fresh water resources. The application of fertilisers and pesticides as well as soil compaction due to the use of heavy machinery burdens 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. The wastage of food is associated not only with environmental burdens, but with economic losses along the whole food chain as well.

7.1 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.

An important issue in the consideration of land use and food production are indirect land use changes (ILUC). 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.

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 refers to 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 one’s 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.

The indirect water consumption in Germany, for example, is about three times higher than the direct water consumption. More than two thirds of the German indirect water consumption is caused by the production of arable crops, nearly one third 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 (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, coffee, beef, rice, wheat, milk and apples. 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. Different studies document that the highest emissions arise from the provision of animal-derived products, although they are disposed of in rather small quantities compared to fruit, vegetables and bakery products. Figure 5 shows the material and carbon footprints of different food groups, referring to annual food waste in Germany.
Figure 5: Material and carbon footprint of food wasted in Germany per capita and year, including the upstream steps of the chain and split by product groups

Source: Göbel et al. 2012

The pie charts illustrate that in Germany fruit and vegetables are disposed of most, followed by some distance by grain products. Although meat products are wasted least, 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 by dairy products and fruit and vegetables.

7.2 Increasing Amount of Bio-Waste

Among the environmental impacts of wasting food are also methane emissions associated with the deposition of organic waste and the need to expand the global landfill capacity. 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 waste is 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 law. The Landfill Directive of 1999 required Member States to limit the share of biodegradable municipal waste going to landfill. 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 75% (by weight) by 2006, to 50% (by weight) by 2009 and to 35% (by weight) by 2016, as compared to 1995. Member States, who have been heavily reliant on landfill, have an additional four years period to comply with the targets set in the directive.

A recent cross-country analysis carried out by the European Environmental Agency shows that only eleven countries reduced per capita municipal waste generated 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 landfill more than 50% of their municipal waste in 2010 (EEA 2013). Figure 6 provides an overview of the percentages of municipal solid waste (MSW) landfilled, incinerated, recycled and composted in 2010 within EU-27.
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, while seven already achieved the 2016 target of 35% by 2010 (EEA 2013).

### 7.3 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. Similar to the ecological impact, economic losses accumulate along the food chain; so one ton of food waste at household level (i.e. at the last stage of the chain) causes much higher economic costs than one ton of food waste in the agricultural sector. 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 about 5.3 million tons of food per year, corresponding to an economic value of £12 million.

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8. OPTIONS FOR ACTION 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 use of food. The full study gives an overview of the measures and instruments under discussion taking into account the experiences already gained in different countries. The focus is on measures and instruments that are deemed in literature or in the current debate as particularly useful, easy to implement and able to achieve long-term gains. The following options that have emerged from this discussion are considered urgent to reach the goal set by the European Commission. They address both European and national governments responsible for the implementation of the suggested options.

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.

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.

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 decreasing food safety.

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. What 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.
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.

Streamlining Food Date 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 revising 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.

Improving Workflows and Supply Chain Management

Improving workflows in the food industry is an important approach to spare 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.

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 be more efficient in the 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 the school curricula.

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 implement these options on a voluntary basis, national legislators should consider introducing them on a compulsory basis. 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.

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.

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 increase 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.

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.

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 facilitating 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.
Assessment of the Technological Development

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.
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This document summarises the findings and conclusion of the STOA study ‘Technology options for feeding 10 billion people - Options for Cutting Food Waste’.

The STOA studies can be found at: http://www.europarl.europa.eu/stoa/cms/studies
or requested from the STOA Secretariat: STOA@ep.europa.eu

In addition a short Options brief is also accessible through the STOA studies website via this QR code: