# Criteria for and baseline assessment of environmental and socio-economic impacts of food waste

**Final report**

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Reducing food waste through social innovation

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# Colophon

Title: Criteria for and baseline assessment of environmental and socio-economic impacts of food waste

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# Summary

This report concludes the research from the FUSIONS Work Package (WP) 1 "Reliable data and information sources, trends and assessment criteria" The aim of this report is to serve as documentation for the existing knowledge base with respect to the socio-economic and environmental impact of food waste and to provide new information on how to proceed towards socio-economic and environmental assessment of the impacts of food waste. According to the FUSIONS definition the term food waste is referring to a fraction of food and inedible parts removed from the food supply chain going to recovery or disposal (incl. composting).

The impact assessment covers the following topics:

- impacts on health and nutrition of food waste
- socio-economic impacts of food waste
- social impacts from food redistribution organisations, such as food banks or social supermarkets
- environmental impacts of food waste

A baseline assessment was carried out to receive estimates for current food waste in EU, to identify data gaps and to draw recommendations. The findings shall serve as a basis for further research.

Some methodologies chosen for the impact assessment within FUSIONS demanded current food waste data on product level. Estimations on product level are taken from Gustavsson et al. (2011) and (2013) FAO FLW (food loss and waste)[1] data. Indicator products for the assessments were chosen by mass of domestic food utilization (2011), which are: apples, tomatoes, potatoes, bread, milk, beef, pork and fish. Chicken was furthermore added to cover possible changes in consumption behaviour of meat.

The impact on **health and nutritional factors** was analysed on the subjects nutrients, micronutrients and partly anti-nutritional factors. Selected nutrients and micronutrients included vitamin A (retinol), beta-carotene, vitamin C, fibre, iron, zinc, n-3 fatty acids, lysine and methionine. Nutrient losses were calculated based on food compositional data of the selected indicator products For this three different nutrient databases (from Netherlands, Sweden and USA) were used. Nutrient and micronutrient losses were estimated for different parts of the food chain (production, processing, retailing, and consumption) and for several indicator food categories. Nutrient losses in terms of human nutrient requirements were analysed and nutrient degradation was investigated on the basis of a literature review. A short overview of anti-nutritional factors for mycotoxins, glycoalkaloids, pesticide residues and other examples was furthermore given. Maximum permitted levels of concentrations for foodstuffs are mentioned.

Results of the baseline assessment show that the estimated amount of vitamin C that is lost in the EU in a year (2011) as a result of food waste is equivalent to the amount of vitamin C that is needed by 90 to 97 million people a day (based on NL and SE composition data base). Losses on retinol equivalents equal the amount needed for 407

[1] Data from FAO is termed "food loss and waste (FLW)" in this report.

and 150 million people a day respectively. Losses on total dietary fibre are estimated to be equal to the amount needed for 139 and 173 million people a day respectively and losses on total iron to 157 and 169 million people a day respectively. Losses on zinc amount to 181 and 210 million people a day regarding their recommended intake on nutrients. As the results are subject to certain biases, it needs to be highlighted that the outcomes can only serve as a first estimation. For a more accurate assessment the composition of food waste (percentage of edible and percentage of inedible parts), disaggregated nutrient concentrations of inedible parts and food waste data on product and product category level are needed as well as data on nutrient concentrations with food waste data on a corresponding level of detail (product level versus product group level). Furthermore it is recommended to analytically measure macronutrient and micronutrient concentrations in inedible parts of food.

Antinutritional factors can be present in a wide range of co-products presenting occasional problems for the use of this material in animal feedstuffs. The literature identified remains mostly of a qualitative nature and hence it is not possible to quantify the amount of food processing waste which is unsuitable for food or animal feedstuffs. However, careful monitoring of anti-nutrients is essential both to ensure compliance with statutory and advisory guidelines and to avoid under-utilization of wastes and co-products as animal feed.

In general, **socio-economic impacts** from food waste prevention and reduction are defined as the resultant changes that may occur in food markets (demand, supply, prices and trade) and welfare of various actors in the various sectors and regions. A comparative qualitative analysis of studies was undertaken to examine the socio-economic impacts of reducing food waste. The reviewed studies are classified into two categories. The first set of studies has sought to develop a theoretical framework for the economics of food losses and wastes and a description of how the framework can be implemented in a quantitative model. The second set of studies have applied economic modelling, primarily scenario analyses to quantify the impacts of reducing global food losses and waste on production, trade, prices and incomes.

Socio-economic causes of food loss and waste (FLW) were detected in a theoretical framework that encompases micro-economic theory, behavioural economics, and macro-economics. Causes at the farm and firm level include limited market access and weak competitiveness while at consumer level low purchasing power and low planning capacity are listed. At the macro-economic level relevant factors such as inadequate infrastructure in developing countries and food price inflation were revealed. A ranking or potential magnitude of the food loss and waste generated of each of the factors is not given as it was beyond the aim of this subtask. The findings for this study are relevant to the FUSIONS deliverable on food waste drivers. The theoretical framework on causes is important and necessary for both further modelling and interpretation of potential socio-economic impacts. Potential socio-economic impacts are discussed in more detail in future reports of FUSIONS.

Empirically, Computable General Equilibrium (CGE) models and Partial Equilibrium (PE) models have been found in the literature review to quantify the potential socio-economic impacts of FLW. All the studies used the Gustavsson et al. (2011) FAO FLW data. The CGE studies (Rutten et al. (2013); Rutten and Kavallari (2013); Rutten et al. (2015)) uses the MAGNET CGE model that quantifies potential socio-economic impacts of reducing FLW from 0 to 50 percent for a segment of the supply chain or for the entire supply chain with a 7 years framework. In contrast, the PE model uses the OECD-FAO AGLINK-COSIMO model in OECD (2014) over a ten-year period to analyse the scenarios of gradually reducing the existing level of FLW so that the reduction rate becomes 20% in ten years. All scenarios assumed that the reductions can be achieved without costs. The welfare impacts corresponds to changes in volumes of production and consumption which influence net trade and prevailing market prices.

The literature suggests that the socio-economic impacts of FLW reduction could be substantial. FLW prevention and reduction is taking place in the EU concurrently to actions in other Regions and the potential impacts on food prices and welfare need to be researched and projected for intra- and inter-regional impacts (Rutten et al., 2015). For instance, households may waste more if food becomes cheaper, counteracting the positive impact of reducing food losses on the supply side or trade-up and spend the saved income from the reduction of food waste for other services or higher quality food.

High level considerations on the socio-economic impacts of food loss and waste need to be balanced with a value chain analysis that includes data on costs related to the prevention and reduction measures to be implemented for the short, medium and long term return on investmets along the food supply chains, including for the end consumption level. What exactly will happen remains an empirical question and is best investigated in an applied model of the whole economy with added real-life complexities (Rutten, 2013).

The assessment of the **impacts of food banks and other initiatives** aimed at the food supply to marginalised social groups was carried out using the methodology of social capital. Indicators for the social capital needed to be adapted to the special focus of food redistribution organisations. The methodology in combination with the new identified social indicators was tested via a survey among food redistribution organisations within Europe.

In a thorough literature review, social, economic and psychological impacts of food redistribution activities as well as impacts on nutrition and health were detected for different stakeholders: Impacts on people in need (e.g. overcoming individual isolation, increasing purchasing power, improving nutritional situation and self determination), impacts on people involved in redistribution activities (e.g. compliance with social and ethical norms, education and training), impacts on donors (corporate social responsibility e.g. impact on staff morale, but also e.g. reputational risk or tax benefits) and impacts on communities and society in general (e.g. public education impact, dignity and social justice, crime rate). The outcome of the literature review and the consultation rounds at the mentioned meetings was a list of social impacts from various stakeholders and steps of the food supply chain. Out of this list only indicators for food redistribution organisations were selected to test the methodology.

The methodology used for evaluating social effects was social capital from World Bank. Five dimensions are analysed in this concept: Groups and networks; trust and solidarity; collective action and cooperation; social cohesion and inclusion; information and communication. In addition to those dimensions it was agreed to include food security and food safety. Indicators found in literature and during consultation rounds were adapted to these dimensions. The methodology was tested through a distribution of a questionnaire to 211 food redistribution organisations in Europe with a response rate of 15%. The results showed that food redistribution can have a rather positive effect on the basic components of social capital, in particular when trust, networks, and cooperation are regarded. Less influence was perceived in terms of information and social inclusion. Obviously, given the specific focus of the initiatives, the largest effect was registered on the food security and safety aspects. The adaptation of the World Bank methodology and the use of the six dimensions have provided stimulating insights and a reference for this assessment. Yet, the assessment is undertaken with several limitations which should be focused on when repeating this assessment (e.g. lack of personal interviews, necessity of a periodic repetition). A recommendation would be to carry out a survey with different typologies and larger amounts of food redistribution activities so to allow an adequate analysis of results in homogeneous contexts (e.g. State, region, local level).

In the **environmental assessment** the methodology of Life Cycle Assessment (LCA) was used, which accounts emissions from cradle to grave covering most of the steps of the food supply chain. Two approaches were tested: Bottom-up approach, starting from specific indicator products and ending with an extrapolation of results, and top-down approach, starting from greenhouse gas emissions on aggregated level over certain steps of the food supply chain and ending at results for emissions related to the total consumed and wasted food. The functional unit of both approaches was agreed to be 1 kg of consumed food. System boundaries are given from primary production, including agriculture, to recovery and disposal of food waste, leaving out the food valorisation and conversion step (e.g. animal feed) due to lack of data. Emissions were related to the current food waste data set of FUSIONS. The impact category Global Warming Potential (GWP) was used in the assessment. Additionally, the acidification and eutrophication potential was looked at in the bottom-up approach to test if there are other significant environmental impacts next to climate change.

The inventory of the bottom-up approach included a database of specific studies with emission data on the selected indicator products, which are apples, potatoes, tomatoes, bread, milk, beef, pork, chicken and fish, and waste emission data from the database of GaBi (owned by thinkstep) and BOKU's own data. Research activities within this task covered behaviours at consumer level in order to cover consumer travel and cooking habits in the database as well as allocation procedures of food waste in the end of life stage to cover a most appropriate picture of food waste recovery and disposal in the EU. The inventory of the top-down approach used Eurostat as the primary source wherever possible to maximise consistency and replicability (Eurostat 2014a-h, 2015).

Results for the total GWP associated with food consumed in the EU in 2011 arrive at a very similar figure for both approaches (around 1,380 Mt $CO_2$ eq.). Yet, the share of food waste related emissions is different in the two approaches used. Food waste related emissions estimated at 16% to 22% of the total emissions of consumed food, which is 227 Mt $CO_2$ eq. in the bottom-up approach and 304 Mt $CO_2$ eq. in the top-down approach respectively. Most of the emissions can be attributed to the production stage, followed by the food consumption stage. Distribution and End of Life play a rather insignificant role. When it comes to an attribution of emissions to the polluter pays principle, the consumption stage shows the most impacts.
Differences of the results arise from different data sources used and the nature of approaches. Nevertheless they provide a useful indication of the scale of the environmental impact of food waste within the EU's food supply chain. To receive a more accurate picture of the GWP of food waste in the entire EU's food supply chain, the following data gaps were identified for further research: food waste data on product category level, data on recovery and disposal options for food waste, data on food and inedible parts removed from the food supply chain to valorisation and conversion on a EU level. Both approaches have its strength and weaknesses. The top-down approach appears to offer a rapid way of approximating the GWP and regularly updated information is available from data sources. The bottom-up approach serves results on an indicator product level and from the perspective of the polluter pays principle, which can serve as a good basis to set targeted waste prevention activities.

As a conclusion, the socio-economic and environmental assessment of food waste has shown that there are still some major data gaps for a more comprehensive assessment. Nevertheless important conclusions have been identified from the investigations and approaches. In the following table, the approaches, inventory, data gaps and recommendations are summarised to give an overview. Recommendations given for each subtask shall be taken further in FUSIONS and in subsequent projects dealing with impact assessment of food waste.

**Table 1.1: Summary of approaches used to assess socio-economic and environmental impacts of food waste within FUSIONS (data inventory used, data gaps identified and recommendations drawn)**

| **Object of impact assessment** | **Approach** | **Data inventory** | **Data gaps** | **Recommendations** | **Classification of indicators** |
|---|---|---|---|---|---|
| Health and nutritional factors | Calculation on product group level (7 indicator products) | • Food composition databases (NL, SE, USA)<br>• Gustavsson et al. (2011 and 20113) FAO FLW data<br>• FUSIONS food waste data set (from Oct. 2015) | • Nutrient concentrations in inedible parts of food<br>• Matching data on nutrient concentrations and actual food waste data (on a product or product category level)<br>• Food waste data on product level | To measure analytically nutrient concentrations in inedible parts of food | Attainable, comparable, measurable when data gaps are fulfilled |
| Anti-nutritional factors | Literature review | • Published studies on anti-nutritional factors in foodstuffs | • Amounts of food waste which is unsuitable for human consumption or animal feed | To improve quantification of anti-nutritional factors in inedible parts of food | |
| Socio-economic factors | Comparative matrix based on a literature review | • Gustavsson et al. (2011 and 2013) FAO FLW data<br>• Embedded information in: (i) MAGNET CGE model; (ii) OECD-FAO AGLINK-COSIMO PE model | • Reliable food waste data by product category level;<br>• Costs and benefits (short, medium and long term) of prevention and reduction measures along the supply chain | • Consider using the value chain approach for estimating losses and waste and for assessing potential impacts and solutions<br>• Harmonized terminology for FLW to generate comparative data<br>• Estimate and incorporate costs for FLW reduction in quantitative analyses | Depends if empirical vs. analytical, but measurable |
| Social factors of food redistribution organisations | Identification of social indicators | • Indicators from reviewed literature<br>• Indicators from audience of various workshops<br>• Categorized by 6 dimensions of the concept social capital | | Test of the methodology covered only one stakeholder group (food redistribution organisation); indicators were also found for other stakeholders (donors, communities, people in need) on which the methodology could also be tested. | A range of indicators detected which might be attainable. Potential impacts are stated in Table 7.1 to Table 7.4. |

| | | | | | |
|---|---|---|---|---|---|
| | Test of the methodology social capital | Questionnaire distributed to 211 food redistribution organisations in Europe (response rate: 15%) | • Impossibility to carry out personal interviews;<br>• Snapshot of the situation in a specific time | The proposed survey should be submitted to different typologies and larger amounts of FRAs so to allow an adequate analysis of results in homogeneous contexts (e.g. State, region, local level) | Time-bound as based on interviews |
| Environmental factors | Global Warming Potential via bottom-up approach | • GHG emissions from research studies (database)<br>• FAO: food domestic utilization in EU in 2011<br>• Gustavsson et al. (2011 and 2013) food waste shares – FAO FLW data<br>• FUSIONS food waste data set (from Oct. 2015) | • Lack of periodic repetitions as database of environmental emissions are based on specific literature sources<br>• Varying system boundaries and the assumptions required to standardise to a common end-point.<br>• EoL stage<br>• Food and inedible parts removed from the supply chain for valorisation and conversion | A creation of a European data set on environmental effects of food waste under consideration of a deeper knowledge of food waste on product level and food going to valorisation and conversion. | Attainable, comparable, measurable |
| | Global Warming Potential via top-down approach | • GHG emissions from Eurostat per step of the food supply chain<br>• FAO: food domestic utilization in EU in 2011<br>• FUSIONS food waste data set (from Oct. 2015) | • EoL stage<br>• Food and inedible parts removed from the supply chain for valorisation and conversion | Periodic repetitions are possible as data inventory sources are updated regularly. | Attainable, comparable, measurable |

# Abbreviations

| Abbreviation | Description |
|---|---|
| ANF | Anti-Nutritional Factors |
| AP | Acidification Potential |
| CGE | Computable General Equilibrium Model |
| $CO_2$ eq | Carbon dioxide Equivalents |
| CSR | Corporate Social Responsibility |
| DoW | Description of Work (document describing the workpackages and tasks within FUSIONS) |
| EC | European Commission |
| EoL | End of Life phase/step/stage (part of the supply chain) |
| EP | Eutrophication Potential |
| EU | European Union |
| FAO | Food and Agriculture Organization of the United Nations |
| FCDB | Food Composition Database |
| FLW | Food loss and waste (this term is used in combination with the FAO study (Gustavsson et al., 2011 and 2013) |
| FRAs | Food Redistribution Activities |
| FTE | Full Time Equivalent |
| GHG | Greenhouse Gas emissions |
| GWP | Global Warming Potential |
| HGVs | Heavy Goods Vehicles |
| HORECA | Hotels, Restaurants and Catering sector |
| ktoe | Kilotonnes of Oil Equivalents |
| LCA | Life Cycle Assessment |
| MAGNET | Modular Applied GeNeral Equilibrium Tool |
| MENA | Middle East and North Africa |
| Mt | Million Tonnes |
| Mtoe | Million Tonnes Oil Equivalents |
| NGO | Non-Governmental Organization |
| OECD | Organization for Economic Co-operation and Development |
| PE | Partial Equilibrium |
| $PO_4$ eq | Phosphate Equivalents |
| RDI | Recommended Daily Intake |
| $SO_2$ eq | Sulfur Dioxide Equivalents |
| SSA | Sub-Saharan Africa |
| tkm | Tonne Kilometre |
| TWh | Terra Watt Hours |

# Contents

# 1 Introduction

The overall objective for the FUSIONS project (Food Use for Social Innovation by Optimising waste prevention Strategies) is to achieve a Resource Efficient Europe by significantly reducing food waste. This is accomplished by harmonisation of food waste monitoring, showing the feasibility of socially innovative measures for optimised food use in the food supply chain and by giving policy recommendations for the development of an EU-28 Common Food Waste Policy. Further on, FUSIONS shall enable, encourage, engage and support key actors across Europe in delivering a 50% reduction in food wastage and a 20% reduction in the food supply chains resource inputs by 2020.

This report is a deliverable from the FUSIONS Work Package (WP) 1 "Reliable data and information sources, trends and assessment criteria" and is a follow up of the Report on "Main definitional choices for the food and drink waste produced within Europe". The Task "Environmental and social impacts of food waste: methodologies and baseline assessment" summarises the findings of two subtasks:

1. Assessment of socio-economic impacts of food waste:
The socio-economic impacts are analysed in detail along the food supply chain from a life cycle perspective, including

- the impact of food waste on health and nutritional issues (1a),
- the socio-economic impacts of food loss and waste reduction in the EU (1b) and
- the impact of food banks and other initiatives aimed at the food supply of marginalised social groups (1c).

Criteria for the assessment of these impacts were developed and a baseline assessment was undertaken.

2. Assessment of environmental impacts of food waste:
The target of FUSIONS is to provide a common approach for the assessment of the environmental impacts of food waste prevention in Europe focusing in a first step on global warming potential (GWP) but also considering other impact categories. To reach this goal, a bidirectional approach was developed and tested which combines top-down and bottom-up methods.

The term 'food waste' in this report is referring to FUSIONS definition. It is defined by the final destination of all food, and inedible parts of food, removed from the food supply chain. Any food and inedible parts of food, removed from the food supply chain sent to recovery and disposal operations are termed 'food waste'. Any food, or inedible parts of food, sent to animal feed, bio-material processing or other industrial uses are termed 'valorisation and conversion' and are distinct from 'food waste'.

# 2 Aim

The impact assessment within FUSIONS shall cover :

- the development of a set of criteria for the assessment of socio-economic and environmental impacts
- a baseline assessment of socio-economic and environmental impacts.

The aim of this report is to serve as documentation for the existing knowledge base with respect to the socio-economic and environmental impact of food waste and to provide new information on how to proceed towards socio-economic and environmental assessment of the impacts of food waste. This includes especially:

- an overview on existing data, applied methodology and gaps in data and information availability
- the identification of criteria for assessment
- the development of assessment methodology
- the test of the suggested methodology by using already existing data as well as new developed modelsthe formulation of recommendations for future approaches towards socio-economic and environmental assessment of food waste

Some approaches used for the impact assessment (e.g. for health and nutritional issues and the bottom-up approach for environmental impacts) demanded a selection of indicator products. The selection procedure, type of products and representativeness of products is handled in chapter 4. Health and nutritional issues are summarised in chapter 5, the socio-economic impacts of food loss and waste reduction in the EU are discussed in chapter 6, the impact of food banks and other initiatives aimed at the food supply of marginalised social groups is handled in chapter 7 and the environmental assessment is covered in chapter 8. The overall conclusion of the different issues is given and discussed in chapters 9 and 10.

# 3 Procedure

The content of this report is based on inputs from partners as shown in Table 3.1. The overall coordination of the impact assessment was handled by BOKU with support of FUSIONS workpackage leader SP. The above mentioned subtasks were elaborated by four subgroups which worked on the specific issues separately. In parallel, regular meetings have been used for update all participants of the task on progress of subtasks during ongoing work and to discuss the general aspects of the task in a broader context. In addition, the work was coordinated and aligned with the overall workpackage tasks through the participation at regular task leader meetings.

During consultation processes at Regional Platform Meetings (RPM) or European Platform Meetings (EPM) within FUSIONS and also at a workshop outside of FUSIONS (International Waste Working Group meeting) valuable input was provided to specific parts of this assessment (especially on social impacts).

At the end, the findings of the subtasks were discussed between task group members and summarized. Recommendations have been formulated in order to identify an approach how to proceed in future towards assessment of the socio-economic and environmental impacts of food waste. The report was reviewed by members of FUSIONS.

**Table 3.1: Partners participating in the different assessment tasks**

| Subtask | Participants (responsible partner underlined) |
|---|---|
| Chapter 5: Impact of food waste on health and nutritional issues | <u>DLO</u>, IFR, FAO |
| Chapter 6: The socio-economic impacts of food loss and waste reduction in the EU | <u>FAO</u> |
| Chapter 7: Impact of food banks and other initiatives aimed at the food supply of marginalised social groups | <u>UNIBO</u>, BOKU |
| Chapter 8: Assessment of environmental impacts of food waste including the selection of indicator products in chapter 4 | <u>BOKU</u>, WRAP, IFR, LUKE |

# 4 Selected indicator products

## 4.1 Approach

The variety of food products is enormous and a complete picture of its socio-economic and environmental impacts for all consumed articles is far from reality. Thus, FUSIONS will use a different approach. Bottom-up approaches applied to specific indicator products will be used in the environmental assessment and in the impact assessment on health and nutritional issues. These indicator products are assumed to be representative of a specific food category. The representativeness of these products has been verified on a mass basis as well as on an environmental basis (Monier et al., 2010). The combination of these indicator product results should give a first impression for the impact of food waste in Europe.
As well as the representativeness by mass of a product, the availability of existing LCA literature was also a crucial point for the selection.

The selected indicator products were:

- Apples (non-organic)
- Tomatoes, loose (non-organic)
- Potatoes (non-organic)
- Bread (non-organic)
- Milk (conventional / non-organic)
- Beef (conventional / non-organic)
- Pork (conventional / non-organic)
- Chicken (conventional / non-organic)
- White fish (wild-caught)

The indicator products were described in greater detail following the initial literature search to represent more accurately the product sold most commonly in the EU. In the case of fish, wild-caught white fish (cod, haddock, pollock, hake & saithe) was chosen as an appropriate sub-division of the indicator product rather than farmed fish, oily fish, pelagic species, crustaceans or shell-fish.

There is a wealth of research papers comparing the environmental impact of organic vs. non-organic food production. However, given the relatively low level of sales of organic food sales in Europe (<2%) (European Commission, 2010), only data for non-organic products is reported.

The feasibility of an extrapolation from these indicator products to the entire European impact of wasted food has to be tested.

# 4.2 Representativeness of indicator products

**Materials and methods**
To estimate the representativeness of the chosen indicator products, the production, food domestic utilization and consumption data of each product were compared to the overall data. Firstly, a data survey was performed to study what kind of data is available regarding production, food domestic utilization and consumption of the chosen indicator products. The survey was also done to provide indicators for the product specific food waste estimations.

In the survey the main datasets found were FAOStat (FAOStat, 2011), Eurostat (Eurostat, 2011) and EFSA (The EFSA) providing EU-average data. The country specific datasets found were: two Finnish datasets "Findiet" and "Balance sheet for food commodities" (Helldán et al, 2013; Luke, 2015), British dataset on food purchases (DEFRA, 2013), Swedish "Food consumption data" (Jordbruksverket, 2013), Irish "National adult nutrition survey" (Walton, 2011) and Dutch "National food consumption survey" (van Rossum et al., 2011).

In the dataset survey the chosen data source for production data was FAOStat which provides EU-averages and country specific information on production amounts, imports and exports of food commodities. Regarding food consumption data it was also decided to use FAOStat data on food domestic utilization. This was because FAOStat data was considered to be the most consistent data which is important to avoid data gaps and double counting. Additionally, consumption datasets were considered as inadequate since most of the data found was over 10 years old and due to the low number of recent datasets (from year 2007 onwards). However, total domestic food utilization was compared to available, insufficient food consumption datasets (food bought or dietary intake) (Table 4.1). Table 4.1 shows that the biggest differences between food domestic utilization and food consumption are especially in "the dairy products -category" and in "the pork -category". These differences, which occured mainly due to data gaps, are not further addressed here since the food consumption datasets (food bought or dietary intake) found were received as incomplete.

**Table 4.1: Comparisons of the amounts of food domestic utilization (in 2011) and consumption (datasets starting from 2007) in the EU**

| **Domestic food utilization, kg per capita** | | **Consumption, kg per capita (consumed food) NOT USED IN THE STUDY** | |
|---|---|---|---|
| Apples and products, kg | 18.3 | Pomaceous fruits (apples, pears etc.), kg | 17.1 |
| Tomatoes and products , kg | 27.4 | Fruit vegetables (incl. tomato), kg | 23.4 |
| Potatoes and potato products, kg | 71.9 | Potatoes and potato products (consumption), kg | 33.8 |
| Cereals, kg | 124.9 | Cereal products, kg | 86.6 |
| | | *Of which is Bread, kg* | *41.0* |
| Dairy products, including cheese, excluding butter | 240.1 | Dairy products, including cheese, excluding butter (consumption) | 112.6 |
| | | *Of which is Milk, kg* | *66.1* |
| Pork (carcass), kg | 40.4 | Pork, kg | 9.7 |
| Beef and veal (carcass), kg | 15.7 | Beef and veal, kg | 11.2 |
| Poultry (carcass?), kg | 21.7 | Poultry, kg [1] | 10.2 |
| White fish (Demersal), kg | 7.2 | Fish, kg | 10.7 |

**Representativeness of indicator products**

The representativeness of the indicator products is shown in Table 4.2 and Table 4.3. According to Table 4.2 , the share of indicator products that are produced in the EU cover 65.9 % of the total production in the EU. Moreover, the indicator products cover 65.7 % of total food domestic utilization, including processed food e.g. not only fresh tomatoes but also ketchup. It should be noted that the domestic utilization food groups are not exactly equivalent to indicator products, e.g. 'Cereals' are further divided to several products and 'Bread' is only one of these products. However, in this case, because of limits of the FAOSTAT data and lack of more detailed product specific data, we have used domestic utilization food groups to represent the indicator products i.e. 'Cereals' represents 'Bread'.

The remaining 34% were covered with a scaling factor for the extrapolation in the bottom-up approach of the environmental assessment. For further calculations it is assumed that the indicator products have the same impacts as the products not considered. This extrapolation was not performed for the health and nutritional section.

**Table 4.2: The amount produced and utilized of the indicator products (food commodities) in the EU in 2011. The amount and relative amount of production and supply of indicator products that are used for food**

| Indicator product, Food commodities | Production in EU 2011 (excl. alcohol) | Supply in EU 2011 (excl. alcohol) | Food domestic utilization in EU 2011 (excl. alcohol) | Food domestic utilization in EU 2011 (excl. alcohol) | Share of total production in EU 2011 (excl. alcohol) | Share of total food domestic utilization in EU 2011 (excl. alcohol) |
|---|---|---|---|---|---|---|
| | Billion kilos/year | Billion kilos/year | Billion kilos/year | Kilos/ capita/year | % | % |
| Apples and products | 11.7 | 12.0 | 9.3 | 18.3 | 1.3 % | 2.1 % |
| Tomatoes and products | 16.3 | 15.1 | 13.9 | 27.4 | 1.8 % | 3.2 % |
| Potatoes and products | 62.3 | 59.6 | 36.5 | 71.9 | 7.0 % | 8.3 % |
| Cereals - Excluding Beer | 293.1 | 278.6 | 63.4 | 124.9 | 33.1 % | 14.2 % |
| Milk - Excluding Butter | 155.5 | 140.6 | 121.8 | 240.1 | 17.5 % | 27.8 % |
| Bovine Meat | 8.1 | 8.0 | 7.9 | 15.7 | 0.9 % | 1.8 % |
| Pig meat | 23.4 | 20.7 | 20.5 | 40.4 | 2.6 % | 4.7 % |
| Poultry meat | 12.3 | 11.4 | 11.0 | 21.7 | 1.4 % | 2.5 % |
| White fish (Demersal) | 1.9 | 4.0 | 3.7 | 7.2 | 0.2 % | 0.8 % |
| Indicator products TOTAL | 584.6 | 550.0 | 288.0 | 567.6 | 65.9 % | 65.7 % |

**Table 4.3: The amount produced and utilized of the indicator products (food commodities) in the EU in 2011. Indicator products representativeness/product category.**

| Product category | Production in EU 2011 (excl. alcohol) | Indicator product /product category | Food domestic utilization in EU 2011 (excl. alcohol) | Indicator product /product category |
|---|---|---|---|---|
| | Billion kilos/year | % | Kilos/capita/year | % |
| Cereals | **293091** | 100.0 % | **125** | 100.0 % |
| Roots & tubers | **62383** | | **72** | |
| *Potatoes and products* | *62298* | 99.9 % | *72* | 99.8 % |
| *Other Roots & tubers* | *85* | | *0* | |
| Oil crops, pulses, sugar crops & nuts | **172976** | - | **70** | - |
| Fruits & vegetables | **130353** | | **216** | |
| *Tomatoes and products* | *16261* | 12.5 % | *27* | 12.7 % |
| *Apples and products* | *11717* | 9.0 % | *18* | 8.5 % |
| *Other Fruits & vegetables* | *102375* | | *170* | |
| Meat & animal fat | **58675** | | **85** | |
| *Pig meat* | *23374* | 39.8 % | *40* | 47.4 % |
| *Poultry Meat* | *12285* | 20.9 % | *22* | 25.4 % |
| *Bovine Meat* | *8059* | 13.7 % | *16* | 18.4 % |
| *Other meat and animal fat* | *14957* | | *8* | |
| Fish & seafood | **6735** | | **23** | |
| *White fish (Demersal)* | 1897 | 28.2 % | *7* | 31.3 % |
| *Other fish, Seafood* | *4838* | | *16* | |
| Dairy & eggs | **162410** | | **252** | |
| *Milk - Excluding Butter* | *155527* | 95.8 % | *240* | 95.2 % |
| *Eggs* | *6883* | | *12* | |
| Other (miscellaneous) | **143** | NA | **22** | NA |

The remaining 34.1 % food production groups (non-indicator products) include 'Sugar crops' (14.1 %), 'Other vegetables' (5.9 %: of which first two product groups are 'Onions' and 'Carrots and turnips'), 'Other fruits' (5.7 %: of which first two product groups are 'Grapes and products (excl wine)' and 'Oranges and Mandarins'), 'Oil crops' (4.9 %) and 'Other' (3,5 %: 'Animal fats' (1.1 %), 'Eggs' (0.8 %), 'Other fish' (0.5 %), 'Pulses' (0.4 %), 'Offals' (0.3 %), 'Other meat' (0.2 %), 'Tree nuts' (0.1 %)).

The remaining 34.3 % domestic food utilization groups (non-indicator products) are shown in the Figure 4.1, where the biggest remaining two food groups are 'Other vegetables' (10.2 %: of which first two product groups are 'Carrots and turnips' and 'Cabbages and other brassicas') and 'Other fruits' (9.5 %: of which first two product groups are 'Oranges and Mandarins' and 'Bananas').

**Figure 4.1: Food domestic utilization in EU in 2011 divided into food groups (The indicator products are shown in red)**

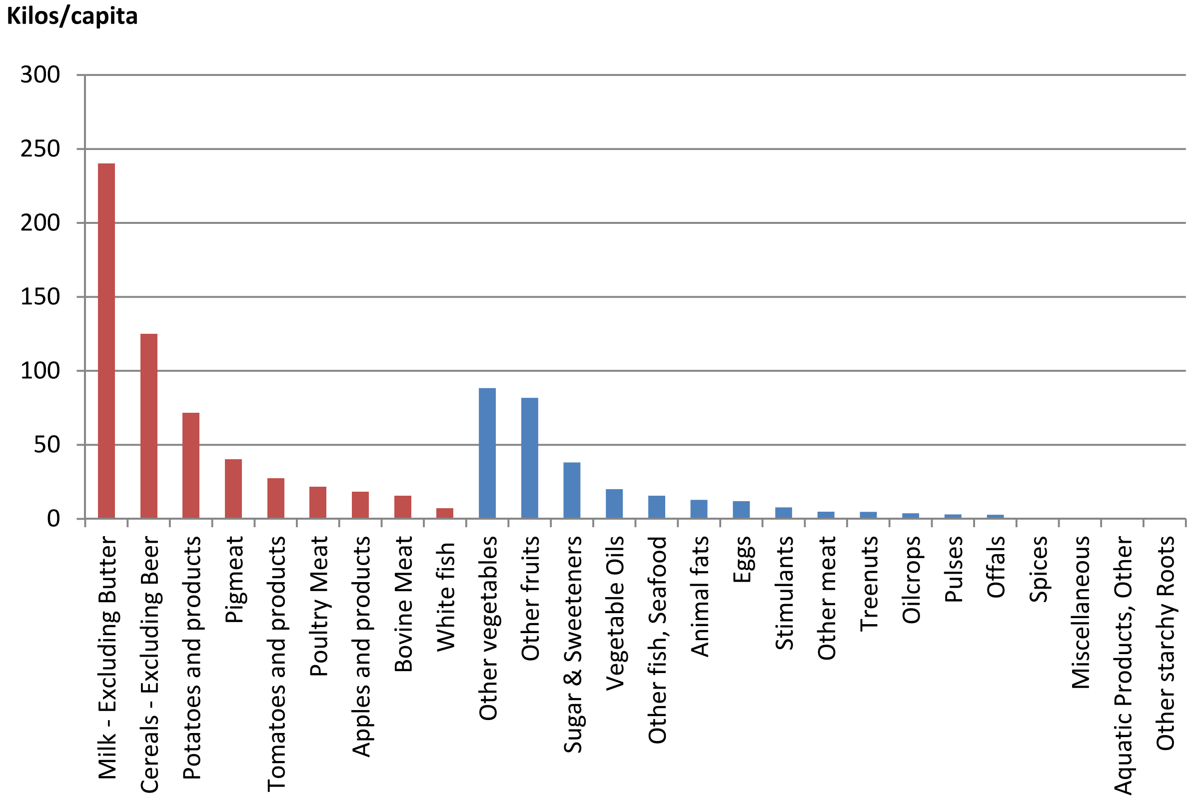



Table 4.4 shows the main producers of each indicator product within the EU and the relative share imported inside / to the EU by EU and non-EU countries. Additionally, the Table shows the main importers that import the indicator products inside/to EU. Production within the EU is generally concentrated within a few countries with the major EU producers (greater than 10% of the total) producing between 36-73 % of total production. Additionally, a relatively large share of food domestic utilization in the EU is produced by EU countries. However, tomatoes and tomato products and fish are exceptions where the EU imports tomatoes and tomato products from Turkey & USA (mainly tomato paste) and demersal fish from Norway.

**Table 4.4: Producers and importers of the indicator products in the EU in 2011**

| Indicator product (Food commodities) | EU countries producing at least 10 % of total EU production (share of production) [1, 2] | Five biggest importers that import inside/to EU (share of imports)[2, 3] | EU countries imports within EU (%) [2, 3] | Non-EU countries imports to EU (%) [2, 3] |
|---|---|---|---|---|
| Apples and products | Italy.21 %<br>Poland.21 %<br>France.16 % | Italy.21 %<br>France.18 %<br>Netherlands.12 %<br>Belgium.7 %<br>Chile.6 % | 79.7 % [4] | 20.3 % [4] |
| Tomatoes and products | Italy.37 %<br>Spain.24 % | Italy.16 %<br>Spain.15 %<br>Netherlands.14 %<br>Turkey.13 %<br>USA.12 % (paste) | 58.5 % | 41.5 % |
| Potatoes and products | Germany.19 %<br>Poland.13 %<br>France.12 %<br>Netherlands.12 % | France.25 %<br>Netherlands.22 %<br>Belgium.18 %<br>Germany.18 %<br>UK.3 % | 96.0 % | 4.0 % |
| Cereals - Excluding Beer | France.22 %<br>Germany.14 % | France.24 %<br>Germany.11 %<br>Hungary.6 %<br>Ukraine.5 %<br>UK.4 % | 78.7 % | 21.3 % |
| Milk - Excluding Butter | Germany.20 %<br>France.16 % | Germany.27 %<br>France.16 %<br>Netherlands.9 %<br>Belgium.9 %<br>Austria.6 % | 99.3 % | 0.7 % |
| Pork and products | Germany.24 %<br>Spain.15 %<br>France.10 % | Germany.25 %<br>Denmark.16 %<br>Netherlands.13 %<br>Spain.11 %<br>Belgium.10 % | 99.7 % | 0.3 % |
| Beef. veal and products | France.19 %<br>Germany.15 %<br>Italy.12 %<br>UK.12 % | Netherlands.16 %<br>Ireland.14 %<br>Germany.14 %<br>France.10 %<br>Poland.7 % | 90.5 % | 9.5 % |
| Poultry and products | United Kingdom.14 %<br>Poland.12 %<br>Spain.12 %<br>France.11 % | Norway.10 %<br>Germany.10 %<br>Denmark.9 %<br>Spain.5 %<br>China.5 % | 84.1 % [5] | 15.9 % [5] |
| Fish | Spain.23 %<br>Denmark.22 %<br>UK.15 %<br>France.13 % | Norway.10 %<br>Germany.10 %<br>Denmark.9 %<br>Spain.5 %<br>China.5 % | 52.0 % | 48.0 % |

[1] Based on: FAOStat, Production: http://faostat3.fao.org/download/Q/*/E
[2] Data from European Market Observatory for fisheries and aquaculture (EUMOFA) http://ec.europa.eu/fisheries/market-observatory
[3] Based on: FAOStat, Trade matrixes: http://faostat3.fao.org/download/T/TM/E
[4] Includes only import of fresh apples, no apple products
[5] Includes only imports of chicken

# 5 Impact of food waste on health and nutritional issues

## 5.1 Scope and definitions

Food and nutrition security[2] is a complex issue, linked to health through malnutrition, but also to sustainable economic development, environment, and trade. Europe and Central Asia as a region has achieved[3] the Millennium Development Goal hunger target of reducing by half the proportion of people affected by hunger. However, childhood stunting and malnutrition continue to be problems in some countries within the region. Moreover, overweight and obesity are an increasing nutrition, health and budgetary concern with child overweight rates double those of the developing world (FAO, IFAD, WFP, 2015). These figures show profound imbalances in consumption and diets.

At the same time, large amounts of food are being wasted, food that still may contain important nutrients and micronutrients. Up till now no indication exists on the amount of nutrients and micronutrients present in wasted food. Despite the lack of data (which will be mentioned in this chapter), an attempt has been made to estimate macronutrient and micronutrient losses resulting from food waste.
An estimation of macronutrient and micronutrient loss resulting from food waste may be helpful for people trying to prevent food waste by engaging the public and companies and increasing awareness on this subject.

The focus of this section is on the losses of nutrients and micronutrients due to food being wasted rather than eaten. An estimation of macronutrient and micronutrient loss resulting from food waste is provided, based on several assumptions. Also a methodology is provided to calculate nutrient losses from food waste. Additional attention has been paid to anti-nutritional factors, which may be present in wasted food preventing its recovery and reuse in the food supply chain. Anti-nutritional factors are natural compounds found in foods that interfere with nutrient absorption.

## 5.2 Approach

The following steps are needed in order to estimate macronutrient and micronutrient losses as a result of wasting food. Below a general approach is presented. Each step is described and clarified in more detail in paragraph 5.3, where the selections made in this chapter are presented as well.

1. Selection of products to include in the calculations.

[2] WHO, Food Security and Health
[3] Tajikistan is the only country in the region not reaching MDG 1C.

2. Amounts of wasted products in a specific region or country in a specific time period.

3. Collection of nutritional data from food composition databases. In the optimal case match the selected database to the country of which the food waste amounts are available.

4. Selection of macronutrients and micronutrients relevant to human nutrition to include in the calculations.

5. Nutrient losses are estimated as relevant per food/food group. Calculation of nutrient loss:

$$Nutrient\ loss = FW amount\ \times nutrient\ concentration$$

6. Analysis of nutrient losses in terms of human nutrient requirements can be performed by comparing nutrient losses resulting from food waste to recommended daily intake (RDI)[4] of that specific nutrient or micronutrient.

Based on a literature search an overview of anti-nutritional factors (ANF) in food waste fractions is compiled. The overview is based on review and other research papers.
This overview of anti-nutritional factors is prepared to assess any safety implications affecting the use of food waste fractions, either for use in food or feed. ANF may be concentrated within the inedible fraction. Examples of ANFs include: mycotoxins, glycoalkaloids, pesticide residues, and other such as oxalate, phytate, tannins, saponins and protease inhibitors. The review is presented in paragraph 5.4.

Health and nutrition indicators and their potential impacts are also noticed in the impact assessment of food banks and other initiatives (see chapter 7.4.1).

## 5.3 Assessment of health and nutritional issues

Estimation of the impact of food waste on health and nutritional issues can be performed by calculation of nutrient losses resulting from food waste. Two parameters are needed to perform such a calculation:

- Amounts of wasted products: Food waste amounts in EU 2011 (totals), after translation of total waste amounts to food categories and to indicator product (groups) see annex 10.1.
- Nutritional data describing the macronutrient and micronutrient composition of indicator product (groups).

This exercise has been performed to make preliminary estimations of the nutritional composition of food waste and in order to test the methodology.

[4] Referring to male adults.

### 5.3.1 Amounts of wasted products

The selection of products to include in the calculations is consistent with the selected products used for the assessment of environmental impacts of food waste (see Chapter 4). Typical basic products have been used for the calculations in the current chapter, see paragraph 4.1 about indicator products. The selected indicator products are apples, tomatoes, potatoes, bread, milk, beef, pork, chicken and white fish (wild caught). The selected indicator products are approximations for their product category, see paragraph 4.2 about indicator representativeness.

The amounts of wasted indicator products are obtained from Annex 10.1, where the estimations of food waste data are described. In Table 10.7 the combined total of edible and associated inedible parts of food leaving the food supply chain of indicator products is provided. These food waste amounts relate to the European Region in 2011.

By using food waste data from Table 10.6, which contains the food waste amounts of indicator products and is not extrapolated to total food waste amounts, the following assumption is made: the estimated amounts of wasted (indicator) product groups are representative for total food waste. This will be an underestimation for the total amount of total food waste, since the share of indicator products that are produced in the EU cover 65,9 % of the total production in the EU.

### 5.3.2 Selection of nutrients and micronutrients

The following macronutrients and micronutrients are included in the calculations. The agreed subset of nutrients and micronutrients are vitamin A (expressed as retinol equivalents, RE), beta-carotene, vitamin C, fibre, iron, zinc, n-3 fatty acids, lysine and methionine (sulphur-containing amino acids). The selection of these components was guided by the relevance related to the potential representation in the formulation of food-based dietary guidelines [5]. As food composition databases contain much more components than selected above (see Table 5.1 in paragraph 5.3.3) it is also possible to use other selection criteria in future studies, e.g. for the calculation of the amount of sugar wasted.

We selected the compounds for the following reasons:

The micronutrient **vitamin A (retinol)** is an essential nutrient needed in small amount by humans for the normal functioning of the visual system; growth and development; and maintenance of epithelial cellular integrity, immune function, and reproduction while the micronutrient **beta-carotene** is a Vitamin A precursor. The dietary needs for vitamin A are normally provided for as preformed retinol (mainly as retinyl ester) and provitamin A carotenoids (among which beta-carotene). Vitamin A Deficiency (VAD) refers to tissue concentrations of vitamin A low enough to have adverse health consequences. VAD impairs normal functioning of the visual system and maintenance of cell function for growth, red blood cell production, immunity and reproduction (WHO, 2009). VAD is the leading cause of blindness in children. However, nonspecific symptoms include dermatitis, increased morbidity and mortality, poor reproductive health, increased risk of anaemia, and contributions to slowed growth and development. Nevertheless, these

[5] Vitamin and mineral requirements in human nutrition Second edition. World Health Organization and Food and Agriculture Organization of the United Nations 2004. http://apps.who.int/iris/bitstream/10665/42716/1/9241546123.pdf

nonspecific adverse effects may be caused by other nutrient deficits as well, making it difficult to attribute non-ocular symptoms specifically to VAD in the absence of biochemical measurements reflective of vitamin A status (WHO and FAO, 2004).
Preformed vitamin A is found almost exclusively in animal products, such as human milk, glandular meats, liver and fish liver oils (especially), egg yolk, whole milk, and other dairy products. Preformed vitamin A is also used to fortify processed foods, which may include sugar, cereals, condiments, fats, and oils. Provitamin A carotenoids are found in green leafy vegetables (e.g. spinach, amaranth, and young leaves from various sources), yellow vegetables (e.g. pumpkins, squash, and carrots), and yellow and orange non-citrus fruits (e.g. mangoes, apricots, and papayas, etc.). Foods containing provitamin A carotenoids tend to have less biologically available vitamin A but are more affordable than animal foods. It is mainly for this reason that carotenoids provide most of the vitamin A activity in the diets of economically deprived populations (WHO and FAO, 2004).

The micronutrient **vitamin C (Ascorbic acid)** according to EFSA (EFSA NDA Panel, 2013) in aqueous solution readily scavenges reactive oxygen and nitrogen species, and is part of the antioxidant network of the body and has a gastrointestinal absorption of about 80 % for an intake of about 100 mg/day. Vitamin C functions physiologically as a water-soluble antioxidant and plays a major role as a free radical scavenger. Vitamin C is part of the antioxidant defence system, which is a complex network including endogenous antioxidants and dietary antioxidants, antioxidant enzymes, and repair mechanisms, with mutual interactions and synergetic effects among the various components. A cause and effect relationship has been established between the dietary intake of vitamin C and the protection of DNA, proteins and lipids from oxidative damage (EFSA NDA Panel, 2009).

According to EFSA there are two broad categories of carbohydrate (EFSA NDA Panel, 2010a): "glycaemic carbohydrates", i.e. carbohydrates digested and absorbed in the human small intestine, and "**dietary fibre**", non-digestible carbohydrates passing to the large intestine. The main glycaemic carbohydrates are monosaccharides, disaccharides, malto-oligosaccharides, and starch. Whole grain cereals, pulses, fruit, vegetables and potatoes are the main sources of dietary fibre.
The role of dietary fibre (macronutrient) in bowel function was considered the most suitable criterion for establishing an adequate intake. Based on the available evidence on bowel function, the EFSA Panel considers dietary fibre intakes of 25 g/day to be adequate for normal laxation in adults. A fibre intake of 2 g/MJ is considered adequate (appropriate adjustment) for normal laxation in children from the age of one year.
The Panel notes that in adults there is evidence of benefit to health associated with consumption of diets rich in fibre-containing foods at dietary fibre intakes greater than 25 g per day, e.g. reduced risk of coronary heart disease and type 2 diabetes and improved weight maintenance (EFSA NDA Panel, 2010a).

The micronutrient **iron**, a mineral, has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells, and as an integrated part of important enzyme systems in various tissues. Most of the iron in the body is present in the erythrocytes as haemoglobin, a molecule composed of four units, each containing one heme group and one protein chain. The structure of haemoglobin allows it to be fully loaded with oxygen in the lungs and partially unloaded in the tissues (e.g., in the muscles). The iron-containing oxygen storage protein in the muscles, myoglobin, is similar in structure to haemoglobin but has only one heme unit and one globin chain. Several iron-containing enzymes, the cytochromes, also have one heme group and one globin protein chain. These enzymes act as electron carriers within the cell and their

structures do not permit reversible loading and unloading of oxygen. Their role in the oxidative metabolism is to transfer energy within the cell and specifically in the mitochondria. Other key functions for the iron-containing enzymes (e.g., cytochrome P450) include the synthesis of steroid hormones and bile acids; detoxification of foreign substances in the liver; and signal controlling in some neurotransmitters, such as the dopamine and serotonin systems in the brain. Iron is reversibly stored within the liver as ferritin and hemosiderin whereas it is transported between different compartments in the body by the protein transferrin (FAO and WHO, 2001).
Moreover, iron is not actively excreted from the body in urine or in the intestines. Iron is only lost with cells from the skin and the interior surfaces of the body – intestines, urinary tract, and airways. The total amount lost is estimated at 14 µg/kg body weight/day. In children, it is probably more correct to relate these losses to body surface. A non-menstruating 55-kg woman loses about 0.8 mg Fe/day and a 70-kg man loses about 1 mg.
EFSA considers that the role of iron in normal formation of haemoglobin and red blood cells applies to all ages, including infants and young children (from birth to three years). The Panel concludes that a cause and effect relationship has been established between dietary intake of iron and contribution to normal formation of haemoglobin and red blood cells (EFSA NDA Panel, 2014b).
Reducing substances (i.e., substances that keep iron in the ferrous form) must be present for iron to be absorbed. The presence of meat, poultry, and fish in the diet enhance iron absorption. Other foods contain factors (ligands) that strongly bind ferrous ions, which subsequently inhibit absorption. Examples are phytates and certain iron-binding polyphenols. Phytates are found in all kinds of grains, seeds, nuts, vegetables, roots (e.g., potatoes), and fruits. In North American and European diets, about 90 percent of phytates originate from cereals.

Minerals such as **iron** and **zinc** are low in cereal and tuber-based diets, but high in animal sources of foods. The addition of legumes can slightly improve the iron content of those diets. However, the bio-availability of this non-heme iron source is low. Therefore, it is not possible to meet the recommended levels of iron and zinc in the staple-based diets through a food-based approach unless some meat, poultry, or fish is included. For example adding a small portion (50 g) of meat, poultry, or fish will increase the total iron content as well as the amount of bio-available iron. For zinc the presence of a small portion (50 g) of meat, poultry, or fish will secure dietary sufficiency of most staple diets. The consumption of **ascorbic acid** along with the food rich in iron will enhance iron absorption. There is a critical balance between enhancers and inhibitors of iron absorption. Nutritional status can be improved significantly by educating households on food preparation practices, which minimise the consumption of inhibitors of iron absorption; for example, the fermentation of phytate-containing grains before the baking of breads to enhance iron absorption. The practical solution for this competition is to increase iron intake, increase its bio-availability, or avoid the intake of foods rich in calcium and foods rich in iron at the same meal (FAO and WHO, 2001)

EFSA states that the micronutrient **zinc** has a wide array of vital physiological functions with a catalytic role in each of the six classes of enzymes. The human transcriptome has 2500 zinc finger proteins, which have a broad intracellular distribution and the activities of which include binding of RNA molecules and involvement in protein–protein interactions. Thus, their biological roles include transcriptional and translational control/modulation and signal transduction (EFSA NDA Panel, 2014a).
The majority of dietary zinc is absorbed in the upper small intestine. The luminal contents of the duodenum and jejunum, notably phytate, can have a major impact on the percentage of zinc that is available for absorption. Absorption of zinc by the enterocyte is regulated in response to the quantity of bioavailable zinc ingested. Albumin

is the major transporter of zinc in both portal and systemic circulation. Virtually no zinc circulates in a free ionised form, and the majority of total body zinc is in muscle and bone; zinc does not have an identified major storage site. The quantity of zinc secreted into and excreted from the intestinal tract depends on body zinc concentrations, and the quantities of endogenous zinc in the faeces and exogenous zinc absorbed in normal adults are related. The kidneys and integument are minor routes of loss of endogenous zinc (EFSA NDA Panel, 2014a).
Consumption of flesh foods improves zinc absorption whereas it is inhibited by consumption of diets high in phytate, such as diets based on unrefined cereal (FAO and WHO, 2001)
Meat, legumes, eggs, fish, and grains and grain-based products are rich dietary zinc sources. On the basis of data from 12 dietary surveys in nine European Union (EU) countries, zinc intake was assessed using food consumption data from the EFSA Comprehensive Food Consumption Database and zinc composition data from the EFSA nutrient composition database. The main food groups contributing to zinc intake were meat and meat products, grains and grain-based products, and milk and dairy products. Published data on phytate intake in the EU are limited and indicate a wide range of dietary phytate intakes (EFSA NDA Panel, 2014a).

The macronutrient **fat** is an important dense source of energy and facilitates the absorption of fat-soluble dietary components such as fat soluble **vitamin A, D and E**. Fats and oils are also important sources of essential fatty acids. Fatty acids are also involved in many other vital processes in the body (e.g. structural components of cell membranes, precursors for bioactive molecules, regulators of enzyme activities, regulation of gene expression) (EFSA NDA Panel, 2010b).

Dietary **proteins** (macronutrients) are the source of dispensable and indispensable amino acids as well as nitrogenous compounds for the body. Both in the diet and in the body, 95 % of the nitrogen is found in proteins and 5 % is found in the form of other nitrogenous compounds, i.e. free amino acids, urea or nucleotides. Data from dietary surveys show that the average protein intakes in European countries vary between 67 to 114 g/d in adult men and 59 to 102 g/d in women, or about 12 to 20 % of total energy intake (E %) for both sexes. Few data are available for the mean protein intakes on a body weight basis, which vary from 0.8 to 1.25 g/kg body weight per day for adults (EFSA NDA Panel, 2012).
Foods of animal origin with a high protein content are meat, fish, eggs, milk and dairy products. Bread and other grain-based products, leguminous vegetables, and nuts are plant foods high in protein. Most of the animal sources are considered high quality protein having an optimal indispensable amino acid composition for human needs and a high digestibility, whereas the indispensable amino acid content of plant proteins and/or their digestibility is usually lower. In European countries the main contributors to dietary protein intake are meat and meat products, grains and grain-based products, and milk and dairy products (EFSA NDA Panel, 2012).

The 20 proteinogenic **amino acids** are classified as indispensable or dispensable amino acids. Nine amino acids are classified as indispensable in humans (histidine, isoleucine, leucine, **lysine**, **methionine**, phenylalanine, threonine, tryptophan, and valine) as they cannot be synthesised in the human body from naturally occurring precursors at a rate to meet the metabolic requirement. The remaining dietary amino acids are dispensable (alanine, arginine, cysteine, glutamine, glycine, proline, tyrosine, aspartic acid, asparagine, glutamic acid, and serine). Among the nine indispensable amino acids, lysine and threonine are strictly indispensable since they are not transaminated and their deamination is irreversible (EFSA NDA Panel, 2012).

High quality protein has an optimal indispensable amino acid composition for human needs and a high digestibility. Most dietary protein of animal origin (meat, fish, milk and egg) can be considered as such high quality protein. In contrast, some dietary proteins of plant origin can be regarded as being of lower nutritional quality due to their low content in one or several indispensable amino acids and/or their lower digestibility. It is well established that **lysine** is limited in cereal protein and that sulphur-containing amino acids (cysteine and **methionine**) are limited in legumes. Most of the Western diets have a Protein Digestibility-Corrected Amino Acid Score (PD-CAAS)[6] equal to or higher than 1 because high quality proteins dominate over low quality proteins. Although proteins limited in one amino acid can complement proteins in the diet which are limited in another amino acid, a high level of cereal in the diet in some countries can lead to a PD-CAAS lower than 1 mainly because of a low content in lysine (EFSA NDA Panel, 2012).

## 5.3.3 Compositional or nutritional data

<u>Selection of food composition databases</u>
The EUROFIR database was the first inventory step and was used for the selection of compositional databases. In the EUROFIR database[7] Food Composition Databases of many EU Member States and some other countries are present.
In order to provide insight in the variation in nutrient concentrations described in these databases three freely available on-line national Food Composition Databases were selected for use:
- **Netherlands:** Dutch Food Composition Database, NEVO-online version 2013/4.0 (NEVO, 2013).
- **Sweden:** The Food Database, version 19-01-2015 (Livsmedelsverket, 2015).
- **USA:** USDA National Nutrient Database for Standard Reference, Release 27 (USDA, 2014). However this database is not European, it was selected as well, because it provides data concerning individual amino acids.

The selected food composition databases provide a wealth of information about the concentration of nutrients and micronutrients in edible food products. At the same time they differ in the number of food items and nutrients included in the database. In Table 5.1 an overview of the number of food items and nutrients per selected database is presented. The USDA database is the most elaborate food composition database.

**Table 5.1: Comparison of number of food items and number of nutrients in the selected food composition databases.**

| FCDB | Number of food items | Number of nutrients |
|---|---|---|
| NL (NEVO, 2013). | 2194 food items | approximately 260 different nutrients, selection online |
| SE (Livsmedels-verket, 2015) | more than 2000 foods and dishes | more than 50 nutrients |
| USA (USDA, 2014) | 8,618 different foods | approximately 150 different nutrients, including amino acids* |

*Only the online database from the USA provides data concerning individual amino acids

[6] The Protein Digestibility-Corrected Amino Acid Score (PD-CAAS) corrects the amino acid score by the digestibility of the protein (FAO/WHO, 1991)
[7] http://www.eurofir.org/?page_id=96

Presence of indicator products in food composition databases

The following indicator products, together with their derived products, are present in all three food composition databases: tomatoes, apples, potatoes, milk, bread, beef, pork, and chicken. However, in the selected food composition databases 'white fish' is not present as a single category (specific species of fish are listed). Whether they are wild caught is not mentioned. The search term describing white fish, as well as their presence in a food composition database is provided in Table 5.2.

**Table 5.2: Presence of indicator product *white fish* in the selected food composition databases**

| **white fish** | **NL** | **SE** | **USDA** |
|---|---|---|---|
| cod | yes | yes | yes |
| whiting | yes | yes | yes |
| haddock | yes | yes | yes |
| hake | no | yes | no |
| pollock | yes: pollack | yes | yes |

Drawback of using nutritional data from food composition databases.

As mentioned before, food composition databases provide information about edible food products. What we need is information about the nutrient and micronutrient composition of wasted foods and inedible parts from the (indicator) food products. However, this information is not available. Therefore we made the following assumption: nutritional data from food composition databases are an estimate for the nutrient composition of waste/inedible parts from the (indicator) food products. This will be an overestimation for the nutrient content of waste for two reasons:

1. degregation of nutrients over time is expected to occur.
2. the inedible parts usually will have lower nutritional content than the edible fraction.

Recalculation of nutritional data to food group level

Nutritional data in food composition databases are on product level (single food level). These food products do not correspond to the classification of food products (or indicator products) in food waste data, which are present in this research on a food group level (indicator product and derived products). In order to estimate nutrient and micronutrient concentrations on a food group level, average concentrations were calculated from the individual food products that may be included in an indicator product group.
However, the selected food composition databases differ in the level of detail they provide in describing a food product. Therefore it is difficult to find exactly the same product in the three different food composition databases. To overcome this problem, and because of the fact that the three food composition databases differ so much in the amount of food products that are included in the database, average compositions of indicator product groups are calculated for the three different food composition databases separately, see Table 5.3 to 5.5.

**Table 5.3:. Average composition of indicator products, based on indicator food groups (indicator product+derived products), per 100 gram. Calculated from NL food composition database.**

| Indicator product group | Retinol (µg) | Beta-caroten e (µg) | Vitamin C (mg) | Total dietary fibre (g) | Total iron (mg) | Zinc (mg) | n-3 pufa* (g) |
|---|---|---|---|---|---|---|---|
| apples | 4 | 18 | 4 | 3 | 0 | 0 | 0 |
| tomatoes | 87 | 503 | 24 | 3 | 1 | 0 | 0 |
| potatoes | 49 | 281 | 9 | 2 | 1 | 0 | 0 |
| bread | 1 | 1 | 0 | 5 | 2 | 1 | 0 |
| milk | 51 | 42 | 1 | 0 | 0 | 0 | 0 |
| beef | 1297 | 50 | 4 | 0 | 2 | 5 | 0 |
| pork | 1625 | 3 | 3 | 0 | 2 | 3 | 0 |
| chicken | 779 | 0 | 2 | 0 | 1 | 1 | 0 |
| whitefish | 10 | 1 | 1 | 0 | 1 | 1 | 1 |
| Grand Total | 436 | 66 | 3 | 2 | 1 | 2 | 0 |

*n-3 polyunsaturated fatty acid

**Table 5.4: Average composition of indicator products, based on indicator food groups (indicator product+derived products), per 100 gram. Calculated from SE food composition database.**

| Indicator product group | Retinol (µg) | Beta-carotene (µg) | Vitamin C (mg) | Fibre (g) | Iron (mg) | Zinc (mg) | n-3 pufa* (g) |
|---|---|---|---|---|---|---|---|
| apples | 11 | 24 | 4 | 2 | 0 | 0 | 0 |
| tomatoes | 1 | 581 | 16 | 3 | 1 | 0 | 0 |
| potatoes | 6 | 62 | 13 | 2 | 1 | 0 | 0 |
| bread | 16 | 9 | 0 | 7 | 2 | 2 | 0 |
| milk | 34 | 19 | 0 | 0 | 0 | 1 | 0 |
| beef | 1001 | 111 | 3 | 0 | 3 | 4 | 0 |
| pork | 11 | 15 | 0 | 0 | 1 | 3 | 0 |
| chicken | 816 | 20 | 4 | 0 | 2 | 1 | 0 |
| whitefish | 15 | 3 | 1 | 0 | 0 | 1 | 0 |
| Grand Total | 268 | 64 | 4 | 2 | 2 | 2 | 0 |

*n-3 polyunsaturated fatty acid

**Table 5.5: Average composition of indicator products, based on indicator food groups (indicator product+derived products), per 100 gram. Calculated from USA food composition database.**

| Indicator product group | Retinol (µg) | Carotene, beta (µg) | Vitamin C (mg) | Fiber, total dietary (g) | Iron, Fe (mg) | Zinc, Zn (mg) | n-3 pufa* (g) | Lysine (g) | Methionine (g) |
|---|---|---|---|---|---|---|---|---|---|
| apples | 0 | 16 | 10 | 2 | 0 | 0 | 0 | 0 | 0 |
| tomatoes | 0 | 874 | 26 | 2 | 1 | 0 | 0 | 0 | 0 |
| potatoes | 9 | 1414 | 11 | 3 | 1 | 0 | 0 | 0 | 0 |
| bread | 9 | 7 | 0 | 5 | 3 | 1 | 0 | 0 | 0 |
| milk | 82 | 8 | 2 | 0 | 0 | 1 | 0 | 1 | 0 |
| beef | 85 | 1 | 0 | 0 | 3 | 6 | 0 | 2 | 1 |
| pork | 40 | 0 | 1 | 0 | 1 | 2 | 0 | 2 | 1 |
| chicken | 228 | 1 | 1 | 0 | 2 | 2 | 0 | 2 | 1 |
| whitefish | 22 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 1 |
| Grand Total | 83 | 67 | 2 | 0 | 2 | 4 | 0 | 2 | 1 |

*n-3 polyunsaturated fatty acid

In order to provide insight in how the selected food composition databases differ in the level of detail they provide in describing a food product and how they differ in the amount of food products that are included in the database, the food products that are used in order to calculate the average nutrient and micronutrient composition of the indicator product group "apples" is presented in the text box below.
The averages described in the tables are simple averages, they can be optimized by weighing for their prevalence, but that has not been performed in the present study.

**Indicator food group: apples (including derived products)**

**Food products present in NL food composition database**
1) Apple Elstar with skin; 2) Apple Elstar without skin; 3) Apple Jonagold with skin; 4) Apple Jonagold without skin; 5) Apple with skin average; 6) Apple without skin average; 7) Apple sauce tinned; 8) Apple sauce without sugar tinned; 9) Apples dried; 10) Apple dried soaked in water

**Food products present in SE food composition database**
1) Apple cake w/ dried bread crumbs; 2) Apple compote; 3) Apple cowberry drink RTD fortified; 4) Apple crumble; 5) Apple drink RTD fortified; 6) Apple fool; 7) Apple juice canned RTD; 8) Apple peeled; 9) Apple pie; 10) Apple pie crust bottom and top; 11) Apple sauce; 12) Apple sauce reduced sugar; 13) Apple sauce unsweetened or with calorie-free sweeteners; 14) Apple soup; 15) Apple with skin; 16) Apples canned; 17) Apples dried; 18) Baked apples; 19) Crab apple; 20) Deep fried apple pie; 21) French apple cake

**Food products present in USA food composition database**
1) Apples, raw, with skin; 2) Apples, raw, without skin; 3) Apples, raw, without skin, cooked, boiled; 4) Apples, raw, without skin, cooked, microwave; 5) Apples, canned, sweetened, sliced, drained, unheated; 6) Apples, canned, sweetened, sliced, drained, heated; 7) Apples, dehydrated (low moisture), sulfured, uncooked; 8) Apples, dehydrated (low moisture), sulfured, stewed; 9) Apples, dried, sulfured, uncooked; 10) Apples, dried, sulfured, stewed, without added sugar; 11) Apples, dried, sulfured, stewed, with added sugar; 12) Apples, frozen, unsweetened, unheated; 13) Apples, frozen, unsweetened, heated; 14) Apple juice, canned or bottled, unsweetened, without added ascorbic acid; 15) Apple juice, frozen concentrate, unsweetened, undiluted, without added ascorbic acid; 16) Apple juice, frozen concentrate, unsweetened, diluted with 3 volume water without added ascorbic acid; 17) Applesauce, canned, unsweetened, without added ascorbic acid (includes USDA commodity); 18) Applesauce, canned, sweetened, without salt (includes USDA commodity); 19) Apple juice, canned or bottled, unsweetened, with added ascorbic acid; 20) Applesauce, canned, unsweetened, with added ascorbic acid; 21) Applesauce, canned, sweetened, with salt; 22) Apple juice, frozen concentrate, unsweetened, undiluted, with added ascorbic acid; 23) Apple juice, frozen concentrate, unsweetened, diluted with 3 volume water, with added ascorbic acid; 24) Apples, raw, red delicious, with skin; 25) Apples, raw, golden delicious, with skin; 26) Apples, raw, granny smith, with skin; 27) Apples, raw, gala, with skin; 28) Apples, raw, fuji, with skin; 29) Apple juice, canned or bottled, unsweetened, with added ascorbic acid, calcium, and potassium.

### 5.3.4 Nutrient losses

Estimation of the impact of food losses and waste on health and nutritional issues can be performed by calculation of nutrient losses resulting from food waste. This exercise is performed to be able to make preliminary estimations of the nutritional composition of food waste and in order to test the methodology.

In short, the calculation of nutrient loss in indicator product (groups) can be descibed as follows:

$$Nutrient\ loss = FWamount\ \times nutrient\ concentration$$

In which
FWamount= amount of wasted indicator product (groups), see paragraph 5.3.1
nutrient concentration=concentration of nutrient or micronutrient in selected indicator product (groups), see paragraph 5.3.2

While performing such a calculation, it is important to bear in mind that nutritional data are on a food product level, therefore food waste data are needed on a product level as well. As these data are not available on an EU wide basis[8], the results will be estimations based on average nutrient composition of the indicator product food groups. Futhermore, nutritional data are available only for edible parts, not for inedible parts. Although not completely realistic, we assume that these data can be used to describe unedible parts as well. This is also mentioned in paragraph 5.3.3.

Estimation of nutrient loss is calculated for the selected nutrients and micronutrients, for the three different food composition databases separately, see Figure 5.1 to 5.3
These figures show, per nutrient or micronutrient in which part of the food chain (production, processing, retailing, and consumption) and in which indicator food category, nutrient losses occur.

Figure 5.1 shows that vitamin A losses are highest in pig meat, at the consumption stage of the food chain. The high values found for vitamin A losses in meat in general are caused by the presence of liver products in the Food Composition Databases, which account largely for the high vitamin A concentrations.
Beta-carotene losses are highest in potatoes and potato products, at the production stage of the food chain. Here a remark has to be added as well: sweet potatoes (which possess a very high beta-carotene content) are also included in this food category.
Vitamin C losses are highest in potatoes and potato products, at the production stage, while vitamin C losses in tomatoes and tomato products are highest at the consumption stage of the food chain.
Losses of dietary fibre, iron, zinc and n-3 fatty acids occur mostly at the consumption stage of the food chain, especially in cereal products.

Estimation of nutrient loss was also performed for the selected nutrients and micronutrients, using two other food composition databases see Figure 5.2 the results by using the Swedish food composition database and Figure 5.3 the results by using the USA food composition database.

[8] However, some Member States, such as the UK do have food waste data for a specific sector on a product level (WRAP 2013a)

**Figure 5.1: Nutrient loss (in kg), based on food waste amounts of indicator products in EU in 2011, and NL food compositional data**

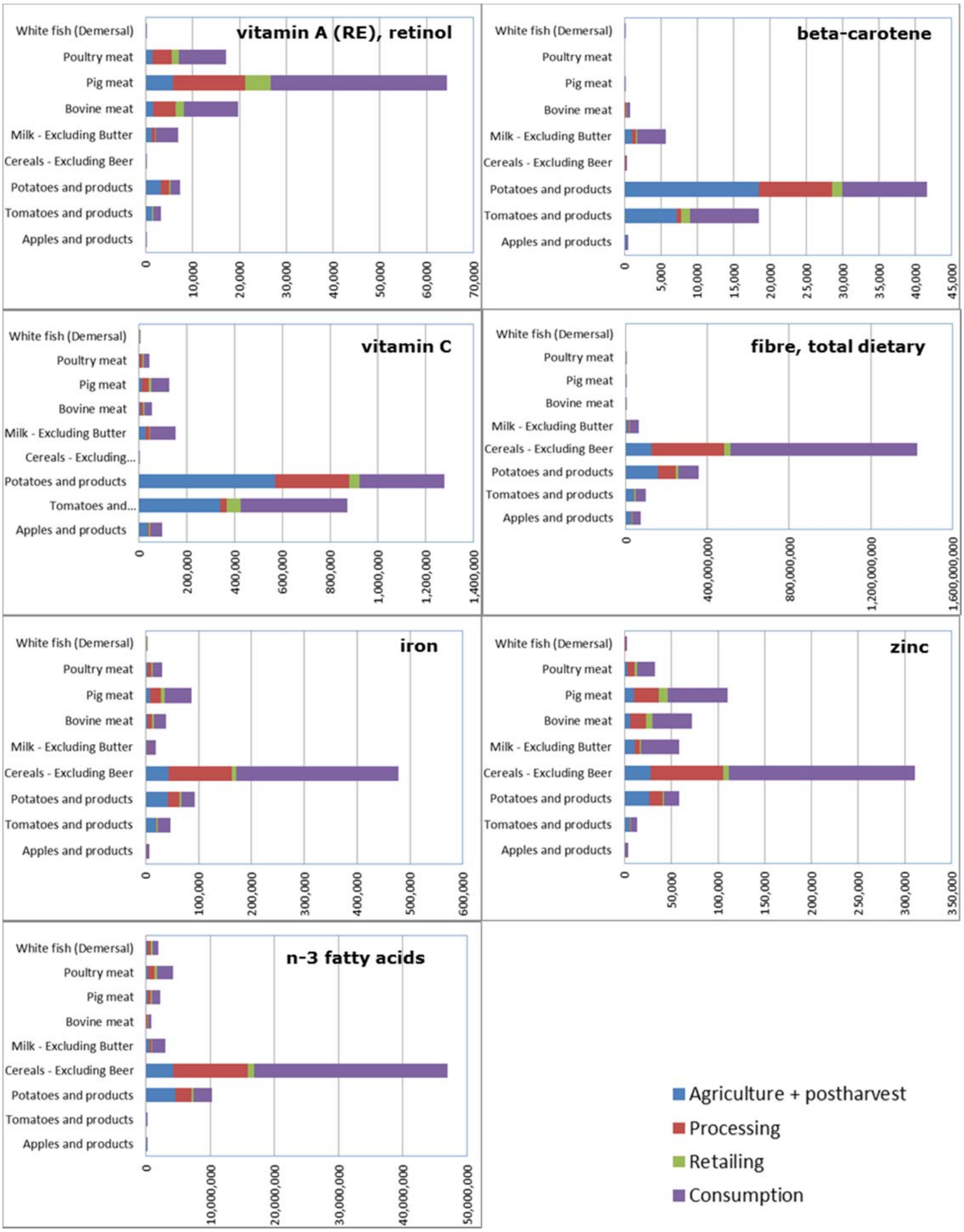


**Figure 5.2: Nutrient loss (in kg), based on food waste amounts of indicator products in EU in 2011, and SE food compositional data**

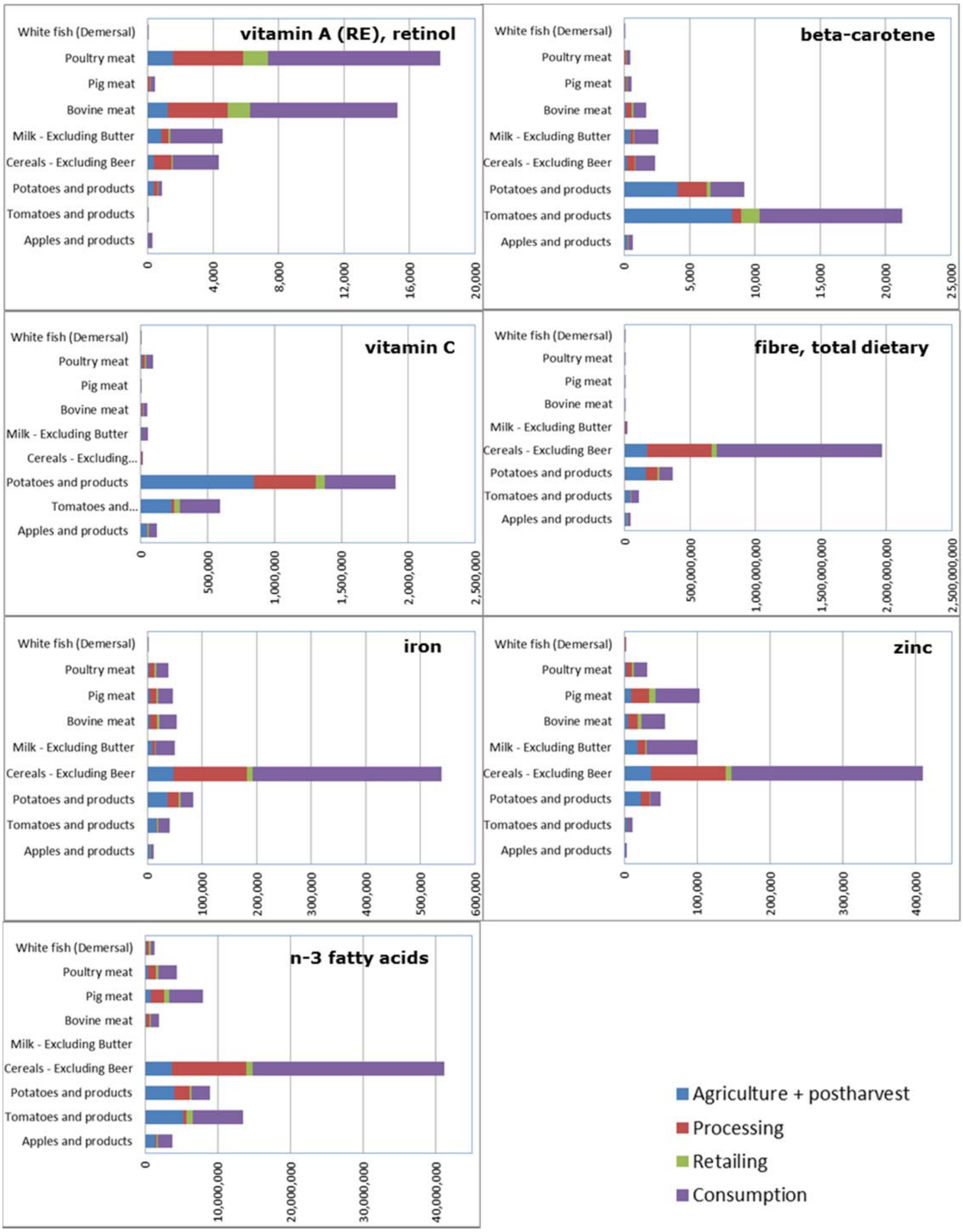
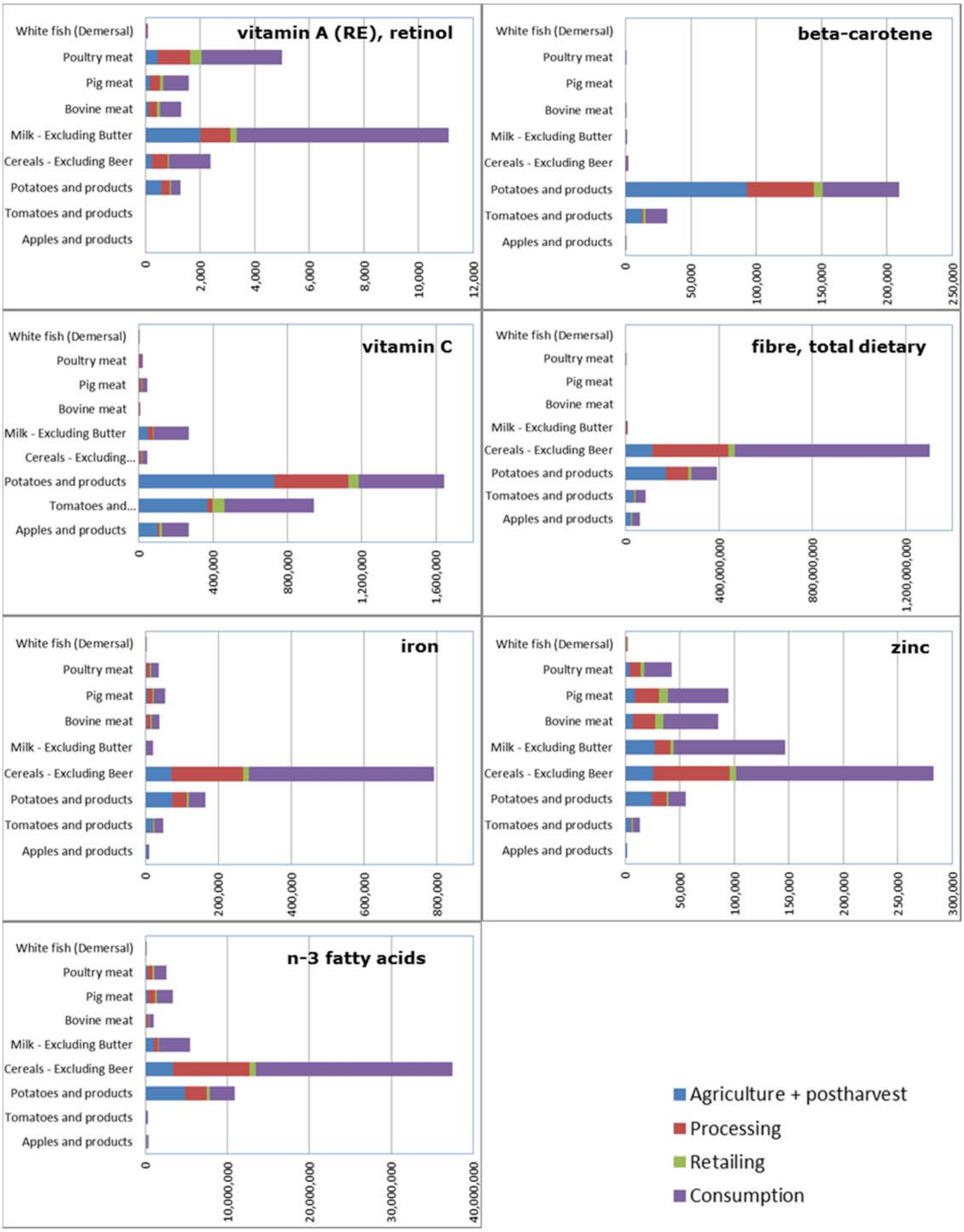


**Figure 5.3: Nutrient loss (in kg), based on food waste amounts of indicator products in EU in 2011, and USA food compositional data**



Comparison of Figures 5.1, 5.2 and 5.3 indicate that the trends in findings, resulting from using three different food composition databases are quite similar for vitamin C, dietary fibre, iron, zinc and n-3 fatty acids. However the total amounts in losses may differ, but this may also be interpreted as a certain range of variation.

The estimated losses of vitamin A and beta-carotene are less consistent, while using the three different food composition databases. The reasons for that are already mentioned: they depend on the presence of the amounts of liver products (vitamin A) or sweet potato (beta-carotene) in the different food composition databases.

Only the food composition database from the USA provides data concerning individual amino acids, therefore the losses of lysine and methionine, calculated using this food composition database are presented in Figure 5.4

**Figure 5.4: Nutrient loss (in kg), based on food waste amounts of indicator products in EU in 2011, and USA compositional data**

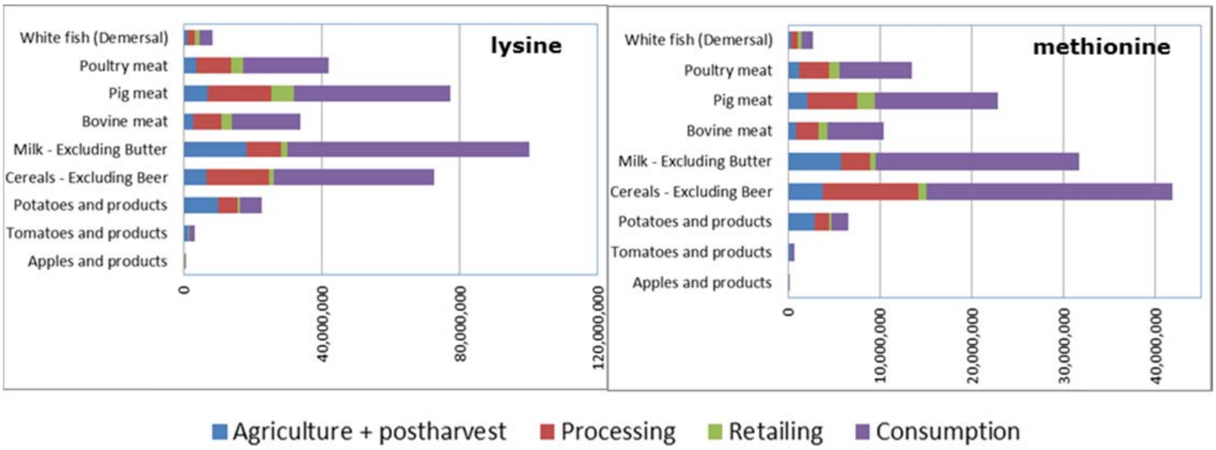



Figure 5.4 indicates that the highest amino acid losses take place at the consumption stage.

### 5.3.5 Comparison of nutrient loss with nutrient requirements

Analysis of macronutrient and micronutrient losses in terms of human nutrient requirements can be performed by comparing loss of nutrients by losing and wasting food, to the recommended daily intake (RDI) of that specific nutrient or micronutrient.

The RDI's of the selected nutrients and micronutrients are presented in Table 5.6.

**Table 5.6: Nutrient requirements, expressed as recommended daily intake (RDI), for the selected nutrients and micronutrients.**

| Nutrient or micronutrient | RDI | reference |
|---|---|---|
| Retinol equivalents (ug) | 800 | (EC, 2011) |
| Beta-carotene (ug) | not set | |
| Vitamin C (mg) | 80 | (EC, 2011) |
| Total dietary fibre (g) | females 30, males 40 | (Health Council of the Netherlands, 2006) |
| Total dietary fibre (g) | >25 | (EFSA NDA Panel, 2010a) |
| Iron (mg) | 14 | (EC, 2011) |
| Zinc (mg) | 10 | (EC, 2011) |
| n-3 polyunsaturated fatty acids (g) | not set | (EFSA NDA Panel, 2010b) |
| Lysine (g) | Not present at an individual amino acid basis | (EFSA NDA Panel, 2012) |
| Methionine (g) | Not present at an individual amino acid basis | (EFSA NDA Panel, 2012) |

A comparison of loss of nutrients by losing and wasting food, with the recommended daily intake (RDI) of that specific nutrient or micronutrient is presented in Table 5.7. Only the compounds for which a RDI is available are presented.

Table 5.7 shows that the estimated amount of vitamin C that is lost in the EU in a year (2011) as a result of food waste may contain the equivalent of 33-41 billion "recommended daily intake portions" which is equivalent to the amount of vitamin C that is needed by 90-111 million people a day (see Table 5.8).

Estimation of retinol losses equal the amount needed for 78-407 million people a day. Losses on total dietary fibre are estimated to be equal to the amount needed for 127-173 million people a day and losses on total iron to 157-228 million people a day. Losses on zinc amount to 181 and 210 million people a day regarding their recommended intake on nutrients. As the results are based on certain biases, it needs to be highlighted that the outcomes can only serve as a first estimation.

**Table 5.7: Recommended daily intake portions (in billions) present in food waste, EU 2011**

| | Based on NL FCDB | Based on SE FCDB | Based on USA FCDB |
|---|---|---|---|
| Retinol equivalents | 150 | 55 | 28 |
| Vitamin C | 33 | 35 | 41 |
| Total dietary fibre | 51 | 63 | 46 |
| Total iron | 57 | 62 | 83 |
| Zinc | 66 | 77 | 72 |

**Table 5.8: Number of people (in millions) that could meet their recommended intake a day from nutrients present in food waste, EU 2011**

| | Based on NL FCDB | Based on SE FCDB | Based on USA FCDB |
|---|---|---|---|
| Retinol equivalents | 407 | 150 | 78 |
| Vitamin C | 90 | 97 | 111 |
| Total dietary fibre | 139 | 173 | 127 |
| Total iron | 157 | 169 | 228 |
| Zinc | 181 | 210 | 198 |

## 5.4 Possible negative health impacts by hazardous food waste contents

### 5.4.1 Introduction

Alongside the evaluation of the nutritional content of food waste, the presence of anti-nutritional factors in food waste fractions is reviewed to assess any safety implications affecting the use of these materials for food or feed production. An overview of anti-nutritional factors in food waste fractions is presented, based on a literature review. These anti-quality factors can be divided into four groups which are listed in the paper by Sen et al (1998): (i) factors affecting protein utilization and depressing digestion, (ii) metal ion scavengers, (iii) antivitamins, (iv) factors other than those in the preceding categories.

Examples include:

- Mycotoxins: these compounds are concentrated (if present) in the outer layers and husks of grains due to fungal growth. Processing may produce waste fractions which are unsuitable for further use even as animal feed.
- Glycoalkaloids: These may be found in the outer peel and outer 1.5 mm of flesh of potatoes, particularly damaged and 'green' ones. Whilst they are unlikely to cause any problem during the consumption of potatoes, they may be concentrated in 'green' potato peel.
- Pesticide residues: Pesticides and other agrochemicals may be concentrated in the outer layers of crops and it is therefore important to undertake routine analysis of pesticides in any extracts produced to ensure their safety.
- Other examples include phenolics, oxalate, phytate, tannins, glucosinolates, saponins, allyl isothiocyanates and proteinase inhibitors.

A methodical review of the occurrence, concentration and localisation of these compounds may give insights to current waste fractions which are unable to be used for food or feed production.

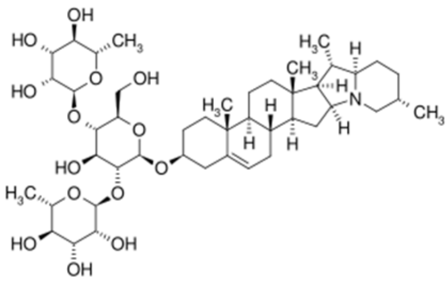
Recent research has challenged the traditional view of the undesirability of these compounds and pointed to some of the classes having beneficial effects at low concentrations e.g. in reducing blood glucose & insulin responses or cancer risks (Gemede & Ratta, 2014).

## 5.4.2 Occurrence

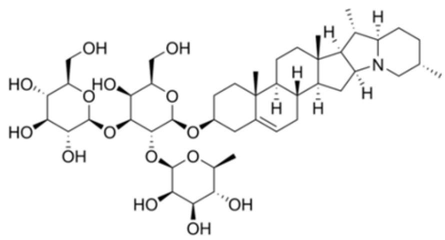
**Glycoalkaloids**

Glycoalkaloids are a group of nitrogen containing compounds which are most commonly found in members of the *Solanaceae* family (e.g. potato, tomato, aubergine and peppers) where they act as natural defence compounds against pathogens and insects (Friedman, Roitman & Kozukue, 2003; Lachman et al. 2013). The two main glycoalkaloids, α-chaconine and α-solanine, comprise ≥ 95% of the total steroidal glycoalkaloids in commercial potato cultivars. α-Chaconine is 10 times as toxic as α-solanine. α-Chaconine causes inhibition of acetyl-cholinesterase, cell disruption and organ damage and is teratogenic in embryos. Partially glycosylated forms are less toxic and the aglycone is much less toxic. Several other glycoalkaloids occur in small amounts.

**Figure 5.5: Molecular structure of the main potato glycoalkaloids**



$\alpha$-Chaconine



α-Solanine

Glycoalkaloids concentrations are greatest in the 1.5–3.0 mm layer immediately under the periderm (Schulzova et al., 1992). Deuβer et al. (2012) analysed the peel and three areas of the flesh and showed a decrease in glycoalkaloid concentration from peel to outer flesh to inner flesh, to undetectable in the pith. Glycoalkaloid content is very variable between varieties and in different growing conditions but chaconine concentrations are usually higher than solanine concentrations. The range in the peel of white and yellow fleshed potatoes in two recent papers is shown in Table 5.8.

**Table 5.8:Glycoalkaloids concentrations in the peel of white and yellow fleshed potatoes**

| | **α-Chaconine** | **α-Solanine** |
|---|---|---|
| Deuβer et al. 2012 16 Dutch cultivars | 0.37 – 3.37 | 0.21 – 1.97 mg/g dry weight |
| Ji et al. 2012 10 Canadian cultivars | 0.38 – 4.07 | 0.22 – 3.23 mg/g dry weight |

In a commercial potato flake factory, steam-peeling has been shown to reduce the glycoalkaloid content (α-chaconine + α-solanine) of the tubers from 29.4 to 6.7 mg/100 g of dry weight (Maeder et al., 2009). Glycoalkaloids were thought to be unaffected by baking, boiling and frying of potatoes (Finotti et al., 2006) although more recent studies have shown that boiling of peeled potatoes was particularly effective in reducing glycoalkaloid content (Lachman et al., 2013). Two-stage French fries processing also achieved a 97% reduction in glycoalkaloid content in coloured-fleshed potatoes as compared to unpeeled potatoes (Tajner-Czopek et al., 2014).

The maximum level of glycoalkaloids allowable in potatoes is considered to be 200 mg/kg fresh weight (Health Canada, 2012; Savage et al., 2000). Whilst this is an informal guideline rather than a legal requirement, commercial cultivars are bred to remain below this level. However, glycoalkaloid concentration is known to increase if the tubers are exposed to light or incorrect storage conditions (Uppal, 1987; Machado et al., 2007).

Potato peel is available as an energy-rich feedstuff suitable as a constituent in a mixed diet for pigs as well as ruminants. However, green potatoes have been known to be toxic in livestock so appropriate precautions are required for feedstuffs other than from approved suppliers.

Potato peel is also of interest to the pharmaceutical industry as a potentially cheap and easily accessible source of glycoalkaloids for use in the development of anti-cancer and anti-inflammatory drugs.

Tomatoes contain different glycoalkaloids (ɑ-tomatine and dehydrotomatine) which have a lower toxicity than ɑ-chaconine & ɑ-solanine. The levels of tomato glycoalkaloids decrease as the fruit ripens and are unlikely to cause a problem unless utilizing green tomatoes for product manufacture. Solanine is also found in aubergine (61 – 113 mg/kg) and peppers (77 – 92 mg/kg) but these lower levels are not considered a problem.

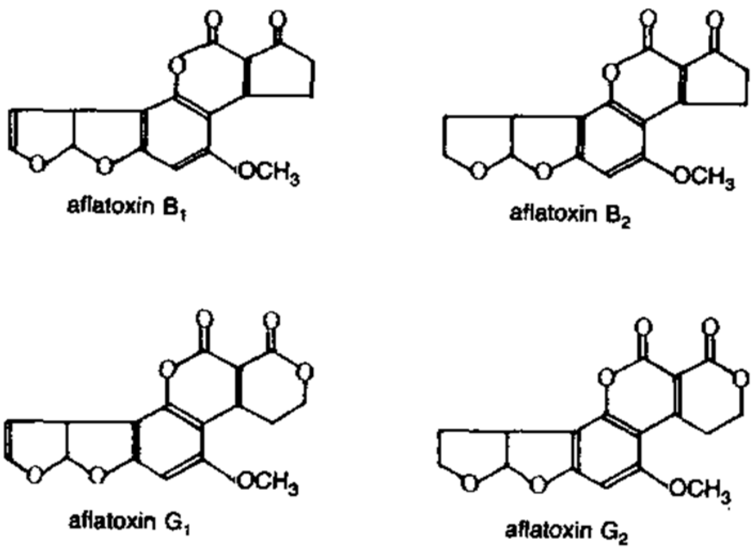
**Mycotoxins**

Mycotoxins are toxic metabolites derived from fungi – the most common of which are aflatoxins, *Fusarium* mycotoxins and ochratoxins. Production of a particular mycotoxin is usually restricted to a relatively small number of fungal species (D’Mello, 2000).

**Aflatoxins**

Aflatoxins are produced by specific strains of Aspergilli which generally occur as storage fungi under high temperature and humidity conditions. The group (aflatoxin B1, B2, G1 and G2) is almost entirely restricted to peanuts, cottonseed and palm kernel although maize contamination has occurred in warm humid regions. Aflatoxin contamination has been observed in various spices, figs and other dried fruit, hazelnuts, almonds, pistachios and Brazil nuts (Food Standards Agency, 2015).

**Figure 5.6: Molecular structure of aflatoxins. Source: Goto and Marabe (1989)**

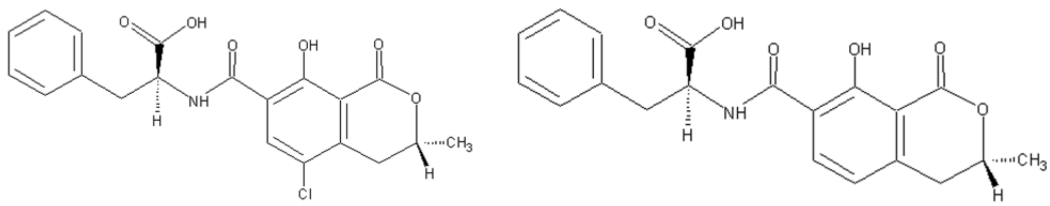



Aflatoxins can be detected in foodstuffs using a variety of analytical techniques (TLC, HPLC, ELISA and immunoaffinity columns).

**Ochratoxins**

Ochratoxins are a group of mycotoxins produced by *Aspergillus ochraceus*, some strains of *Aspergillus niger* and some *Penicillum* species. Ochratoxin A (the most common form) and Ochratoxin B are the only forms to occur as contaminants. Ochratoxin A occurs predominantly in cereals & cereal products and the tissues of animals fed on these cereals but has also occurred in coffee (Studer-Rohr et al., 1995), dried fruit (Iamanaka et al., 2005), red wine (Remiro et al., 2013), grape juice, spices and liqourice (Food Standards Agency, 2015).

**Figure 5.7: Molecular structure of the main ochratoxins. Source: The Aspergillus Website.**



Ochratoxin A Ochratoxin B

In common with aflatoxins, ochratoxins can be detected in foodstuffs using a variety of analytical techniques (TLC, HPLC, ELISA and immunoaffinity columns).

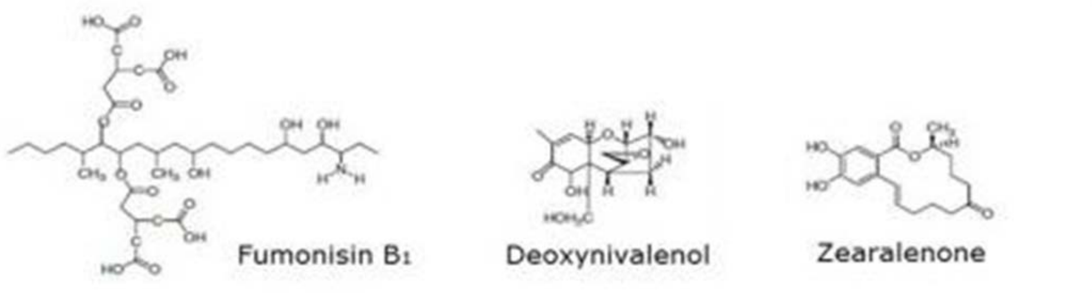
Ochratoxin A can also be found in winery by-products such as grape pomace since it remains on the skin of the grape. Grape pomace represents 13% by weight of the initial grapes and remains as a by-product after wine production. Grape pomace is often utilised as animal feed or as a soil conditioner. Recent research has studied the levels of ochratoxin A in winery by-products due to safety concerns. A survey of 12 grape pomace samples from the Douro region of Portugal found that the mean concentration of ochratoxin A was 0.07 ± 0.04 μg/kg, which represents an extremely low value (Ribeiro & Alves, 2008). However, higher levels were observed in a 2004-2005 study of grape pomace (34.2 – 456.8 μg/kg) and wine lees (48.3 – 602.5 μg/kg) from the production of

Italian red wine (Solfrizzo et al., 2008). Indeed, 70% of the samples in this study exceed the EC recommended level for complementary and complete feedstuffs for pigs and poultry.

**Fusarium mycotoxins**

*Fusarium* fungi are commonly found in the soil and produce and range of mycotoxins, particularly trichothecenes (including deoxynivalenol), zearalenone and fumonisins.

**Figure 5.8: Molecular structure of the main *Fusarium* mycotoxins. (Source: corntoxins.org.)**




These can represent a particular problem in cereal grains and animal feed and may be hazardous to human and animal health even at low concentrations. As such, legislation (European Commission, 2006) sets maximum limits for fusarium mycotoxins in cereals and cereal products for human consumption.

The maximum limits apply to unprocessed cereals to avoid contaminated material entering the food chain. Lower limits apply to intermediary products such as flours and finished goods (e.g. bakery items and breakfast cereals) since processing can reduce the mycotoxin content. Husks and outer layers removed during grain processing are likely to contain higher levels of mycotoxins.

**Table 5.9 Maximum permitted levels of *Fusarium* mycotoxins in foodstuffs.**

| Foodstuff | Maximum permitted levels (µg/kg) |
|---|---|
| **Deoxynivalenol** | |
| Unprocessed cereals other than durum wheat, oats & maize | 1250 |
| Unprocessed durum wheat, oats and maize | 1750 |
| Unprocessed maize | 1750 |
| **Zearalenone** | |
| Unprocessed cereals other than maize | 100 |
| Unprocessed maize | 200 |
| **Fumonisins (sum of $B_1$ & $B_2$)** | |
| Unprocessed maize | 2000 |
| **Type A trichothecenes** | |
| T-2 toxin | Under consideration |
| HT-2 toxin | |

Edwards (2009a) determined the level of *Fusarium* mycotoxin contamination in approximately 300 samples of wheat from across the UK each year from 2001 to 2005. The levels of contamination were found to fluctuate from year to year although overall the percentage that would have failed the legal limits introduced in 2007 varied between 0.4% and 11.3% and, as such, were considered low. Edwards noted that these levels were lower than those frequently found in Europe and North America. A similar study of UK oats (Edwards, 2009b) found no samples exceeded the limits for deoxynivalenol or zearalenone. However, the levels of T-2 & HT-2 type A trichothecene mycotoxins were above the investigative limits for these toxins. Legislation for levels of T-2 & HT-2 is currently under consideration. A Dutch survey of winter wheat from 86 fields found 3 of the samples to exceed the legal limit for deoxynivalenol (van der Fels-Klerx et al., 2012).

The fate of mycotoxins in UK oats during industrial processing was examined by Scudamore et al. (2007). The study found that the concentration of mycotoxins remaining in oat flakes was 5-10% of that present in unprocessed oats. Very high levels of mycotoxin were observed in the discarded hull by-product (4 to 10 times the concentration of the unprocessed oats). Careful consideration of potential uses for this by-product is required although it is unlikely to be suitable for food or feed use.

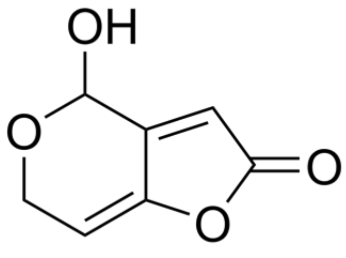
Scudamore & Patel (2009) studied the output streams of three maize mills and found that maize grits and flours had the lowest mycotoxin levels with mycotoxins being concentrated in the bran, meal & germ-derived fractions. In a second study, the distribution of deoxynivalenol in scab-infected soft wheat mill streams showed lower levels in the flour fractions comprised mainly of endosperm and higher levels in the fractions rich in aleurone and pericarp tissues (Seitz et al., 1985).

The distribution of Fusarium mycotoxins in UK wheat mill fractions was studied by Edwards et al. (2011). Deoxynivalenol was lower in the white flour by an average of 30% compared to the level in the original cleaned wheat, while bran was higher by 282%. The situation was less clear for zearalenone although the levels appear to be higher in bran and lower in the white flour. Differences were noted between years and between mycotoxins.

Since fusarium mycotoxins are produced in the field, their management is primarily through codes of good agricultural practice such as that produced by the UK Food Standards Agency (Food Standards Agency, 2007).

### Patulin

**Figure 5.9: Molecular structure of patulin (4-hydroxy-4*H*-furo[3,2-*c*]pyran-2(6*H*)-one).**




Patulin is a mycotoxin produced by a variety of moulds, particularly *Aspergillus*, *Penicillium* and *Byssochlamys*. It is most commonly found in apple juice and apples & pears with brown rot and hence legislation was introduced in 2007 by the European Commission to set maximum permitted levels of patulin in apple products.

Patulin is associated with storage disease and moulds and therefore represents a much higher risk in stored fruit. The fungi is often observed on the surface of the fruit although it is possible for it to enter via insect damage or the calyx and therefore not to be obvious by sight.

It is highly heat resistant and not eliminated by the standard pasteurisation procedure for apple juice and cider (Dong et al., 2010). However, it is readily broken down in the presence of sulphur dioxide when this is added to the juice as a preservative. Since sulphur dioxide is added after pressing, patulin may still be present in the residual pomace, which may be used as a feed ingredient.

**Table 5.10 Maximum permitted levels of patulin in apple products (Source: Horticultural Development Company).**

| Maximum permitted levels | Products |
|---|---|
| 50 µg/kg | Fruit juices, concentrated fruit juice as reconstituted and fruit nectars.<br>Also in spirit drinks, cider and other fermented drinks derived from apples or containing apple juice. |
| 25 µg/kg | Solid apple products intended for adults, including apple compote and apple puree for direct consumption. |
| 10 µg/kg | Apple juice and solid apple products including apple compote and apple puree for infants and young children |

Patulin is also destroyed by the fermentation process, and so is much less common in drinks such as cider. Generally, this is only considered to be a possible issue in certain sweet ciders, French ciders and 'French-style' ciders when unfermented apple juice is added to the cider after fermentation (Food Standards Agency, 2003; Leatherhead Food Research, 2015). The UK Food Standards Agency commissioned a survey of 100 ciders on sale at UK supermarkets and found that all were below the detectable limit of 3 µg/kg (Food Standards Agency, 2003). However, in Michigan, a survey of 493 apple cider samples showed 18.7% above the limit of detection and 2.2% above the action level of 50 µg/kg (Harris et al., 2009).

Little information was found in the literature regarding levels of patulin in apple by-products and pomace.

**Phytate/phytic acid**

Inorganic phosphorus is principally stored in cereals and grains in the form of phytate up to a level of approximately 5% by weight (Maga, 1982). Phytate is an anti-nutritional factor that forms complexes with minerals such as Ca, Mg, Zn and Fe reducing their bioavailability (Ficco et al., 2009). The phosphorus bound within the phytate is not available to humans or any non-ruminant animal (Gemede & Ratta, 2014). Ruminant animals such as cows and sheep are able to use an enzyme within their first stomach compartment to separate and utilise the phosphorus.

The terms phytate and phytic acid are often used interchangeably in the literature referring to the salt and free acid forms respectively. In addition to cereals and grains, phytates can be found in seeds, oilseed cakes, cocoa, nuts, mandarins, mango seed kernel, oranges and lemons (Ferrando, 1981; Diarra, 2014).

Anti-nutrients such as phytate are principally located in the outer aleurone layer of wheat grains along with the minerals (Ficco et al., 2009) although, in oilseeds, phytate is distributed throughout the kernel. Dehulling resulted in an increase in phytic acid levels in both peas and lentils according to Wang and co-workers (Wang et al., 2009; Wang et al., 2010). In red kidney beans, phytic acid was present in unprocessed samples at a level of 6.1 mg/g (Yasmin et al, 2008). Processing was generally ineffective at reducing phytic acid levels although germination (and presumed increased phytase activity) resulted in a 43% reduction. Diarra (2014) reports two studies indicating a reduction in phytate levels in mango seed kernel can be achieved through soaking and/or boiling.

**Proteinase inhibitors**

Proteinase inhibitors are typical examples of heat-labile anti-nutritional factors and are widely distributed in plants, particularly in leguminous seeds such as soy beans (*Glycine max*), field beans (*Vicia faba*), winged beans, pigeon pea (*Cajanus cajan*), chickpea (*Cicer arietinum*) and cow pea (*Vigna unguiculata*) (D'Mello, 2000; Frias et al., 2000). The proteinase inhibitors are likely to have a role in defence of the seed from attack by predators or disease. However, they also act to inhibit pancreatic serine proteases impairing protein digestion and utilization (Guillamón et al., 2008). It should be noted that whilst much research has been done on proteinase inhibitors as anti-nutritional factors, recent research has also focussed on their potential role as natural bioactives having anti-carcinogenic properties (e.g. Clemente et al., 2004).

Diarra (2014) reports the occurrence of trypsin inhibitor in mango seed kernel meal and notes that trypsin inhibitor activity as low as 2.8 mg/kg has been associated with poor growth in broiler chickens.

Guillamón et al. (2008) studied a range of grain legumes including chickpea, lentils, common beans (*Phaseolus vulgaris*), broad/field beans, lupin, soy beans and peas. Higher levels of trypsin inhibitor were generally observed in soy beans and common beans with low levels in lupin and field beans. However, the levels were also dependent on the cultivar.

Trypsin inhibitors are present at a slightly (but significantly) higher level in the dehulled flours than the whole grain in the case of lentil (Ma et al, 2011) although two further studies in peas and lentils indicate that trypsin inhibitor activity is decreased by de-hulling (Wang et al., 2009; Wang et al., 2010).

### 5.4.3 Technologies for reducing anti-nutritional factors

Anti-nutritional factors can be divided into two primary categories: a heat-sensitive group, containing lectins, proteinase inhibitors and cyanogens, which can be reduced by standard processing temperatures, and a heat-stable group including condensed tannins and glucosinolates, amongst others (D'Mello, 2000).

**Thermal treatment**

Much research has been undertaken to examine the effect of thermal treatment on the heat-sensitive anti-nutritional factors. Thermal treatments may include cooking, steaming, roasting, autoclaving or microwave treatments, all of which can be applied for varying durations.

For example, Diarra (2014) reports a reduction of 98 – 100% in trypsin inhibitor activity in mango seed kernel upon boiling in water (100°C, 30 min) or soaking for 24 hours following by boiling for 30 minutes. This is in agreement with Ma et al. (2011) who studied the effect of thermal treatments on lentil, chickpea and pea flours. Roasting (80°C, 1 min) and boiling were found to result in significant reductions in the trypsin inhibitor activity (up to -95.6%). In addition, the roasted and, particularly, the boiled flours exhibited superior functional properties such as increased fat and water absorption capacity, gelling and emulsifying activity. Similar results were found by Wang & co-workers (Wang et al., 2009; Wang et al., 2010) in lentil, common beans, chickpea and peas.

Frias et al (2000) also observed the total elimination of trypsin inhibitor activity in chickpeas after soaking and cooking in water, citric acid solution or sodium bicarbonate solution although dry roasting much less effective despite being at a higher temperature for a longer period (120°C, 15 min) than in the work of Ma et al (2011).

There is some evidence to suggest that different isoforms of trypsin inhibitor may be more stable than others to thermal processing. A study on trypsin inhibitor activity in 17 pea cultivars showed that values fell by 42-91% after soaking and cooking. Of the six to ten isoinhibitors found in each cultivar, only three remained after heat treatment (Morrison et al., 2007).

Hydrothermal treatments were also shown in be effective in the reduction of phytate levels in barley, wheat, rye and rice (Bergman et al., 1999, 2001). A hydrothermal treatment was devised for whole barley kernels comprising of two wet steeps with lactic acid solution and two dry steeps followed by successive drying. Using temperatures around 48-50 °C and 0.8% lactic acid solution, the amount of phytate could be reduced by over 95% and the content of free *myo*-inositol increased. Similar results were seen for wheat, rye and rice (Bergman et al., 2001).

**Fermentation**

The traditional technique of fermentation has been studied as a potential method to reduce antinutrient factors in legumes and to improve their palatability.

Martín-Cabrejas et al. (2004) examined the effect of natural fermentation and lactic acid fermentation on chymotrypsin inhibitor in common beans (*Phaseolus vulgaris*). The fermentation did not lead to a decrease in inhibitor levels and subsequent autoclaving at 121°C for 20 min was required. The effect of autoclaving alone is not shown.

Coda et al. (2015) also used lactic acid bacteria fermentation to try to reduce trypsin inhibitor and phytic acid in fractionated field bean flour (*Vicia faba*). The fermentation was effective at reducing trypsin inhibitor activity in both protein-rich (fine) and starch-rich (coarse) fractions as well as the whole flour. Phytic acid levels were unaffected by the fermentation process.

As mentioned previously, fermentation is effective at destroying patulin (Dong et al., 2010). This is reflected in the results of Harris et al. (2009) which showed much lower patulin concentrations in apple cider compared to apple juice in a survey of apple-based beverages sold in Michigan retail stores (24.2 ± 3.9 μg/litre vs. 257.5 ± 97.7 μg/litre).

A study of winery by-products (Ribeiro & Alves, 2008) showed that ochratoxin A was not significantly degraded by the wine making process (fermentation). Ochratoxin A is the most significant mycotoxin in wine.

**Irradiation**
Some research has been undertaken to examine the effect of γ-irradiation on the levels of anti-nutritional factors in foods. For example, Hamza et al. (2012) found that γ-irradiation or / and extrusion significantly reduced the levels of phytic acid, tannins and trypsin inhibitor in soy flour.

**Cleaning during grain processing**
Grain mills employ a range of techniques to clean their raw materials to ensure they are free from stones, metal objects, contaminants, dust, straw and broken seeds (Scudamore & Patel, 2009). These techniques will often reduce the mycotoxin concentrations although this can be quite variable e.g. Seitz et al. (1985) demonstrated a reduction in mycotoxin levels of 16% in wheat after cleaning although the cleaner was only effective on lightweight, severely scab-infected kernels or part kernels. Infected kernels of near-normal size and weight could not be separated.

**UV processing**
Dong et al. (2010) evaluated the use of UV radiation for the reduction of patulin in fresh apple cider. UV radiation of $<100 mJ/cm^2$ was effective at reducing patulin levels with no quantifiable changes in the chemical composition or organoleptic properties of the cider. UV radiation was also found to be more effective at reducing patulin levels than thermal pasteurisation in a survey of apple cider samples in Michigan (Harris et al., 2009).

**Extrusion cooking**
Alonso et al. (2000) compared the use of extrusion cooking for reduction of antinutritional factors in field and common beans to traditional techniques such as dehulling, soaking and germination. Extrusion cooking was seen to provide a significant reduction in phytic acid levels although germination for 72 hours was the most effective treatment especially for field beans.

## 5.5 Discussion and Conclusions

The assessment of the impact of food waste on health and nutritional issues by calculation of nutrient losses resulting from food waste is merely an estimation. This calculation has been performed for two reasons:

- to be able to make preliminary estimations of the nutrient losses along with food waste and
- to test the methodology.

In the process of preparing the estimation of nutrient losses resulting from food waste the following assumptions were made:

- Estimated amounts of wasted (indicator) product groups are representative for total food waste. This will be an underestimation for the amount of food waste.
- FUSIONS defintion of food waste comprises the combined fraction of edible and inedible parts of food. It would be the ideal situation when the nutronal value of the

inedible part and the fraction of the inedible parts of a food product are known. As this is not the case nutritional data from food composition databases, this means only edible parts, are used as an estimate for the nutrient composition of waste/inedible parts from the (indicator) food products. This will be an overestimation for the nutrient content of waste.

Also the following remarks are important:
- Food waste data of indicator product groups are based on available data in the EU from 2011 (see Chapter 4).
- Nutritional data from food composition databases describe edible products only, they do not match exactly with the food waste data, which include amounts of edible and inedible products.
- Nutritional data at food product level are recalculated to nutritional data at food group level.

Taking the above mentioned in mind, the following data gaps are observed:
- The composition of food waste (percentage of edible and percentage of inedible parts) is needed.
- Nutrient concentrations of inedible parts such as present in waste fractions and by-products are lacking.
- Matching data on nutrient concentrations with food waste data are needed on a corresponding level of detail (product level versus product group level).
- Food waste data on a product level are useful, this facilitates the use of food composition databases for the estimation of nutrient and micronutrient composition.
- Reliable food waste data on product category level can be used, provided that the nutrient and micronutrient composition of corresponding product categories are available, either by calculation from the individual food products or by analytical measurement of nutrient and micronutrient concentrations in samples of a product category.

Next to nutrients and micronutrients, also anti-nutritional factors may be present in food waste fractions. These ANF's can be divided into four groups:
(i) factors affecting protein utilization and depressing digestion, (ii) metal ion scavengers, (iii) antivitamins, (iv) other factors.
Antinutritional factors can be present in a wide range of co-products presenting occasional problems for the use of this material in animal feedstuffs. The literature identified remains mostly of a qualitative nature and hence it is not possible to quantify the amount of food processing waste which is unsuitable for food or animal feedstuffs. However, careful monitoring of anti-nutrients is essential both to ensure compliance with statutory and advisory guidelines and to avoid under-utilization of wastes and co-products as animal feed.

## 5.6 Recommendations

Given that matching data on nutrient and micronutrient concentrations and actual food waste data are needed on a corresponding level of detail (product level versus product group level), it is recommended that a database consisting of nutrient and micronutrient concentrations in inedible parts (such as waste fractions and by-products) is compiled.

This can possibly be done by an intensive literature review, but up until now little data is available on the presence of nutrients and micronutrients in inedible parts.

Another method to populate such a database is to measure analytically nutrient and micronutrient concentrations in inedible parts (such as waste fractions and by-products), but this will be a time-consuming and costly effort.

Furthermore it is recommended that the quantification of anti-nutritional factors in waste fractions and by-products is improved, and their presence in waste fractions and by-products is carefully monitored in order to ensure compliance with statutory and advisory guidelines and to avoid under-utilization of wastes and co-products as animal feed.

# 6 The socio-economic impacts of food loss and waste reduction in the EU: a comparative analysis

## 6.1 Introduction

This section of the report focusses on "Socio-economic impacts of food loss and waste prevention and reduction in the EU" delivered by the Food and Agriculture Organization of the United Nations (FAO). The report provides a comparative analysis of knowledge available to date on the topic and draws from work done by FAO and by other institutions.

FAO, in line with its mandate of leading global efforts in reducing hunger and malnutrition, has a long history of involvement in the reduction of food losses. Dating back to the 1960s with the Freedom from Hunger Campaign, FAO has been assisting developing countries to identify post-harvest food losses and to implement programmes for the reduction of food losses at the national level through direct action projects. However, with the dramatic changes over the last two decades in global agri-food systems, FAO in collaboration with its partners, is taking a new look at the issue of post-harvest food losses and now considering waste at the consumer and retail levels. The latter has meant expanding the scope of focus to include developed countries and applying a sustainable food systems approach to food loss and waste reduction, one that enhances resource use efficiency while ensuring food safety and quality. This work is currently undertaken within the framework of the Global Initiative on Food Loss and Waste Reduction (SAVE FOOD[9]), a partnership with the public and private sector as well as civil society for: (i) awareness raising; (ii) coherent and effective networking of worldwide efforts; (iii) evidence-based policy, strategy and programme development; and (iv) technical support to programmes and projects.

The social and economic impacts (hereafter referred to as socio-economic impacts) of tackling food loss and waste (FLW) reduction in the global economy have received little attention, apart from a few recent studies. This has been due to the general lack of consistent and reliable data, itself fed by differences in and/or disagreement on definitions and methods and priorities of data collection and areas of intervention across countries.

Socio-economic impacts of food loss and waste prevention and reduction are defined as the resultant changes that may occur in food markets (demand, supply, prices and trade) and welfare of various actors in the various sectors and regions. Welfare effects also consider implications for food and nutrition security[10]. A-priori, it is expected that food prices are higher, incomes are lower and food security is negatively affected by the existence of food losses and/or waste. Conversely, with reduction of FLW, improvements

[9] http://www.fao.org/save-food/en/
[10] Food security is defined as "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

in the three parameters are expected. However, this viewpoint has often been expressed with respect to the poor and vulnerable people in developing countries (Rutten et al., 2013). Only recently have considerations of socio-economic impacts of FLW been extended to cover industrialized countries and regions such as the EU. The primary reason for this shift in focus is two-fold. First, a realization of the persistently high number of malnourished people globally estimated at 795 million juxtaposed with significant amounts of food wasted in the EU region (Gustavsson et al., 2011). Second, high and volatile food prices since the crisis of 2007-2008 (HLPE, 2014) that highlighted the need for a holistic food systems approach in tackling food availability worldwide and renewed the focus on reducing food losses and waste.

While Europe and Central Asia[11] as a region has achieved the Millennium Development Goal hunger target of reducing by half the proportion of people affected by hunger, child malnutrition continues to be a problem in some countries within the region. Moreover, overweight and obesity are an increasing nutrition, health and budgetary concern in the region. Childhood obesity[12] rates are double those for the developing world (FAO, IFAD, WFP, 2015)

Therefore, this report has the objective to leverage the information in the public domain on FLW and their potential socio-economic impacts in order to enable future effective decision making for inclusive and coherent public and private policies.

## 6.2 Scope and methodology

The FAO adopted a phased approach to deliver the report on "The socio-economic impacts of prevention and reduction of food loss and waste in the EU: A comparative analysis."

The first phase was to develop an economic theoretical framework for understanding FLW. Consequently, FAO commissioned a background paper on the economics of FLW (Segrè et al., 2014) aimed at informing the subsequent quantitative analysis of socio-economic impacts of FLW. The quantitative analysis focused on quantifying the FLW reduction impacts on food prices, a study jointly undertaken by FAO and LEI Research Institute (Rutten et al., 2015).

Due to the increased awareness on FLW and its potential socio-economic impacts, additional studies were undertaken by other organizations concurrent to the FAO studies. This chapter of the FUSIONS report brings together all the studies with the aim to synthesize and compare the knowledge on FLW socio-economic impacts to date.

The comparative analysis is divided into two sections. The first section discusses a set of studies that have sought to develop a theoretical framework for the economics of FLW. The second section analyses empirical studies. These studies have applied economic modelling, primarily scenario analyses to quantify the impacts of reducing global FLW on production, trade, prices and incomes.

[1] Member Countries: Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxemburg, TFYR of Macedonia, Malta, Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, Ukraine, United Kingdom, Uzbekistan. Member Organization: European Union.
[12] EU Action Plan on Childhood Obesity 2014-2020.
http://ec.europa.eu/health/nutrition_physical_activity/docs/childhoodobesity_actionplan_2014_2020_en.pdf

In line with the objectives of the FUSION project, the analysis is limited to studies that are specifically focused on the European Union or are global in nature. While many studies have looked at the regional or global environmental impacts of FLW, they are excluded under this assessment.

## 6.3 Theoretical framework for assessing FLW socio-economic impacts

Despite the wide recognition of the significant magnitude of FLW by 2010-2011 there was no theoretical framework to explain the phenomenon. In an attempt to address this knowledge gap, FAO commissioned the University of Bologna to develop a background paper on the economics of FLW (Segrè et al., 2014). The objective of the paper was to identify factors that cause FLW along the food value chain by analysing the decision making process of the economic actors.

The study identified the conditions that impact FLW generation, prevention, and reduction drawing from (i) micro-economic theory and behavioural economics (e.g. utility and profit maximization of individuals and firms); (ii) macro-economic theory (economy wide impacts and government policies e.g. inflation; trade at national/regional/global level); and (iii) non-economic factors that influence economic decisions (e.g. social norms, policy, and climate). A graphical synthesis of the conceptual framework appears in Figure 10.1 of the Annex 10.2.

At the farm and firm level, a profit maximizing producer may generate FLW due to information asymmetry; uncertainty; inefficient mechanism of price transmission; inelasticity of production; weak competitiveness; low level of technology innovation; limited market access; inappropriate food contact materials (FCM); weak management capacity (bad planned procurement and weak stock management); resulting in suboptimal supply of agri-food products. Similarly for the consumer, the observed behavior may differ from that of an "ideal consumer" or "representative behaviour" suggested by the neoclassical theory of consumer behaviour. Low planning capacity concerning food management in the household and outside the household; new values guiding consumer choices (that may be linked to aesthetic characteristics, social status); relationship between low purchasing power and the consumption of low nutritional food; new food preferences; increased opportunity-cost related to housework and food preparation; high use of precooked and ready to eat products; portion sizes that may not meet the needs of a dynamic social structure; lack of capacity to comprehend and implement decisions on food items that are related to food labels, standards and expiration dates, are some of the factors that may lead to FLW at the consumer level.

Limitations of neoclassical consumer theory to explain individual choices have led to the application of behavioural economics. The latter takes into account other factors such as psychology to interpret deviations from the predictions of economic models. Also applying the value chain approach, the authors identify challenges that are encountered within the food supply chain such as inadequate storage; imperfect information; lack of access to financial resources; missing markets or linkages to these; out-dated technology or lack of access to technology; lack of technical knowledge or lack of access to technical knowledge; limited market access; out-dated, inadequate or inefficient production and harvest techniques; and transportation of food over long distances amongst others.

At the macro-economic level, inadequate infrastructure or unreliable utilities especially in developing countries can cause FLW. Changes in demographics and employment structure coupled with urbanization and diet changes can impact FLW generation as well as potential for reduction and prevention (Segrè et al., 2014). The trade and globalization dimension captures the rise of global supply chains characterized by complex logistics and increased distances between the actors involved in the different production stages; processed food imports and the development of retail chains in low-income countries might have an impact on local food systems reducing the competitiveness of local producers that do not meet certain quality and safety standards; lack of integration among the segments of the food supply chain. Lastly, food price inflation might cause failure to allocate the entire food production on the market, a reduction and re-orientation of consumer choices and preferences with a progressive reduction in the consumption of certain types of products (i.e. meat, fish and other more expensive food items), increased preference of consumers for discounts and special offers with a potential effect on consumers' planning capacity, increased food waste at household level and health impacts.

Non-economic factors such as culture and social norms (e.g. preparing more food than required at events) may affect FLW generation and reduction. Household composition (size, education, age, job, gender); lack of experience in planning/ preparing meals; uncertainty in the number of meals prepared and eaten at home per week; living standards and new life style; low civic sense and institutional trust; low perception of the impact of food loss and waste; and challenges concerning gender roles were indicated for the social dimension. Furthermore, Segrè et al. (2014) identify factors at policy level such as poorly designed subsidies on production, ineffective legislation and regulation on food safety and quality standards as contributing to FLW. Lack of capacity to provide agro-meteorological forecasts; lack of capacity to provide price forecasts; poor information flow, coordination, and outreach; lack of preparedness or delays in adaptation to climate change; absence or poor insurance schemes or strategies for risk management are additional others. Weak horizontal and vertical coordination of policies across sectors further contributes to the generation of food loss and waste and its associated impacts.

Finally, the paper identifies **environment** and **climate conditions** such as weather adversities; natural disasters; climate change; seasonality; slow and inadequate governmental responses to climate change; lack of farmer responses to climate change; and lack of innovation and climate smart agricultural practices as factors that can lead to FLW. While expansive in coverage and providing insights on assumptions that may be applied in modelling the impacts of FLW the paper does not provide a ranking of the factors nor an indication of potential magnitudes attributable to each of the factors.

Rutten (2013) applies economic theory and uses graphical illustrations to analyse the impacts of FLW on demand and supply of food. The paper shows that if a certain amount of food waste is prevented, so that this food comes on the market, this does not mean that food consumption and production will increase by that same amount. Instead, market prices will decrease and supply and demand will adapt to the change. Contrary to assumptions commonly made by advocates for FLW reduction, the paper hints that the ensuing lower food prices could promote even more food waste. The paper serves to highlight the complex interactions between demand and supply and their ripple effects on the wider economy. For instance, it argues that if a consumer reduces food waste, s/he will not need to purchase as much food. This will have an effect on the producer, who would be selling less, and as a result would need to produce less meaning the producer hires fewer people resulting in a decrease in employment. It is very uncertain whether a producer who invests in reducing production losses in the short term can profit from these investments in the long term. Production may be increased, but the reduced prices may outweigh the additional sales, with smaller returns as a result. These tradeoffs, combined with the national and international interactions between the various links in the chain, lead to the paper's conclusion that the effects on food security and the well-being of producers and consumers are indistinct and should be studied further. The cost involved in reducing waste also needs to be taken into account when evaluating the impacts.

A paper by de Gorter (2014) has similar findings to Rutten (2013) and Segrè et al. (2014) but summarizes the theoretical reasons for FLW generation into three conflicts between private and social optimality: (i) negative externalities, (ii) imperfect information for optimising agents, and (iii) non-optimising agents with psychological biases.

The paper highlights imperfections in the market as factors contributing to the generation of FLW. Additionally, it highlights that, worldwide, interventions should have a sustainable food systems approach that is, concurrently addressing the social, economic, and environmental dimensions.

What the papers have in common is that FLW generation is a result of market imperfections due to a mismatch between private and social incentives. The papers highlight the need for more reliable data on FLW, increased understanding of causal factors, as well as more knowledge about consumer behaviour and wider interactions along the food supply chain.

## 6.4 Empirical Studies on Socio-Economic Impacts of FLW in the EU

The modelling of FLW and/or reductions is very much in its infancy, primarily due to the lack of reliable and consistent data. However, a few empirical studies have recently been conducted to quantify socio-economic impacts in the EU. Most studies have employed scenario analysis, an important tool to help policy makers, researchers, and other stakeholders to envisage what the future may look like and guide the formulation of policies that are contingent on future expectations. The impacts have been considered in relation to another region and often focused on a segment of the value chain.

FAO together with LEI Institute (Wageningen University) conducted a study on the impacts of reducing food loss and waste in the European Union (EU) on Sub-Saharan Africa (SSA)[13]. The focus is on **food prices and price transmission effects** modelled and quantified using the MAGNET Computable General Equilibrium (CGE) model[14]. The analysis considers impacts across the food supply chain and for welfare. The paper is focused on the linkages between the EU and Sub- Saharan Africa given the strong trading relationship between the two regions. Moreover, the EU is a major actor in food losses and notably waste (EC, 2010) whereas SSA is a food insecure region with many of the world's poorest people. FLW estimates in the EU range between 180 kg-280 kg per

[13] Rutten et al, 2015.

[14] MAGNET (Modular Applied GeNeral Equilibrium Tool, release version 2) is a multi-sector, multi-region Computable General Equilibrium (CGE) model that has been widely used to simulate the impacts of agricultural, trade, land and biofuel policies on global economic development (Woltjer et al., 2014). MAGNET is based on the Global Trade Analysis Project (GTAP) model but can be extended in various directions in a modular fashion, depending on the policy questions at hand.

capita per year (EC, 2010; Gustavsson et al., 2011). The downstream yearly food waste at consumer level for the EU is thought to be about ten-fold that in SSA, estimated around 110 kg per capita in Europe compared to only 11 kg per capita in SSA (Gustavsson et al., 2011).

This paper uses Gustavsson et al. (2011) data on FLW in Europe (including Russia) as a proxy for FLW data in the EU (Table 5), the most reliable regional data source available, which distinguishes FLW percentages by commodity group and stage in the food supply chain.

**Table 6.1: Food loss and waste estimates by commodity and stage of the food supply chain, Europe incl. Russia (Percentage of production)**

| Commodity | Agricultural supply (production, post- harvest handling and storage)* | Processing and Packaging | Distribution (retail) | Consumption |
|---|---|---|---|---|
| **Cereals** | 6 | 5.25** | 2 | 25 |
| **Roots and tubers** | 29 | 15 | 7 | 17 |
| **Oilseeds and pulses** | 11 | 5 | 1 | 4 |
| **Fruits and vegetables** | 25 | 2 | 10 | 19 |
| **Meat** | 3.8 | 5 | 4 | 11 |
| **Fish and seafood** | 9.9 | 6 | 9 | 11 |
| **Milk** | 3.8 | 1.2 | 0.5 | 7 |

**Source:** adapted from Gustavsson et al. (2011). *Percentages for agricultural production and post-harvest handling and storage have been added together. **A simple average of the two percentages (0.5 per cent and 10 per cent) in the original table.

Four reduction scenarios were implemented, in addition to a baseline, 'Business as Usual' (BaU) scenario modelling i) Food Losses in Agricultural supply (AFL), ii) Food Losses in Food Processing (PFL), iii) Food Waste in Retail (RFW), iv) Food Waste in Final Consumption (CFW). Subsequently, all scenarios have been combined into a fifth overall Food Loss and Waste reduction scenario (FLW). The shocks were analysed on four dimensions: (i) Impacts on EU market in 2020; (ii) Price transmissions to SSA in 2020; (iii) Impacts on SSA market in 2020; (iv) Welfare impacts in 2020.

All four scenarios[15] show a decrease in the market prices due to the reduction of 50 percent in FLW in the EU. The largest impact in the EU market prices is in the aggregate scenario which models a 50% FLW reduction in all the segments of the value chain this is closely followed by the food losses in agricultural supply chain scenario and food waste in final consumption scenario, within which individual commodities vary in the magnitude of their price decrease. The market price for EU primary producers decreases within a range from -0.07 (in the RFW scenario) to -8.15 (in the FLW scenario) percentage. In SSA the price for primary producers decrease from -0.009 (RFW) to -0.80 (FLW) percentage relative to the BaU scenario due to price transmission. Price transmission in all scenarios is less than 100 per cent due to import and export taxes, transport costs, and trade shares.

The most important stages in the EU food supply chain in terms of impacts of FLW reductions on SSA prices are the stage of final consumption followed by the stage of agricultural supply. Reductions in food waste in final consumption and food losses in

[15] See Tables in Rutten et al., 2015

primary agricultural production stages are therefore relatively large in size respectively and have a much stronger price impact in SSA compared to FLW reductions in the other segments of the EU food supply chain.

Geographically, the effects are highest in the region where action is taken to reduce FLW, *ceteris paribus*, with the impact on the other regions depending on trade intensities (shares) and the relative importance of traded food commodities in domestic food consumption.

On aggregate, the results suggest that, *ceteris paribus*, reducing food loss and waste in the EU does not benefit SSA. This outcome is the result of different, i.e. positive and negative, impacts on various actors in the SSA economy:

- producers as sellers to the EU losing out from increased competition from EU food producers;
- producers as buyers of intermediate agri-food inputs from the EU benefiting from lower prices and so lower costs and;
- consumers of food commodities from the EU benefiting from lower prices.

The scenario analyses of the study (Rutten et al., 2015) revealed that: (i) complex interactions between supply and demand shifts are a challenge for modelling potential impacts; (ii) in cases where reduction in FLW occurs, market prices decrease but the price transmission is less than 100% with more welfare gains in the region or country that is implementing the reduction interventions; (iii) there are large gaps on FLW data by product category. Moreover, there are information gaps on costs and benefits of measures of preventing and reducing FLW in different time periods (short, medium and long term).

**Table 6.2 EU food loss and waste reduction scenarios in Rutten et al., 2015***

| **SCENARIO:** | **Reducing Food Losses in Agricultural Supply (AFL)** | | **Reducing Food Losses in Food Processing (PFL)** | | **Reducing Food Waste in Retail (RFW)** | | **Reducing Food Waste in Final Consumption (CFW)** | |
|---|---|---|---|---|---|---|---|---|
| **Stage of Food Supply Chain (FSC):** | **Agriculture** | | **Food processing** | | **Retail** | | **Consumption** | |
| **Shocks (percentage change) applied by commodity and stage of FSC** | **Output-augmenting technological change applied to:** | | **Intermediate input-augmenting technological change applied to:** | | **Intermediate input-augmenting technological change applied to:** | | **Negative change in consumer preference applied to:** | |
| **Cereals** | Input use in cereals | 3 | Cereal use in processed rice and 'other food' | 2.63 | Processed rice and 'other food' use in retail | 1 | Household demand for processed rice and 'other food' | 12.5 |
| **Sugar cane, beet** | Input use in sugar cane, beet | 14.5 | Sugar cane, beet use in sugar | 7.5 | Sugar use in retail | 3.5 | Household demand for sugar | 8.5 |
| **Oilseeds** | Input use in oilseeds | 5.5 | Oil seeds use in vegetable oils and fats | 2.5 | Vegetable oils and fats use in retail | 0.5 | Household demand for vegetable oils and fats | 2 |
| **Vegetables, fruits and nuts** | Input use in vegetables, fruits and nuts | 12.5 | Vegetables, fruits and nuts use in 'other food' | 1 | Vegetables, fruits and nuts use in retail | 5 | Household demand for vegetables, fruits and nuts | 9.5 |
| **Cattle, other animal products** | Input use in cattle, other animal products | 1.9 | Cattle use in red meat and other animal product use in white meat | 2.5 | Red and white meat use in retail | 2 | Household demand for red and white meat | 5.5 |
| **Fish** | Input use in fishing | 4.95 | Fish use in 'other food' | 3 | Fish use in retail | 4.5 | Household demand for fish | 5.5 |
| **Raw milk** | Input use in raw milk | 1.9 | Raw milk use in dairy | 0.6 | Dairy use in retail | 0.25 | Household demand for dairy | 3.5 |

* The figures in the Table 6.2 illustrate a 50% reduction for those displayed in Table 6.1

The OECD (2014) paper[16] uses the partial equilibrium model OECD-FAO Aglink-Cosimo to estimate the market and trade impacts of FLW reduction, based on the latest set of quantitative medium-term projections for world and national agricultural markets provided by the model for 2014-23. Similar to Rutten et al. (2015), the study applies Gustavsson et al. (2011) estimates of FLW to examine four different scenarios[17]. However the geographical coverage is expansive including all regions (Table 6.3).

**Table 6.3 Food loss and waste reduction scenarios using Aglink-Cosimo (OECD 2014)**

| Region | Commodity | Stages of food supply chain concerned | Timeframe | Reduction level |
|---|---|---|---|---|
| All | All | All | 2014-2023 | 20% |
| North America, Europe including Russia, Turkey, Iran, North Africa | Cereals | Distribution-Consumption | 2014-2023 | 20% |
| Developed countries | Meat and dairy products | Distribution-Consumption | 2014-2023 | 20% |
| Developing countries | Cereals and oilseeds | Agriculture production Processing and packaging | 2014-2023 | 20% |

Reductions in consumer waste are modelled as a negative demand shock, which reduces domestic prices and quantities, and lowers international prices via cumulative impacts that depend on countries' integration with world markets. Reductions in food losses during production are modelled as a positive supply shock, which raises domestic supplies and lowers domestic prices, again leading to lower international prices. At the country level, the final impacts correspond to changed volumes of production, consumption and net trade at new (lower) domestic and international prices.

The first scenario consists of reductions in producer losses and consumer waste for all countries and commodities[18] covered by Aglink-Cosimo. In global terms, Scenario 1 suggests that the biggest impacts on international markets would come from demand reductions rather than supply impacts.

The remaining three scenarios focus on: reduced food waste from cereal consumption in North America, Europe and North Africa; reduced food waste in consumption of meat and dairy products in developed countries; and reduced food losses from crop production in

[16] OECD. 2014. Working Party on Agricultural Policies and Markets Market and Trade Impacts of Food Loss and Waste Reduction.
http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/CA/APM/WP(2014)35/FINAL&docLanguage=En
[17] The Aglink-Cosimo model is a recursive-dynamic, partial equilibrium, supply-demand model of global agriculture, developed by the OECD and FAO. It covers annual supply, demand and prices for nearly 50 of the principal agricultural commodities produced, consumed and traded globally. Model simulation is utilised to make projections for the coming ten years, which are included in an annual publication of the OECD-FAO Agricultural Outlook (OECD/FAO, 2014). The model focuses in particular on the potential influence of agricultural and trade policies on agricultural markets in the medium term. An important capacity or strength of this modelling framework is for scenario analysis - answering "what if" type questions of future market developments or possible policy changes. (OECD, 2014). The underlying assumptions on economic growth and demographic trends are provided in OECD-FAO Agricultural Outlook 2014-2023 (OECD/FAO, 2014).
[18] The AGLINK-COSIMO model is used to simulate the development of annual supply, demand and prices for the main agricultural commodities produced, consumed and traded worldwide in each of the regions it covers. AGLINK-COSIMO contains: - 67 countries and regions - 139 commodities - 720 attributes

developing countries. In each case the scenario reduces gradually the existing level of FLW so that the reduction rate becomes 20% in ten years, on the assumption that this can be achieved without cost.

The paper compares the value of each market in US dollars between baseline and scenario, and calculates savings made by consumers. The total consumer saving throughout commodities and regions in 2023 amounts to USD 458 billion, and the accumulated total from 2014 to 2023 is USD 2.52 trillion. The total consumer savings in 2023 are distributed across commodities and regions, where pigmeat, beef and wheat show high consumer savings, and the regions with the greatest benefits are the European Union, China and the United States. When the savings are further reported atcommodity level in a region, the largest consumer savings come in the following sectors: pigmeat in China and the European Union, rice in China, wheat in the European Union, beef in the United States and fresh dairy products in India. Reduced food waste in cereal consumption (Scenario 2) suggests larger gains for consumers of wheat and coarse grains than for rice, reflecting the large food use of wheat in developed countries. Under this scenario, the international price of wheat drops by 3.1% in 2023.

Livestock production and exports in developed countries increase with the reduction in feed cost from lower coarse grain prices. Reduced food waste of meat and dairy products in developed countries (Scenario 3) leads to relatively larger impacts on international trade, with substantial increases in pigmeat exports from developed countries (7%) and larger imports by developing countries (8%) as a result of lower prices. Dairy exports from the United States increase, whereas exports from the European Union and New Zealand decline, reflecting their considerable exports to developed countries where demand is reduced in the scenario.

Reduced crop losses in developing countries (Scenario 4) lead to higher crop supply in these countries, where reduced prices from efficiency gains benefit both developing and developed countries. While this scenario targets developing countries, they are not the only beneficiaries as crop supplies increase feed available in both developing and developed countries and livestock and dairy producers benefit from lower feed costs. Exports increase for some developing countries, while others import more at lower prices. Global rice production increases by 5.5 Mt with the international price decreasing by nearly 10%. Increase in both exports and imports of rice by developing countries under Scenario 4 boosts rice trade between developing countries.

Comparison between the four scenarios indicates that the demand side policies in developed countries can have larger market impacts and consumer savings. The paper provides indicative estimates of the market and trade impacts of FLW reduction. The primary underlying data indicate that the estimates should be treated with caution. Additionally, the analysis does not include important sources of FLW, including the fruit and vegetable sector as well as the processing industry.

The comparative analysis identifies the gap in knowledge on investments needed for the FLW prevention and reduction. The 2014 Session of the Committee on World Food Security (CFS 41) highlighted FLW prevention and reduction guidelines in *Principles for Responsible Investment in Agriculture and Food Systems* (i.e. increase sustainable production and productivity of safe, nutritious, diverse, and culturally acceptable food and reduce food loss and waste in production and post-harvest operations, while enhancing the efficiency of production, the sustainability of consumption, and the productive use of waste and/or by-products). OECD (2014) has provided an indicative potential classification for the required investments to reduce FLW:

**Table 6.4 Adapted from costs to reduce food loss and waste (OECD 2014)**

| Category | Agricultural production | Postharvest handling and storage | Processing and packaging | Distribution: Supermarket Retail | Consumption |
|---|---|---|---|---|---|
| Infrastructure and hardware | Agriculture machinery | Postharvest infrastructure and storage, e.g. silos | Processing and packaging equipment | Roads, ports, stockyards, etc.<br><br>Electricity for refrigerator | Better storage facilities |
| Technology | Prevention and treatment to avoid loss | Introduction of better postharvest treatment | Reuse of by-products for food | Improvement of distribution, e.g. distance, temperature, pests<br><br>Provision of small/varied portions | New materials to prevent waste<br><br>Redistribution of foods<br><br>Provision of small/varied portions |
| Information | Market information on demand and supply<br><br>Opportunity costs to gain market information | Extension of knowledge to farmers<br><br>Opportunity costs to gain new technology | Extension of knowledge and technology to other industry participants | Arrangements for smooth information flow between buyers and sellers | Extension of knowledge<br><br>Opportunity costs to plan the purchase exactly and timely |

FAO (2012) provides policy guidance on the role of producer organizations in reducing FLW and highlights the need for improved storage facilities, infrastructure and cold chains. Producer organizations have a crucial role in collaborating with both the private and public sectors for investments in local food processing services, dry and cold transportation and storage facilities for safe preservation of fresh produce such as fruits, vegetables, meat and fish. Moreover, investments in research aimed at the identification of cost-effective drying methods and business models to support their adoption, as well as on promising options to replace chemical insecticides during storage, can yield significant gains in terms of PHL reduction at the farm level in sub-Saharan Africa (World Bank, Natural Resources Institute, Gustavsson et al., 2011).

Rutten et al. (2013) using the MAGNET model found that stimulating agricultural growth by tackling food losses in the Middle East and North Africa outperforms manufacturing and service-led growth in terms of enhancing food security, reducing dependence on and vulnerability to changes in the world food market, and decreasing rural poverty. Whereas trade-offs occur in terms of production and employment in different sectors, this policy is potentially more beneficial by avoiding the fiscal consequences of tax or subsidy policies.

Furthermore, costs associated with measures to reduce food losses may counteract beneficial impacts and should be avoided as much as possible. The study specifically compared three alternative policies and their impacts in Middle East and North Africa, focussing on outcomes in terms of economic growth, changes in (agri-food) production and prices, employment and wage impacts, impacts on households' food security and poverty. The policies include a policy of reducing import tariffs, a policy of stimulating a manufacturing and service-led growth agenda, and a policy of reducing food losses in the supply of primary (agricultural) commodities in particular. These policy scenarios implemented in the global economic simulation model, MAGNET, for the period 2010 to 2020, and relative to a baseline scenario in which world food prices are rising (modelled via an increase in world cereal prices).

The impacts are shown to depend on the extent to which FLW are avoidable, factors that cause them to arise (notably food prices), and the immediate costs associated with measures to reduce them.

On the demand side, tackling food waste will incur trade-offs because the reallocation of spending on previously wasted foods causes some producers to be worse off and some to be better off. For example, if consumers were to waste less vegetables, they would need to buy less vegetables (assuming that their preferences have not changed). This would make vegetable producers worse off as their sales go down. However, consumers may spend the money they saved, for example, on meat or perhaps on non-food products, which would benefit meat or non-food producers. If consumers delay spending the money they saved from reducing vegetable waste, these impacts may occur only in the longer term.

On the supply side, producers tackling losses may have to incur welfare losses in the short term, due to costs involved and/or a fall in revenues because of declining agri-food prices, with gains in terms of increased sales, if any, occurring later. As a consequence, the impacts, notably on food security and welfare, are ambiguous, and need to be investigated in more detail in applied and context-specific studies.

A study focusing on healthy and sustainable diets, known as the 'protein puzzle' found that a reduction of FW modelled via a 15 per cent global supply chain efficiency increase reduces agricultural prices by about 4 per cent which generates an increase in food consumption (Westhoek et al., 2011).

Additionally, other studies have sought to calculate economic impacts by estimating the value of FLW. Gustavsson et al. (2013) estimates the value of FLW to be approximately US$750 billion (at producer prices), or US$470 a tonne. However, as the value of food increases through the supply chain the true economic cost of FLW is thought to be much higher. WRAP (2013c) estimates that the value of food waste in the UK increases from around US$1,500 a tonne for manufacturers to US$4,800 a tonne for consumers.

Similar approaches have been used by other studies such as Nahman and De Lange, (2013) that estimates the value of FLW in South Africa to increase from around US$450 a tonne to over US$1,100 a tonne between agriculture and consumption. Moreover, Buzby et, al, (2014) estimated that 60 million tonnes of food that was wasted at retail and consumer stages in the USA had a retail value of US$162 billion ($2,700 a tonne). Additionally, the Ministry of Agriculture Forestry and Fisheries in Japan has estimated that about 23 million tonnes of food was wasted in 2007 worth the equivalent of US$110 billion, or an average of US$4,800 a tonne (OECD, 2014).

The key elements of the four studies discussed above are synthesized in Table 6.5.

**Table 6.5: Synthesis of main empirical studies on socio-economic impacts of FLW**

| Author (s) | Source of data | Geographical coverage | Econometric model | Timeframe | # of scenarios | Impacts assessed | Impacted actors | Welfare impacts |
|---|---|---|---|---|---|---|---|---|
| Rutten, M., Nowicki, P., Amaryan, L., and Bogaardt, M-J., (2013) | Gustavsson et al. (2011) - FAO FLW data | European Union | MAGNET (Modular Applied GeNeral Equilibrium Tool, release version 2) | 2013-2020 | 10<br>30% reduction<br>40% reduction<br>50% reduction | EU food waste reduction by households and retail | Households and retail | Calculates savings made by consumers. Trade-offs occur depending on the targeted sectors or actors. |
| Rutten, M. and Kavallari A., (2013) | Gustavsson et al. (2011) - FAO FLW data | Middle East and North Africa (MENA) | MAGNET | 2012-2020 | 4 policy changes | MENA FLW reduction in the agricultural supply via technological shocks | Producers, consumers, and overall welfare | Stimulating agricultural growth by tackling FLW in MENA outperforms manufacturing and service-led growth in terms of enhancing food security, reducing dependence on and vulnerability to changes in the world food market, and decreasing rural poverty. Trade-offs occur depending on the targeted sectors or actors. World Cereal Prices (WCP), import tariff reductions in response to WCP, Agricultural growth targeting food losses (AFL) in response to WCP, Manufacturing and service-led growth in response to WCP |
| Okawa, K. (2015) | Gustavsson et al. (2011) - FAO FLW data | Global* | AGLINK-COSIMO Model (a recursive-dynamic, partial equilibrium, supply-demand model of world agriculture) | 2014-2023 | 4<br>20% reduction | Market and trade impacts of FLW reduction | Production and consumption | At country level, the final impacts correspond to changed volumes of production, consumption and net trade at new (lower) domestic and international prices. Trade-offs occur depending on the targeted sectors or actors. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rutten M., Verma M., Mhlanga M., Bucatariu C., (2015) | Gustavsson et al. (2011) - FAO FLW data | European Union and Sub- Saharan Africa | MAGNET | 2012-2020 | 5<br>50% reduction | FLW reduction impacts on food prices and price transmission | The study analyses the impacts of reductions in FLW on the supply and demand side of food in the global market, global food prices and their transmission to domestic food prices (consumer and producer prices) in the medium- to long-term. | Differential impacts across producers and consumers in the EU and SSA. The effects are highest in regions where action is taken to reduce food loss and waste, i.e. the EU. Trade-offs occur depending on the targeted sectors or actors. |

* Countries covered in the AGLINK-COSIMO model

## 6.5 Discussion of welfare impacts

The studies discussed in Section 6.4 are not necessarily comparable due to differences in models used and the focus. Nonetheless, the empirical studies show that potential welfare (social-economic impacts) of FLW reduction can be significant. According to Rutten et al. (2013) reducing FLW by EU households could lead to annual households savings of between 92–153 Euro by 2020 that translates to an annual total saving of 56–94 billion Euro for the EU. Similarly, OECD (2014) estimates global total consumer savings of USD 458 billion in 2013 from FLW reduction (cumulative total consumer savings of USD 2.52 trillion). However, Rutten et al. (2015) while showing positive welfare gains for the EU reports welfare losses for SSA (*ceteris paribus*). These SSA welfare losses are nonetheless modest and represent only a negligible fraction of GDP. Overall, the stated potential impacts give impetus for policy makers to take actions to reduce FLW.

An attempt to provide comparative results is provided by OECD (2014) that compares FLW scenarios for the specific sector of red-meat. The exercise involved performing an estimation using data similar to the one by Rutten et al. (2013), using the AGLINK-COSIMO model. Table 6.6 summarises the two simulation results, where the consumption of beef and sheep meat in the European Union was shocked in the Aglink-Cosimo model by the same percentage to 94.5% in 2023.

**Table 6.6 Comparison between the OECD (2014) and Rutten et al. (2013) studies[19]**

| Item | Subcategory | OECD study (in 2023) | LEI study (in 2020) |
|---|---|---|---|
| Per capita consumption | Red meat | -4.2 % | -5.44 % |
| Production | Red meat | -2.53 % | -4.31 % |
| Producer price | Beef | -16.04 % | -0.137 % |
| | Cattle | | |
| Consumer price | Beef | -3.44 % | |
| | Red meat | | -0.058 % |
| Exports | Red meat | 15.35 % | |
| | Red meat products | | 0.201 % |
| Imports | Red meat | -18.43 % | |
| | Red meat products | | -4.36 % |

* Comparison of scenario results - 50% reduction of food loss and waste in consumption of red meat in the European Union
Source: Rutten et al. (2013), OECD (2014)

The results from the two studies show similar trends but different magnitudes in terms of impacts. Per capita consumption in the Rutten et al. (2013) shows a reduction of almost 5.5% in 2020, and that of OECD shows a reduction of 4.2% after the new market equilibrium. The smaller reduction in production than in consumption implies that the reduction in consumption has led more to the decrease of imports and the increase of exports (OECD, 2014).

[19] OECD, 2014

Both models project that consumer and producer prices are decreasing. However, the OECD study projections in comparison to Rutten et al. (2013) differ by a factor of more than ten fold, which implies that supply-response in the OECD study (AGLINK-COSIMO model) is inelastic compared to the LEI model (MAGNET). The orientations towards more exports and less imports are common in the two studies, but again the degrees of trade impacts are observed much larger in the OECD study.

## 6.6 Information gaps and limitations of reviewed studies

Various simplifying assumptions are used in the studies. For example, the analysis undertaken by Rutten and her co-authors assume that all losses in the production and supply of commodities are avoidable therefore can be reduced at no cost. In reality, the reduction in FLW may have costs that may impact directly the welfare gains. Moreover, if losses increase with scale (and price), the observed impacts of reducing food losses will be greater if the market is of a reasonable size (i.e. the quantity demanded and supplied is large) and the price is high; and vice versa, if losses decrease with scale (and price), impacts of reducing losses will be bigger if the market is small and the price is low.

The predicted outcomes are also based on the presumption that all things remain constant (the *ceteris paribus* condition). Specifically, Rutten et al. (2015) assumes action only by the EU, yet, observed behaviour shows that regions apply coping mechanisms to changes in the market conditions. For instance, these could be in terms of trade measures and domestic policy support for farmers. In fact, SSA has prioritized FLW reduction in its regional frameworks and has targeted to halve current levels of post-harvest losses by 2025. [20] If these actions are to take place concurrently to actions in the EU, the observed effects on prices and welfare are likely to differ from those reported in the study. Futhermore, the *ceteris paribus* condition does not take into consideration the effect of the resultant lower prices. For instance, households may waste more if food becomes cheaper, counteracting the positive impact of reducing food losses on the supply side. What exactly will happen remains an empirical question and is best investigated in an applied model of the whole economy with added real-life complexities (Rutten, 2013). Similar assumptions are applied in the OECD (2014) study.

Another limitation specifically in the OECD (2014) study is that interactions with other markets and actors are ignored. Moreover, the model excludes the fruits and vegetables

[20] Refer to Malabo Declaration adopted by the African Union Heads of State and Government in 2014. Furthermore, food loss and waste reduction is being tackled at the global level through the Zero Hunger Challenge. This vision applies a sustainable food systems approach under the aim of zero food loss and waste. The Committee on World Food Security (CFS), the world's foremost inclusive intergovernmental and multi-stakeholder platform for food security and nutrition, at its Forty-first Session on "Making a difference in food security and nutrition", called on all concerned stakeholders to undertake cost-effective, practicable and environmentally sensitive actions according to their priorities and means to reduce food loss and waste. Additionally, food loss and waste reduction and monitoring are being discussed for the Post-2015 Development Agenda within the potential Goal number 12 on ensuring sustainable consumption and production patterns.

sector as well as the processing industry which data suggest are important sources of FLW.

For a comprehensive assessment of socio-economic impacts of FLW a thorough reflection on the economic mechanisms that are behind the phenomenon is needed in order to validate the scale of reductions that are achievable with a net economic gain, and to calibrate the associated shifts in supply and demand curves (Buzby et al., 2014, Gunders, 2012, Rutten et al., 2013 and 2015). Nuanced information on causes and solutions and associated costs along the food supply chain is required.

## 6.7 Conclusions and policy implications

Existing literature suggests that the socio-economic impacts of FLW reduction could be substantial.

All papers analysed in this report provide relevant considerations for policy makers on levers that they may select to influence the demand and supply of commodities while reducing FLW. The potential policy actions are suggested by the shocks applied in the different modelled scenarios. However, caution must be taken in deciding on the intervention to ensure coherence and considerations of the environmental dimensions while exploring current instruments that could provide the required drivers for FLW reduction.

High level considerations on the socio-economic impacts of food loss and waste need to be balanced with a value chain analysis that includes data on costs related to the prevention and reduction measures to be implemented for the short, medium and long term return on investmets along the food supply chains, including for the end consumption level.

FLW prevention and reduction is taking place in the EU concurrently to actions in other Regions and the potential impacts on food prices and welfare need to be researched and projected for intra- and inter-regional impacts (Rutten et al., 2015). For instance, households may waste more if food becomes cheaper, counteracting the positive impact of reducing food losses on the supply side or trade-up and spend the saved income from the reduction of food waste for other services or higher quality food.

Therefore, the Global Initiative on Food Loss and Waste Reduction (Save Food)[21] has designed a case study method in which researchers analyse primary data such as the levels and causes of food losses, including the socio-economic drivers, impacts and identification of effective solutions. It has been applied in several countries, including in Kenya for banana, maize, milk, and fish subsectors (FAO, 2014)[22].

The methodology refers to a 4-S as approach described below:

I. Preliminary Screening of Food Losses ('Screening'). Based on secondary data, documentation and reports, and expert consultations (by phone, e-mail, in person) without travel to the field.

[21] Global Initiative on Food Loss and Waste Reduction (Save Food). http://www.fao.org/save-food

[22] FAO (2014) Food Loss Assessments: Causes and Solutions. Kenya: Banana Maize Milk Fish. Rome.

II. Survey Food Loss Assessment ('Survey'). A questionnaire exercise differentiated for either producers, processors or handlers/sellers (i.e. warehouse manager, distributor, wholesaler, retailer), complemented with ample and accurate observations.

III. Load Tracking and Sampling Assessment ('Sampling'). For quantitative and qualitative analyses at any step in the supply chain.

IV. Solution Finding ('Synthesis'). Used to develop an intervention programme for food losses, based on the previous assessment methods.

Combining econometric modelling with a value chain analysis is an effective approach that allows the identification of critical FLW hotspots points along the food supply chains and facilitates the identification of main socio-economic criteria for decisions on effective solutions, for food loss reduction including required investments in the short, medium and long term.

# 7 Impact of food banks and other initiatives aimed at the food supply of marginalised social groups

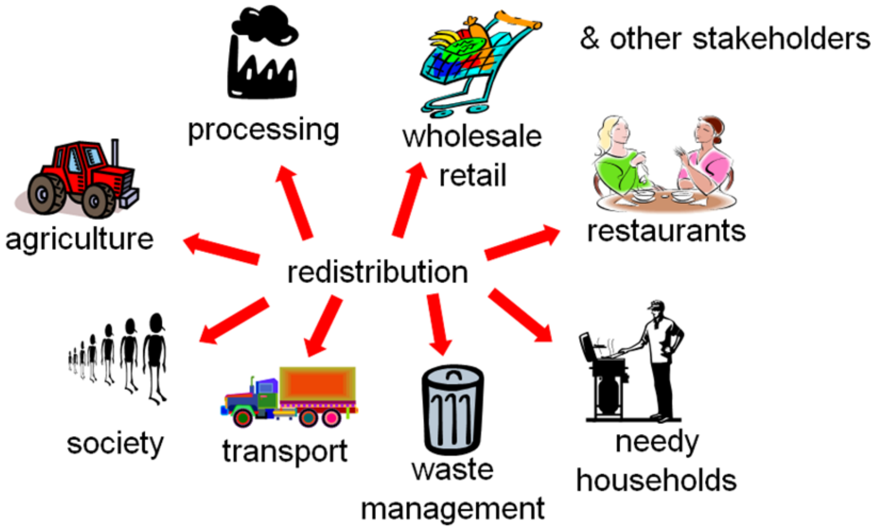
## 7.1 Introduction

This section aims to assess "the impact of food banks and other initiatives aimed at the food supply to marginalised social groups" along the food chain from a life cycle perspective. The hypothesis developed is that there are several positive and negative socio-economic impacts due to redistribution activities on the different stakeholders of the food supply chain. The aim is to identify relevant impacts, to quantify them, to relate them to indicators, to develop a methodology to assess the overall situation and test the methodology in practice.

## 7.2 Scope and definitions

Figure 7.1 gives a scheme of the interactions between redistribution and other stakeholders. Some of the affected stakeholders can be named very clearly (e.g. the beneficiaries of redistribution which are the needy households), while others are involved rather indirectly (e.g. employees of transport companies).

**Figure 7.1: Scheme of interactions between redistribution activities and stakeholders along the food supply chain**




In order to define the used terms properly it was decided to use existing definitions from the literature as far as possible. In general, "food banks and other initiatives" include organisations which distribute edible food which was intended to be wasted directly or indirectly to needy people. These activities are summarised by the term "redistribution". Most of the mentioned organisations distribute surplus food to a large extent but not exclusively depending on the specific project. This means that partly food is offered which could also be marketed in a common way. In specific, several initiatives have been distinguished for the collection of more detailed data. The following definitions are taken from the annual report of Feeding America (2010) in order to ensure a harmonised wording[23]. According to this, the following terms can be defined:

- A "food bank" is a charitable organisation that solicits, receives, inventories and distributes donated food and grocery products pursuant to appropriate industry and regulatory standards. The products are distributed to charitable human service agencies (e.g. food pantries) which provide the products directly to clients through various programmes.
- A "food pantry" is a charitable distribution agency that provides clients with food and grocery products for home preparation and consumption.
- A "soup kitchen" is a charitable programme whose primary purpose is to provide prepared meals, served in the kitchen, to clients in need.
- A "shelter" is a charitable programme with a primary purpose to provide shelter or housing on a short-term or temporary basis to clients and typically serves one or more meals a day.

Those definitions were used for the initial inventory of organisations existing in Europe. Beside this focus, the literature review on social impacts also included food aid organisations regardless of the source of the food distributed (e.g. donations, surplus food or regularly bought). In the results section the terms used correspond to the original literature in order to allow a differentiation between surplus food and common food

[23] The definition for food bank, food pantry and soup kitchen is also used by Poppendieck (1994). In contrast, Lambie-Mumford et al. (2014) use "food bank" instead of the above mentioned "food pantry" for those organisations providing ready parcels of food to take away and prepare and eat at home.

distribution whenever possible. According to Lambie-Mumford et al. (2014) "food aid" is defined as an "*umbrella term used to describe any type of aid giving activity which aims to provide relief from the symptoms of food insecurity and poverty. It includes a broad spectrum of activities, from small to large scale, local to national, emergency one-off operations or well established food banks.*"

"Marginalised social groups" are characterised by low income (e.g. below a specific income level or minimum wage) and/or precarious living situation (e.g. women living in a women's refuge).

## 7.3 Approach

Social impacts were evaluated in the following steps:

1. Contact list of food redistribution organisations in Europe:
First steps was the preparation and circulation of a template (data sheet) on food banks and similar organisations in June 2013, which was answered by Task 1.4 partners as well as other selected FUSIONS project partners (from Greece, Hungary, Denmark). The aim of the data collection was to have a contact list and an overview on available information about the redistribution organisations on a European basis. To cover most of the European countries, certain countries were allocated to each partner taking into account location and language knowledge. The type of social organisation engaged in redistribution activities was distinguished into six groups:
   - food bank
   - food pantry
   - soup kitchen
   - shelter
   - mixed form
   - no information

The idea behind that approach was that there may be a different social impact on the target groups, staff members or also on other involved stakeholders depending on the type of redistribution activity. This initial survey ended on August 16$^{th}$, 2013. In the case of Austria, Germany and Switzerland the survey was already more detailed as for other countries in order to have an overview on available data with respect to social impacts on different stakeholders, e.g. quantity of certain products or product groups diverted from the end-of-life stage, number of people supported through food banks or similar organisations, economic value of the redistributed food, number of volunteers etc.

2. Literature review on social impacts of food redistribution:
Starting in autumn 2013, a literature review was conducted to collect international papers, reports and further information sources related to social impacts of redistribution on different stakeholders. The aim of this review was to identify positive and negative social impacts on different stakeholders due to redistribution, to quantify them and perhaps also find information how to translate them to indicators and to assess. Various databases (Scopus, Austrian libraries, internet) were searched for relevant studies, using different keywords and combinations in English and German (food bank, food pantry, soup kitchen, food rescue, donated food, food donation, food redistribution, food bank impact assessment, food pantry impact assessment, food donation impact assessment,

food redistribution impact assessment, food bank social impact) to find detailed literature dealing e.g. with the health situation of redistribution clients, the socio-economic benefits of redistribution to the community, discrimination issues connected with redistribution and so on. More than 80 studies, papers and additional information were found. The findings from the literature were used to have a first list of optional indicators for the assessment.

3. Consultation workshops at Sardinia Symposium and at the FUSIONS EPM in Brussels:
In addition to the literature review, two workshops have been conducted to learn more about the experts´ opinion and experiences on social impacts of redistribution actitivities related to the involved stakeholders. One workshop was held in the course of the Sardinia Symposium on 30th of September 2013 in Italy. It was prepared and conducted by BOKU in cooperation with the IWWG[24] task group on Prevention of Food waste as well as with the help of FUSIONS partner MTT (LUKE). In total, 17 participants joined the workshop covering e.g. Austria, Belgium, Denmark, Finland, Italy, Japan, Norway, Spain, The Netherlands and UK. The aim of the workshop was to discuss possible social impacts of food waste prevention initiatives in general and to find indicators as well as to identify potential data sources. After a short introduction on food waste in general, a brief introduction of FUSIONS and social impacts, the participants were split into three groups with the task to list food waste prevention measures, describe them briefly and find associated positive and negative social impacts. The results of each group were noted within a table. In a next step one person per group highlighted a couple of most important measures and the attached social impacts. Afterwards some impacts where picked out in the plenary and possible indicators which could be used within a social assessment were named in addition with available data sources. The second workshop was held during the FUSIONS European Platform meeting on 18th of October 2013 in Amsterdam. The topic of the workshop was "Indicators and impacts of wasted food" and was prepared and conducted by BOKU and FAO with support of MTT. About 30 participants (from Eurostat, McDonald´s Finland, SIK, Sweden Environmental Institute, Last Minute Market, Spar Austria and Wrozlav University Poland etc.) took part in the workshop which was split into two sections of which the second one was dedicated to social impacts of redistribution. The task for the participants grouped in four teams was to consider positive and negative social impacts of food redistribution in the different levels of the food supply chain (redistribution, agriculture, retail sector, HORECA[25], transport, waste management, needy households, society). The participants were asked to use green cards for positive social impacts and red cards for negative impacts and related the impacts to certain food supply chain levels. After the collection of the cards they were categorised by pinning them on a flip chart and briefly discussed in a plenary session.

4. Identification and Test of a methodology for the social impact assessment of food redistribution:
As a methodology the social capital concept from the World Bank was identified. A literature review on this methodology was carried out to detect the suitability for the purpose of this assessment.
After the literature review, indicators were identified following the five dimensions of social capital in addition to food safety and food security in combination of the findings of the literature review of social impacts and the consultation workshops. The methodology was tested in practice and questionnaires were sent out to food redistribution

[24] IWWG = International Waste Working Group, http://www.tuhh.de/iue/iwwg/welcome.html
[25] HORECA = hotels, restaurants and catering sector

organisations, collected in step 1, over Europe. Results of these questionnaires were analysed and interpreted.

# 7.4 Literature review

## 7.4.1 Literature review on social impacts of redistribution

Besides several scientific papers in English, there was also a large number of publications in German (22) dealing with different impacts and aspects of food redistribution activities. 85 studies were screened and classified into 5 classes according to its considered relevance for the present study (1 = very useful, 5 = not relevant). Eight studies were classified as very useful while others often repeated content and findings from those original studies. The results are summarised and grouped according to the affected stakeholder.

In general, it can be summarised that there is little research which provides evidence on the benefits and disadvantages of different types of redistribution. Lambie-Mumford et al. (2014) analysed the situation of food aid services in UK by including information from other countries and state that detailed related information has been missing so far. They also conclude that it is impossible to give an accurate estimate of the number of people reached by charitable food aid in UK, which is also true for other European countries (cf. Molling and Selke, 2012) as in most cases only rough estimations are available or detailed facts only cover particular initiatives. Most of the available literature can be broadly categorized as

- case studies about specific food redistribution activities covering a specific region (e.g. Alexander and Smaje, 2008; Askew, 2010; Bernhofer and Pladerer, 2013; Bono, 2002; Bull and Harries, 2013; Feeding America, 2010; Food Banks Canada, 2013; Koshy and Phillimore, 2007; Lambie, 2011; Lambie-Mumford et al., 2014; Leitsberger, 2012; Novotny, 2011; Mulquin et al., 2000; Schnedlitz et al., 2011; Tarasuk and Eakin, 2003; von Normann, 2003)
- critical discussions on the role of food redistribution in society (e.g. Cooper and Dumpleton, 2013; Curtis, 1997; Hartmann, 2012; Hawkes and Webster, 2000; Lorenz, 2012; Molling and Selke, 2012; Poppendieck, 1994; Riches, 2002; Selke, 2009)
- studies focussing on nutritional aspects of food insecurity and in food redistribution schemes (e.g. Hamelin et al., 2002; Handforth et al., 2013; Holben, 2012; Loopstra and Tarasuk, 2012; Ross et al., 2013, Shimada et al., 2013)

There are considerable differences between the various types of food aid initiatives (cf. Lambie-Mumford et al., 2014). Therefore, an effect of a redistribution activity can both be positive and negative, depending on the characteristics of a specific redistribution activity, and from the perspective of different stakeholders. For example, food redistribution activities differ in

- type (food bank, food pantry, soup kitchen, shelter)
- product range
- product choice (free choice for clients or provision of prepacked bags)

- prices (free distribution, symbolic price, reduced price)
- eligibility criteria
- services offered in addition to food provision
- acceptance of donations
  - only products or also money
  - from organisations/ companies/ retail/ restaurants or also from private individuals
  - acceptance of products past their best-before-date

Lambie-Mumford et al. (2014) found, that in the UK, most of the organisations running food aid initiatives were engaged in more than one type of project.

#### 7.4.1.1 Impacts on people in need

The majority of literature covers impacts on the clients of food redistribution activities. The variety of aspects has been grouped into different categories, for the sake of clarity and readability. However, it has to be taken into account that there are a lot of interrelationships between different aspects (e.g. external barriers such as eligibility criteria can create psychological effects) and that some aspects could be considered in more than one category. Thus, the classification applied below presents just one of many possibilities. Table 7.1 provides an overview about the aspects discussed in literature and their potential impact. In the following chapters, these aspects are described in more detail.

**Table 7.1: Overview about potential impacts of food redistribution on people in need, discussed in literature**

| aspect | pot. impact | references |
|---|---|---|
| **Social impacts** | | |
| exchange of information via direct contact | + | Bono (2002), Leitsberger (2012), Poppendieck (1994) |
| overcome individual isolation | (+) | Bono (2002), Poppendieck (1994), Mulquin et al. (2000) |
| support integration of socially excluded people | -/+ | Bono (2002), Leitsberger (2012), Schneider (2012) |
| encouraging competence via additional activities (practical training for cooking or nutritional issues, medical services, information by social workers) | + | Hawkes and Webster (2000), Bernhofer and Pladerer (2013), Food Banks Canada, 2013 |
| informal access to emergency food programs | + | Poppendieck (1994), Curtis (1997) |
| feeling part of a community | + | Lorenz (2012) |
| **Economic impacts** | | |
| increase purchasing power | (+) | Bono (2002), Poppendieck (1994), Leitsberger (2012), Schneider (2012), Lorenz (2012), Ponstingl (2011) |
| covers existential needs | (+) | Leitsberger (2012) |
| better get along with household budget | + | Sellmeister (2010), Schnedlitz et al. (2011), Stoubenfol (2013) |
| helps to bridge the gap between benefit payment and food needs | + | Selke (2009) |
| allows some planning, saves money for harder times | + | Hamelin et al. (2002) |
| **Nutrition and health** | | |
| health benefits | -/+ | Koshy and Phillimore (2007), Poppendieck (1994) |
| improve nutritional situation | -/+ | Hawkes and Webster (2000) |
| reduce the likelihood of repeated severe food insecurity | - | Loopstra and Tarasuk (2012), Lambie-Mumford et al. (2014) |
| unsuitable food (type, quality) | - | Loopstra and Tarasuk (2012), Selke (2009) |
| risk of receiving food which is unsafe to eat | - | Teron and Tarasuk (1999), Selke (2009) |
| lower food quality | - | Selke (2009), Lambie (2011) |
| limited choice/ range of products | - | van Normann (2003), Selke (2009), Bernhofer and Pladerer (2013), Ross et al. (2013), Hamelin et al. (2002) |
| have to conform to available donated products | - | Selke (2009) |
| ensures some variety to the menu | (+) | Hamelin et al. (2002) |
| more food available | (+) | Poppendieck (1994) |
| **Psychological impacts** | | |
| charge of symbolic price supports feeling of self-determination and dignity | -/+ | Bono (2002), Leitsberger (2012), Mulquin et al. (2000) |
| feeling of degradation (shame, social acceptability, personal values) | - | Loopstra and Tarasuk (2012), Teron and Tarasuk (1999), Selke (2009) |
| barriers (access and information) have to be overcome, confusion | - | Loopstra and Tarasuk (2012) Poppendieck (1994), Sellmeister (2010), Mulquin (2000) |
| increase stigmatization | - | Bono (2002), Hawkes and Webster (2000), Schneider (2012) |
| "undignified" way to receive food | - | Loopstra and Tarasuk (2012), Lambie-Mumford et al. (2014) |
| limits clients autonomy | - | Sellmeister (2010) |

| | | |
|---|---|---|
| shame | - | Selke (2009) |
| conflicts due to limited available products | - | Selke (2009) |
| lack of independence | - | Selke (2009) |
| decrease of social position | - | Lorenz ( 2012) |
| purchasing limits | (-) | Bernhofer and Pladerer (2013) |
| requires clients to give up their privacy by revealing personal social and economic circumstances | - | Curtis (1997) |
| experience of powerlessness (inability to make choices) | - | Curtis (1997) |
| expectation of gratitude by volunteers | (-) | Curtis (1997) |
| feeling of social injustice | - | Lambie (2011) |
| self-determination | -/+ | Hartmann (2012) |
| cement the low social status of poor elderly | - | Mollin and Selke (2012) |
| sense of social alienation | - | Hamelin et al. (2002) |

pot. (potential); + ... positive, (+)... rather positive, -/+... controversial (positive and negative views can be found), (-)... rather negative, - ... negative

**Social impacts**

Due to large differences among existing redistribution initiatives their social impact depends on the individual model of redistribution. Bono (2002) assumes that in general the recovery of surplus food is beneficial for people in need. The direct contact with the needy clients enables low-threshold exchange of information which otherwise would not reach the affected people. Redistribution is seen as an important opportunity to **overcome individual isolation** and loneliness and **support the integration** of socially excluded people as well as for synergistic effects (e.g. information provision) (Bono, 2002; Mulquin et al., 2000; Mollin and Selke, 2012). Lorenz (2012) hypothesises that the possibility to join a community is one of the main incentives for people to use food redistribution programmes, rather than hunger. This was confirmed by a case study in a soup kitchen in Belgium by Mulquin et al. (2000) who found that customers came as much for **socialization** as for food. Hamelin et al. (2002) concludes that the use of food banks has become an accepted part of life for a large number of food insecure people in Canada and that "*food banks are seen by clients as a 'community service and a necessity rather than an embarrassment'*".

Positive response is given towards **additional services offered** by food redistribution organisations besides food provision (Bull and Harries, 2013). These services include information towards welfare-entitlements, practical training for cooking or nutritional issues, medical services, skill-building programmes and broad social service programmes (cf. Food Banks Canada, 2013). Often food redistribution places are a gateway to get in contact with those who do not use social workers´ help on their own (Hawkes and Webster, 2000). This portfolio is regarded as an important aspect in parallel with food provision by persons responsible for the food aid programmes, as Lambie-Mumford et al. (2014) identified in their studies. Leitsberger (2012) who conducted nine problem-focused interviews with clients from a social supermarket[26] in Austria, found that the social supermarket served as a **place for social inclusion, communication options and consulting** for the clients, besides its function for saving costs for food (see also Schneider, 2012; Lorenz, 2012; Bernhofer and Pladerer, 2013). Especially the cafeteria which is located at the social supermarket was seen as an area for encounters and exchange (Leitsberger, 2012). Similar experiences are also reported by Poppendieck (1994) and Sellmeister (2010).

[26] The social supermarket surveyed offers food products to registered people in need at very low prices.

Poppendieck (1994) reports that several hundred clients in New York City expressed a preference for the treatment they received in emergency food programmes due to the **informal nature** and the absence of extensive bureaucratic procedures in comparison to their individual experiences in income maintenance centres (cf. also Curtis, 1997).

**Economic impacts**

Redistribution activities **increase the purchasing power** of the people in need as the restricted amount of available money can be used to cover more/other needs than without redistribution (Schneider, 2012; Selke, 2009; Hamelin et al., 2002; Poppendieck, 1994). This food aid enables clients to **better get along with their household budget** (Sellmeister, 2010; Stoubenfol, 2013; Schnedlitz et al., 2011; Lorenz, 2012) and helps to bridge the gap between benefit payments and basic food needs (Selke, 2009). It allows them to save money for harder times and enables some planning (Hamelin et al., 2002). The saved money is most frequently used for paying rents and electricity bills, followed by purchases at discount supermarkets (Ponstingl, 2011). Eight out of nine clients of social supermarkets who were interviewed by Leitsberger (2012) stated to spend the money saved on additional food bought elsewhere.

In interviews conducted with 199 needy Canadian households who did not use food banks, 38 % mentioned that they had **insufficient need to use a food bank**. Common answers were that they still could afford to buy food and had enough to eat although not using food banks (Loopstra and Tarasuk, 2012).

**Nutrition and Health**

Loopstra and Tarasuk (2012) defined that **household food insecurity** is the inadequate or insecure access to food due to inadequate financial resources. Household food insecurity is accompanied by a lot of negative **consequences**: e.g. poor dietary quality, increased nutritional vulnerability, risk of chronic health problems, exacerbations of health conditions that require special dietary management (Loopstra and Tarasuk, 2012), psychological issues (feeling of constraints, stress) and socio-familiar disturbances (Holben, 2012; Hamelin et al., 2002). Lambie-Mumford et al. (2014) concluded from their literature research that food insecure people were less likely to eat fruit, vegetables or salad in comparison to food secure individuals. Views about the effect of food redistribution activities on the nutritional status and health status of their clients are controversial.

Koshy and Phillimore (2007) identified **benefits** for the people in need related to **health issues** in the course of redistribution activities in Western Australia. In comparison to households which were not taking part in food redistribution programmes the food bank studied by Koshy and Phillimore (2007) ensured the provision of safe, culturally acceptable and nutritionally adequate diet to their clients. Also Poppendieck (1994) identified that there was more food available for people in need due to redistribution activities than without.

The study report of Hawkes and Webster (2000) indicates that the number of people benefiting from surplus food redistribution activities is significant although exact numbers are lacking. The authors discuss the **critics of unsuitable** food (e.g. due to lack of nutrition value, lack of client´s knowledge how to cook less common vegetables) and found several **positive examples** where the redistribution organisations address this potential disadvantage by providing education workshops, introducing cooperation with farmers, handing out cooking brochures etc. Due to strict UK food safety rules in the UK, Hawkes and Webster (2000) could not agree with literature that the **food quality** of redistributed food was poor and could have negative impacts on clients´ health. Also other experts such as Evans and Dowler (1999) cited by Hawkes and Webster (2000) found that redistribution organisations have a significant potential to improve the **nutritional situation** of homeless people although reliable data was lacking. Some studies revealed high **levels of satisfaction** with the amount and quality of donated food among clients. A survey of Feeding America (2010) among 60,000 clients of shelters, pantries and kitchens in the U.S. revealed that more than 90% of the adult clients were satisfied with the **amount, quality and variety** of food they received. Stoubenfol (2013) who conducted interviews with 178 clients of a food pantry in Austria found that the majority of clients were content with the offered product range. Also a survey among 532 clients of 32 food pantries in Milwaukee resulted that the clients generally liked the food and customer service and felt respected and welcomed at the food pantry (Askew, 2010). Leitsberger (2012) noticed a general satisfaction with the offer among the clients of an Austrian social supermarket. Interviews with 98 low-income households in and around Quebec revealed that the use or food banks ensured some variety to the menu (Hamelin et al., 2002).

In contrast, Teron and Tarasuk (1999) found that neither the **amount** nor the **quality of food assistance** available were sufficient to cover nutritional needs of food assistance clients in Toronto. Their study is based upon interviews with 102 clients and records of the contents of the hampers of 85 clients. Also the majority of interviewed clients from food shelves in Minnesota (Verpy et al., 2003) argued that the amount they received was inadequate. In particular, needs for people with different ethnic backgrounds or age groups were not satisfied by donations (Verpy et al., 2003). Molling and Selke (2012) consider that the offered range of products is insufficient to cover the needs for special diets for diseases of the elderly.

Food banks offer their clients only **a limited choice** regarding the types, quantity and nutritional composition (Ross et al., 2013; von Normann, 2003). Interviews with directors from 6 food banks in California showed that less perishable and heavier produce varieties – such as apples, carrots, potatoes, onions, oranges, broccoli and cauliflower - were preferred by the food banks because they were easy to handle and robust (Ross et al., 2013). Part of the available food in redistribution is disposal driven instead of demand driven meaning that it does not belong to those food categories most desirable from a nutritional or clients preference point of view (Poppendieck, 1994). An inventory of food redistribution organisations in Vienna by Bernhofer and Pladerer (2013) indicated that in particular more staple foods, frozen food products, ready-made meals and long-life foods such as tinned food would be needed for redistribution. On the other hand, there was often a surplus of bakery products (Bernhofer and Pladerer, 2013; Novotny, 2011). Clients have to conform to available donated products, to accept that the **range of available products** is restricted as well as a lower product quality (cf. Selke, 2009). Some of the donated food were reported in North America to be **unsafe to eat** (cf. Teron and Tarasuk, 1999; Verpy et al., 2003). In a survey among clients of programmes supplied by Daily Bread Food Bank in Toronto, over half of the 102 respondents "*had at some time received food that they believed was unsafe to eat*" (Teron and Tarasuk, 1999). Also clients from food shelves which also receive donations from individual residents in Minnesota reported to have received out-of-date or spoiled products (Verpy et al., 2003). However, von Norman (2003) reported for Germany that there has not been any documentation that a food bank client had suffered any food poisoning or other harm from donated food. Furthermore redistribution organisations within the EU must comply with strick food safety rules (Cseh, 2015).

Loopstra and Tarasuk (2012) focused on **reasons why** food insecure households did **not use a food bank** in Canada. They found that 33 % of the interviewed 199 needy households not using food banks mentioned "**barriers**" (e.g. access, information) and 65 % of respondents listed reasons such as insufficient need (38 %), **unsuitable food** (22 %), identity (12 %) and feelings of degradation (11 %). "Unsuitable food" summarised issues related to poor quality of the provided food (e.g. rotten, past best before date), lack of fresh food, lack of healthy food (e.g. junk food, canned food) and lack of food meeting individual dietary requirements of the clients (e.g. Halal compatible food). "Identity" as a reason for not using a food bank refers to people who felt that this offer was not made for them but for homeless, unemployed and other welfare recipients and that they did not want to take something from those specific population (Loopstra and Tarasuk, 2012).

The potential positive impact on the health of people in need is also limited due to the fact that **only a minority** of potential food insecure households **use redistribution offers**. For Canada, Loopstra and Tarasuk (2012) report that only 22 % of food insecure families in Canada use food charity. Even from families with severe food problems only 33 % are clients of food charities. In addition, Loopstra and Tarasuk (2012) conclude that continued food bank use seems not to reduce the **likelihood of repeated severe food insecurity**. Lambie-Mumford et al. (2014) summarised results from UK literature and found that food insecure households who struggled to receive enough food often implemented other strategies such as postponement of bill payments in order to avoid the need to ask for help. They also conclude that according to the available evidence only limited impact of food aid on the general household food security status can be found in the UK.

**Psychological impacts and stigmatization**

Concerns that food redistribution activities would increase **stigmatization** of the clients are frequently mentioned as negative impact (Bono, 2002; Schneider, 2012; Selke, 2009). It is hypothesised that going to a food bank or food pantry will decrease the **social position** of the clients (Lorenz, 2012) and impair their **autonomy** (Sellmeister, 2010), **self-determination** (Hartmann, 2012) and **self-esteem** (Mulquin et al., 2000). Lambie (2011) reports that the clients of food banks of the Trussel Trust Foodbank Network in the UK keenly feel the **social injustice** of having to go to a charitable food project. Hamelin et al. (2002) speak about the **sense of social alienation** which food insecure people may feel. In interviews with 98 low-income households in and around Quebec city they found that **shame** was felt when clients approached a food bank for the first time (Hamelin et al., 2002; see also Leitsberger, 2012). Clients usually cannot freely decide when to use a food pantry or food bank since opening hours and often also access are limited. This inability to make choices increases feelings of **powerlessness** (Curtis, 1997), dependency and semi-determination (cf. Selke, 2009). By having to reveal personal, social and economic circumstances, clients are required to give up their **privacy** (Curtis, 1997). Loopstra and Tarasuk (2012) summarise that it seemed that using a food bank was perceived as **point of desperation** and "*last resort*". This perception was also identified by Lambie-Mumford et al. (2014) who concluded from their expert workshops that food insecure people wanted to be like everybody else and not to receive food through "*undignified*" ways.

**Barriers** such as long waiting lines, rush at opening time, eligibility criteria, purchasing limits (cf. Loopstra and Tarasuk, 2012; Poppendieck, 1994; Sellmeister, 2010; Mulquin et al., 2000; Lambie-Mumford et al., 2014) and the fact that offered products are no longer valuable for the donating companies may further evoke feelings of **shame** (cf. Selke, 2009) and **discrimination** (Sellmeister, 2010; von Normann, 2003; Schneider, 2012;

Selke, 2009; Bernhofer and Pladerer, 2013). Selke (2009) also mentions **conflicts** due to product quality and available quantity, when some clients claim better quality. In interviews with 199 food insecure households in Canada by Loopstra and Tarasuk (2012), 33% of respondents reported not to use a food bank because of **barriers** such as schedule conflicts due to limited opening hours, long queues, lack of transportation options to reach a food bank, over-strict eligibility criteria and rejection because of staff members who were too busy. In addition, 18 % of the households who did not use food banks stated a lack of information as barrier to use a food bank (Loopstra and Tarasuk, 2012). Poppendieck (1994) criticises the **fragmentation of redistribution activities** resulting in several underserved neighbourhoods and - due to non-concerted opening hours - in **confusion** of the clients. Distances to a redistribution facility and anonymity may also play a relevant role for the use of redistribution offers (cf. von Normann, 2003). Molling and Selke (2012) who focus on elderly and retired food bank clients report that particularly elderly clients have difficulties to reach the nearest food bank, which is one of several other barriers for **elderly**. Therefore Molling and Selke (2012) consider that food banks are not a real support for elderly and that they rather cement the low social status due to dependency and unequal power between volunteers with high social status and clients with low status. Curtis (1997) generally mentions that there is an **asymmetric relationship** between volunteers or staff and recipients who are expected to respond with gratitude to charitable service by volunteers.

Leitsberger (2012) concluded that the clients of an Austrian social supermarket did not feel any **social exclusion** due to their social supermarket membership. However, clients report to have experienced negative feelings (e.g. emabarrassment) during their **first visits** at a social supermarket, which disappeared with increasing positive experience Some clients also reported to feel an inhibition treshold to enter the cafeteria of the social supermarket because the situation was unfamiliar to them. Although the clients expected potential negative reactions from others related to their membership of a social supermarket, they had mostly received **positive feedback from their friends** (Leitsberger, 2012). Riches (2002) found that many food bank recipients of the Daily Bread Food Bank in Toronto **were highly appreciative** of the service provided and of the attitudes of the staff. In contrast, Loopstra and Tarasuk (2012) report that 11 % of interviewed 199 needy Canadian households who did not use food banks felt **degradation** if they would use food banks. Those feelings originate in the perception that depending on food banks is socially unaccepted (leads to shame if using food banks), would not correspond with family values or due to previous individual negative experiences with food banks.

In redistribution models where people can choose food by themselves for a **symbolic price**, this supports the feelings of **self-determination** and **dignity** (Mulquin et al., 2000). All interviewed Austrian clients of a social supermarket stated that they would feel like a beggar if they did not have to pay for the food products they received. By paying a small amount of money they experience individual appreciation due to the active role as consumer (Leitsberger, 2012; von Normann, 2003).

#### 7.4.1.2 Impacts on people involved in redistribution activities

Table 7.2 provides an overview about the aspects discussed in literature and their potential impact. In the following chapters, these aspects are described in more detail.

**Table 7.2: Overview about potential impacts of food redistribution on people involved in redistribution activities, summary of literature review**

| aspect | pot. impact | references |
|---|---|---|
| **Employment possibility** | | |
| employment possibility for people with disabilities | + | Koshy and Phillimore (2007) |
| possibility of volunteering for unemployed people | (+) | Tarasuk and Eakin (2003) |
| higher prospects on the labour market | (+) | Schneider (2012) |
| education and training | + | Alexander and Smaje (2008), Schneider (2012) |
| positive impact on skills | + | Hawkes and Webster (2000) |
| re-integration of unemployed | + | Sellmeister (2010) Schnedlitz et al. (2011) Bernhofer and Pladerer (2013), Ponstingl (2011) |
| social integration | + | von Normann (2003) |
| raise self-confidence of (long-term) unemployed | + | Schneider (2012) |
| **Psychological impacts** | | |
| feeling of satisfaction, usefulness | + | Hawkes and Webster, (2000), von Normann (2003) |
| compliance with social or ethical norms | (+) | von Normann (2003) |
| comply with feeling of spiritual concerns | + | Curtis (1997), Lambie (2011) |
| expected advantages from external effects of volunteering | (+) | von Normann (2003) |
| self-realisation | (+) | Selke (2009) |
| burnout | - | Poppendieck (1994), Loopstra and Tarasuk (2012) |
| concern about nutritional adequacy | - | Loopstra and Tarasuk (2012), Handforth et al. (2013) |
| pressure to acquire donations | - | Loopstra and Tarasuk (2012) |
| social pressure (feeling responsible) | - | Selke (2009) |
| feeling of powerlessness (limited supply, quality of distributed food out of their control) | - | Tarasuk and Eakin (2003) |
| concerns (to jeopardize relationships with donors, discomfort selecting permitted foods, fear of reducing total amount of food distributed) | - | Handforth et al. (2013), Shimada et al. (2013) |
| concerns about low quality | - | Selke (2009) |
| difficulties with high demands of clients | - | von Normann (2003) |

pot. (potential); + ... positive, (+)... rather positive, -/+... controversial (positive and negative views can be found), (-)... rather negative, - ... negative

**Employment possibility**

A lot of redistribution organisations work with **volunteers** who are often **socially marginalised** themselves, i.e. unemployed, former and current food bank clients (Tarasuk and Eakin, 2003; Sellmeister, 2010). Koshy and Phillimore (2007) identified **opportunities for part-time employment** of disabled people due to redistribution activities: The WA (Western Australian) food bank cooperates with the Rocky Bay Employment Service which enabled the part-time employment of five people with profound physical disabilities for the last decade. This model has served as a successful prototype of engagement for other companies offering employment to people with disabilities (Koshy and Phillimore, 2007). Food banks offer the possibility to **re-integrate** unemployed people (Sellmeister, 2010; Stoubenfol, 2013; Schnedlitz et al., 2011, Bernhofer and Pladerer, 2013; Ponstingl, 2011). Training and support of long-term unemployed people can raise their self-confidence, skills and prospects on the labour market (Hawkes and Webster, 2000; Schneider, 2012).

**Psychological impacts**
Literature findings support that the volunteers **are satisfied** by doing something useful and to be able to "express their feelings of common concern for their fellow human beings in a very practical way" (cf. von Normann, 2003; Hawkes and Webster, 2000). Badelt (1985 cited by von Normann, 2003) identified further positive impacts of volunteering, which are compliance with social or ethical norms, social integration (both self and others), acquisition of social status and hope for future benefits from external effects of volunteering (e.g. advantages due to personal contacts, learning of new skills). Norms and motives can be manifold, such as a feeling of obligation to be concerned for others (Selke, 2009). Interviews with workers at food banks in Toronto found that "*displays of **gratitude** were central to the satisfaction some workers derived from their jobs*" (Tarasuk and Eakin, 2003). On the other hand, von Normann (2003) mentions that it may be difficult for volunteers if clients are dissatisfied with the offered product range and complain about it.

**Burnout** was identified by Poppendieck (1994) as common among volunteers and programme directors. Committed volunteers who feel responsible for their colleagues, the food bank and its clients, may feel high **social pressure** to be available and solve problems whenever needed (cf. Selke, 2009). Loopstra and Tarasuk (2012) blame the Good Samaritan Laws in Canada which relate the **liability** of individuals and corporations of donated food to shift the burden of managing food donations with a diversity of potential risks to food bank volunteers and operators spending considerable time for separating inedible food from edible ones, repacking food and making food "presentable". This impact may be reduced in a European context, as inedible food is not allowed to be donated or distributed (Cseh, 2015). Furthermore several findings report that food bank workers may develop pressure in order to acquire more monetary donations to buy additional food or to find more "healthy food" donors (Loopstra and Tarasuk, 2012; Selke, 2009). Efforts of food bank staff to provide more fresh produce were also reported by Handforth et al. (2013) who conducted qualitative interviews with food bank personnel of selected food banks in the Feeding America Network. The main obstacles to implementing nutrition policies were concerns and **uncertainty about donor reactions**, discomfort selecting permitted foods and fear of reducing the total amount of food distributed (Handforth et al., 2013; Shimada et al., 2013). Limited available supply for food distribution and the perception that the quality of the food they distribute is largely outside their control increase the workers´ **feeling to be powerless** (Tarasuk and Eakin, 2003). Alexander and Smaje (2008) analysed the British charity FareShare and its franchises for redistribution to charities and concluded that "*the hierarchy of donor, redistributive agency and client limits the clients´ ability to control food flows*".

### 7.4.1.3 Impacts on donors
Table 7.3 provides an overview about the aspects discussed in literature and their potential impact. In the following chapters, these aspects are described in more detail.

**Table 7.3: Overview about potential impacts of food redistribution on donors, summary of literature review**

| Aspect | Pot. impact | references |
|---|---|---|
| **Cooperate social responsibility** | | |
| achievement of corporate social responsibility goals | + | Koshy and Phillimore (2007), Lorenz (2012), Bernhofer and Pladerer (2013) |
| impact on staff morale | + | Hawkes and Webster (2000) |
| allows company to be viewed as responsible community partners | + | Riches (2002) |
| corporate pride | (+) | Teron and Tarasuk (1999) |
| enhanced customer loyalty | (+) | Teron and Tarasuk (1999) |
| product exposure | (+) | Teron and Tarasuk (1999) |
| **Psychological impacts on donors** | | |
| positive feeling associated with helping others | + | McGrath (2013) |
| sense of satisfaction | + | McGrath (2013) |
| concerns about reputational risk | - | McGrath (2013) |
| concerns about possible staff reactions | (-) | McGrath (2013) |
| concerns about food safety | (-) | McGrath (2013), Wie and Giebler (2013) |
| concerns about liability | - | Adams and Tabacchi (1997) |
| positive feedback that their efforts were helpful | + | Verpy et al. (2003) |
| sense to provide assistance to hungry people | + | Verpy et al. (2003) |
| liability problems | - | Adams and Tabacchi (1997) |
| **Economic impacts and food waste reduction** | | |
| tax benefits | + | Hawkes and Webster (2000), Shimada et al. (2013), Adams and Tabacchi (1997) |
| cost savings (reduced disposal costs) | + | Teron and Tarasuk (1999), Stoubenfol (2013), Schnedlitz et al. (2011), Lorenz (2012), Bernhofer and Pladerer (2013) Guidi (2012) |
| donation increases awareness about generated food waste, which may lead to a decrease of food waste generation | + | Adams and Tabacchi (1997) |
| profit from higher purchasing power of food bank clients | (+) | Ponstingl (2011) |

pot. (potential); + ... positive, (+)... rather positive, -/+... controversial (positive and negative views can be found), (-)... rather negative, - ... negative

**Corporate social responsibility**

Benefits attributable to the achievement of **corporate social responsibility** (CSR) goals are mentioned e.g. by Koshy and Phillimore (2007), Lorenz (2012) and Bernhofer and Pladerer (2013). Koshy and Phillimore (2007) demonstrate for Western Australia that a Foodbank Bulletin, which is disseminated among a network of 1800 individuals and organizations three times a year, encourages CSR and allows the corporate sector to encourage charitable responses from staff and customers. Riches (2002) mentions that the cooperation with food banks allows the corporate food industry to be viewed as responsible community partners. Hawkes and Webster (2000) highlight the positive impact of donations on staff morale due to the good-will gesture. Also corporate pride, enhanced customer loyalty and product exposure are considered to be potential incentives for companies to donate food (Teron and Tarasuk, 1999).

**Psychological impacts on donors**
Verpy et al. (2003) investigated the motivation of individuals who donated food to food shelves in Minnesota and identified the sense to provide assistance to hungry people in their community and **positive feedback** that their efforts were helpful, as important **motivators**. Also feelings of **spiritual concerns** were identified as motivators (Curtis, 1997; Lambie, 2011), as volunteering in redistribution activities enables Christians to undertake the social action work (helping people in need) that their faith calls them to do (Lambie, 2011). Other positive impacts are a sense of **satisfaction** and the prevention of food waste (McGrath, 2013; Selke, 2009). In contrast, there may also be negative impacts, such as **concerns about food handling, reputational risk** and adverse reactions from staff (McGrath, 2013).In particular, concerns about food safety (cf. McGrath, 2013;Wie and Giebler, 2013) and liability (Adams and Tabacchi, 1997) are often reported as the main barrier for the donation of food.

**Economic impacts and food waste reduction**
Saving money due to the donation of surplus food related to **disposal costs** (e.g. Teron and Tarasuk, 1999; Stoubenfol, 2013; Schnedlitz et al., 2011; Lorenz, 2012; Bernhofer and Pladerer, 2013; Guidi, 2012) and **tax benefits** (Hawkes and Webster, 2000; Shimada et al., 2013; Adams and Tabacchi, 1997) are often mentioned as incentives for companies to take part in redistribution systems, without listing exact numbers. Hawkes and Webster (2000) summarise findings from literature from the US, Australia and Canada which indicate that companies and also redistributing organisation agree to this fact. In addition, one expert is cited who sees more benefits for the donors in the long-term due to tax deduction and charity status than for the recipients in short-term due to stigmatisation. According to Selke (2009) donors do not fear income losses due to donations. Donating food and keeping track of the quantities can increase awareness about food generation in an organization, which can lead to a **reduction of food waste** and subsequently to lower amounts available for donations. This mechanism was observed by Adams and Tabacchi (1997) who investigated restaurants which participated in food-donation programmes in the United States. Smaller amounts of donations increase costs and effort for collection (cf. Adams and Tabacchi, 1997), making donations inefficient. But this discussion ends again in the question about what target is tackled by the redistribution organisations – to reduce surplus food and to provide supplement food offer for people in need by redistributing it or to offer as much food as possible to feed the hungry.
Ponstingl (2011) sees an indirect positive impact on retail. The use of food redistribution offers increases the purchasing power of people in need, from which retail could profit in turn.

#### 7.4.1.4 Impacts on communities and society in general
Table 7.4 provides an overview about the aspects discussed in literature and their potential impact. In the following chapters, these aspects are described in more detail.

**Table 7.4: Overview about potential impacts of food redistribution on society, summary of literature review**

| aspect | Pot. impact | references |
|---|---|---|
| **Economic impacts** | | |
| can provide extra services if they receive free food | + | Hawkes and Webster (2000) |
| costs deriving from voluntary labour | - | Alexander and Smaje (2008) |
| effort for coordination of volunteers | - | Alexander and Smaje (2008), Schedlitz et al. (2011), Schneider (2012) |
| cost savings (reduced disposal costs) | -/+ | Riches (2002) |
| cost benefits (saving money for food procurement, logistic costs, personnel costs) | + | Koshy and Phillimore (2007) |
| **Local and community oriented aspects** | | |
| network building, advocacy and lobbying | (+) | Poppendieck (1994), Lambie-Mumford et al. (2014) |
| local and community-orientation | + | Hawkes and Webster (2000), Lambie (2011) |
| time and effort binds resources | - | Hawkes and Webster (2000) |
| raising community awareness towards food insecurity | (+) | Riches (2002), Feeding America, (2010), Lambie (2011) |
| give food insecure households a voice | (+) | Lambie-Mumford et al. (2014) |
| positive public education impact | -/+ | Hawkes and Webster (2000) |
| possibility to create synergies among non profit organisations, companies and authorities | + | Guili et al. (2013) |
| **Social justice** | | |
| legally enforceable rights, protections or recourse | - | Poppendieck (1994), Lorenz (2012) |
| dignity and social justice | (-) | Lambie (2011) |
| **Politics and food poverty** | | |
| dependency on good will and generosity of volunteers and donors | - | Poppendieck (1994) |
| dependency on surplus food and donations | (-) | Poppendieck (1994), Hawkes and Webster (2000), Tarasuk and Eakin (2003) |
| dependency on volunteers (their skills and energy) | (-) | Lambie-Mumford et al. (2014) |
| permit state to neglect their obligation to protect vulnerable and powerless people | - | Riches (2002) |
| indicates prevalence of food poverty and failure of welfare state | - | Riches (2002), Selke (2009), Lorenz (2012), Cooper and Dumpleton (2013), Fell et al. (2013), Curtis (1997) |
| contribution to solve poverty and food related issues | (-) | Hawkes and Webster (2000) |
| contribution to solve "excess food production" topic | (-) | Hawkes and Webster (2000) |
| supplement to public welfare | + | Hawkes and Webster (2000) |
| local short-term non governmental food aid, emergency response | (+) | Lambie-Mumford et al. (2014), Cooper and Dumpleton (2013), Lambie (2011) |
| symbolic gesture | (-) | Tarasuk and Eakin (2003) |
| facilitate further erosion of income supports | - | Tarasuk and Eakin (2003) |
| provide data on social marginalisation | -/+ | De Schutter (2013) |
| could increase social problems as a separate supply system with missing legal and market basis is established | - | Lorenz (2012) |
| **Reduction of crime rate** | (+) | Koshy and Phillimore (2007) |

| | | |
|---|---|---|
| **Food waste prevention** | + | Poppendieck (1994) Hawkes and Webster (2000), Bernhofer and Pladerer (2013), Guidi (2012) |
| decrease of generated food waste | -/+ | |

pot. (potential); + ... positive, (+)... rather positive, -/+... controversial (positive and negative views can be found), (-)... rather negative, - ... negative

**Economic impacts**

Koshy and Phillimore (2007) identified several **cost benefits** for the West Australian (WA) community agencies: the cooperation with the WA food bank saves money in food procurement (at least 80% based on anecdotal evidence) and has also a positive impact on the community´s logistic costs including saved personnel costs due to volunteers supporting the food bank activities. Besides the positive effects of voluntary labour for food banks, such as financial and indirect social benefits (enhanced community involvement, employment and training), there are also some disadvantages. Voluntary labour can **involve costs in terms of managerial input**, inefficient working practices and sub-optimal deployment of available staff resources (Alexander and Smaje, 2008; Schnelditz et al., 2011; Schneider, 2012).

Koshy and Philimore (2007) conclude that the effective implementation of a food redistribution programme by the WA food bank brings together a number of community support agencies where the combined effort creates better effective outcomes for the community. The **relieved community resources** (both personal and financial) could be used to focus on additional issues than food aid (Koshy and Phillimore, 2007). Hawkes and Webster (2000) support this finding also for the UK. However, Riches (1997) cited by Hawkes and Webster, 2000) notes that the disposal costs for surplus food are already included in the companies´ food prices, so that the community has already paid for it.

**Local and community oriented aspects**

Hawkes and Webster (2000) highlight the local and community-oriented aspects (cf. also Lambie, 2011) and the **good cooperation** of surplus food redistribution activities in UK as positive impact, which is also recognised and appreciated by people involved in redistribution activities. The fact that in most cases local communities/charities profit from local cooperations is valued by the people. Lambie-Mumford et al. (2014) identified a proper coordination between different food aid projects as well as between food aid activities and other agencies as a key success factor to their operation. Also Guili et al. (2013) mention the possibility to create synergies among non profit organisations, companies and authorities as one of the drivers of satisfaction. The offer and delivery of free food according to the demand of the charity by redistribution organisation enables the charities to provide extra services to their clients which otherwise would not exist (Hawkes and Webster, 2000). On the other hand, experts criticise that the time and effort going into redistribution **bind resources** which could be used for potentially more useful community activities (Hawkes and Webster, 2000).

Besides a lot of negative issues, Poppendieck (1994) highlights the **network building and lobbying** undertaken by representatives of food redistribution organisations related to the general problem of poverty, which otherwise would lack to a large extent. Food banks can play an important role in **raising community awareness** towards food insecurity (Riches, 2002; Feeding America, 2010; Lambie, 2011). Riches (2002) also identify a possible positive future role for food banks in public education and advocacy but at the same time classify this option as an unlikely course. Lambie-Mumford et al. (2014) conclude from their international literature review that the non-governmental food aid providers can have an important and constructive role in civil society related to

**advocacy** and lobbying as well as to give food insecure households a voice. Hawkes and Webster (2000) found also facts for a positive public eduction impact of redistribution actitivities as long as there is no belief that redistribution can help to alleviate the causes for hunger and poverty and a deeper structural analysis is not necessary.

**Social justice**

Lambie-Mumford et al. (2014) concluded from their literature review and UK expert workshop results that the increasing UK trend to redistribute surplus food as main source of food aid programmes should be further discussed with respect to moral obligation (to use food which otherwise would be landfilled) and to interrelations of corporate interests for donations (see also Lambie, 2011). Lambie (2011) also claims a public discussion on the aspects of **dignity and social justice** and the extent to which redistributing surplus food is in line with these principles.

Poppendieck (1994) assessed the strengths and weaknesses of emergency food programmes which distribute food (either as prepared meals or as groceries) to people in need from a social justice standpoint. From his point of view, there are two different types of models to response to poverty and hunger – the **charity model and the justice model**. While the charity model can be related to personal involvement, localism, neighbourliness, voluntarism and spiritual good, the justice model refers to dignity, entitlement, accountability and equity. The justice model includes **justiciable rights** for the involved persons which can be enforced through legal activities which are missing in the charity models. So, there are **no legally enforceable rights**, protections or recourse in case people in need cannot be supported by emergency food programmes. This can be seen as negative impact not only on the clients itself but also on society in general, as the findings of Riches (2002) show (see chapter 7.4.1.4). Poppendieck (1994) also complain the fragility and dependency of such programmes upon the good will of volunteers and donors.

**Food poverty and politics**

Food bank use is a **symptom for larger problems** in society (Food Banks Canada, 2013). The presence of food banks is seen as a significant **indicator of the prevalence of food poverty** and the **failure of the welfare state** (cf. Riches, 2002; Sellmeister, 2010; Selke, 2009; Lorenz, 2012; Cooper and Dumpleton, 2013; Fell et al., 2013; Curtis, 1997). Food banks represent an up-to-date source of data on social marginalisation in a society (De Schutter, 2013). Riches (2002) explored the growth of foodbanking in Canada and analysed its role in terms of advancing the human right to food. Due to the increasingly significant role as charitable partners with governments in Canada´s public safety net, food banks permit the state to neglect their obligation to protect vulnerable and powerless people and encourage the society´s view that food poverty is not a critical public policy issue (Riches, 2002; Stoubenfol, 2013; Cooper and Dumpleton, 2013). Therefore, Riches (2002) classifies food banking in Canada as an inadequate response to food poverty. This finding is also supported by Poppendieck (1994) who states that *"the institutionalization of such programs seems to embody, or at least accept, the idea that destitution is to be a permanent part of our society and that it is acceptable for poor people to be dependent for their basic needs on the generosity of strangers, on wholly discretionary giving. Such beliefs erode the cultural foundations of public entitlements."* Tarasuk and Eakin (2003) agree that food giving by food banks is more a **symbolic gesture** than a response to need. They found that food banks in Canada lacked the capacity to meet the food needs of those who seek assistance and conclude that foodbanks *"unwittingly facilitate the further erosion of income supports to those at the bottom, leading to increased poverty and income inequality and a growing need for charitable food assistance" (Tarasuk and Eakin, 2003; cf. Stoubenfol, 2013).* Also Lorenz

(2012) thinks that redistribution activities **could increase social problems** due to the establishment of a separate supply system which lacks a legal and market basis.

To minimise the damage from redistribution activities, Poppendieck (1994) concludes that they should not be seen as a substitute *"for reliable, public and permanent cash assistance or food assistance entitlements"* but as **complementary**. Therefore, it is important that advocates and emergency food providers do not stop to claim the need for government action in order to reduce food poverty (cf. Lambie, 2011). More or less the same conclusion is drawn by Hawkes and Webster (2000) after surveying surplus food redistribution schemes in UK, North America and Europe. They summarise that it is not a politically effective way to resolve the "poverty and food" related issue as well as the "excess food production" topic (cf. Bull and Harries, 2013). Hawkes and Webster (2000) claim a wider debate on long-term implications of surplus food redistribution and the relation to welfare provision and longer-term structural responses to food poverty. But they also mention that at least the UK food redistribution schemes have never claimed to tackle the hunger problem and therefore do not expect to be assessed against this indicator. Also none of the surveyed redistribution systems see themselves as substitution for public welfare organisations but as a supplement.

Lambie-Mumford et al. (2014) mention the **vulnerability of food aid** in case of **dependency on donations and volunteers** as well as the appropriateness and value of volunteer´s energy and skills. The dependency of redistribution on donations from retailers leads to a conflict of priority between demand and supply (Hawkes and Webster, 2000; Tarasuk and Eakin, 2003). The findings of Lambie-Mumford et al. (2014) indicate that some experts see a positive impact for local short-term non-governmental food aid in the light of the present economic and policy situation. In conclusion of all consulted information they recommend an ongoing focus on causes of household food insecurity in order to achieve best results in parallel to different food aid projects (Lambie-Mumford et al., 2014).

Hawkes and Webster (2000) compared private food redistribution programmes to the public organised Food Stamps Program in the US. A food stamps or vouchers programme allows eligible individuals or households to buy food at a cheaper price than market price or to obtain a food portion (Lambie-Mumford et al., 2014). In 2000, both models served similar numbers of people - 23 million people were supported by the public organised Food Stamps Program and about 26 million people by private programmes. Due to the fact that also in Europe the private organisations have been expanding, Hawkes and Webster (2000) claim consideration of their potential impacts to the welfare state. Lambie-Mumford et al. (2014) conclude that systematic UK **government-driven food aid** results in measurable positive impact on household food security while informal food aid does not.

**Crime**

According to the Western Australian Police Force about 25 % of break-ins occur as people being forced to steal food or money for food. Koshy and Phillimore (2007) assume that due to the additional support by the WA food bank, this also has a positive influence on the break-ins although difficult to quantify.

**Food waste prevention**

One issue is only covered briefly in most of the surveyed literature on social impact: **food waste prevention** (cf. Poppendieck, 1994; van Normann, 2003; Schnedlitz et al., 2011; Bernhofer and Pladerer, 2013; Guidi, 2012). Poppendieck (1994) lists waste prevention due to redistribution as positive impact as in the general society the aversion to wastage of food is strong and prevention therefore seen as positive issue. But there should also be mentioned that if the awareness building purpose towards food waste prevention is successful and prevention measures are implemented in companies, the surplus amounts provided by the donors will decrease, which means a dilemma for both the redistribution programmes and the companies, too. Also Hawkes and Webster (2000) highlight that waste reduction is fundamental for surplus food redistribution and that without surplus the schemes would not exist.

### 7.4.2 Results from the workshops

The first workshop held in Sardinia did not focus on redistribution activities but on food waste prevention measures in general. Thus, the results also included other issues than redistribution. In the following, only the results related to redistribution should be taken into consideration and are summarised in Table 7.5.

The measure of a Belgian food waste prevention regulation was highlighted by one group. The regulation sets the obligation that businesses (retail) are not allowed to waste food but have to donate surplus food to food banks instead. A similar measure was reported from Finland where schools offer the surplus food from children`s lunch to the public for a reduced price. The mentioned positive social impacts for both measures included less waste, saved money, healthier people, less poverty and less pressure on health services. As negative social impacts job losses and less profit/economic impact were mentioned. It is assumed that there is a positive impact on the target group of the school canteens by receiving one warm meal a day at least. A similar positive impact could be assumed for the target group of the food banks in Belgium. The health issue was discussed controversially as it depends on the type of donated/sold products but often the surplus products of businesses consist of fresh produce such as fruits and vegetables. The main target group in Finland includes people who could not afford a warm meal under normal conditions. This implies that the mentioned negative social impact on competitive restaurants due to a shift of clients can be assumed as minor as the target group does not correspond to a client group of those businesses. A similar argument could also be applied to the example from Belgium as the clients of food banks often can not afford to buy sufficient food items at all.

One idea was mentioned from Denmark where surplus food is intended to be sold at low prices to people in need (this concept is known as social supermarket in other countries). A positive impact is that companies could use their redistribution participation for CSR activities and improve their image of responsible acting stakeholders. A negative impact was the fact that affected people could wait until the products approach their expiration date to receive the products cheaper than usual. This could have a negative impact on the earnings of the companies.

Another contact also mentioned a food bank with an assumed positive impact related to improved food supply and better health.

In the plenary it was discussed which indicators could be used to assess the assumed impacts and which data sources were available. With respect to the health issues which were mentioned for different measures the suggestion included monitoring either changes in health expenses or individual mass of the target group. With the latter indicator, it was discussed whether body weight would decrease or increase if more fruit and vegetables were eaten. Those data could be obtained from official statistics, e.g.

from health and nutrition departments. But several questions arose if those indicators could really map the assumed impact on the target group and how exact the interrelation between assumed impact and corresponding indicator was.

**Table 7.5: Overview on redistribution measures and assumed social impact at Sardinia workshop**

| measure | where/who | positive social impact | negative social impact |
|---|---|---|---|
| regulation on donation of supermarket surplus to food banks | Belgium | less waste, saved money, healthier people, less poverty, less pressure on health services, target group receiving healthy food | job losses, less profit/economic impact for competitive shops |
| surplus food from schools at reduced price to public | Finland | less waste, saved money, healthier people, less poverty, less pressure on health services, target group at least receiving one warm meal a day | job losses, less profit/economic impact for competitive restaurants |
| donated surplus food sold to people in need at low prices | Denmark (not implemented yet) | positive CSR for donors | people could wait for price reduction products which has a negative impact on earnings of companies |
| food bank | retailer deliver food to NGO/social organisation | more people supplied with food, better health | not mentioned |

The second workshop conducted in the course of the FUSIONS European Platform Meeting in Amsterdam had the focus on social impacts of food redistribution. Table 7.6 lists the mentioned positive and negative social impacts for different levels of the food supply chain. Issues which were mentioned but did not fit to the aim of the workshop (e.g. were not related to redistribution for human consumption) were removed from Table 7.6. The impacts per level relate to different stakeholders, this means that e.g. impacts occurring due to redistribution in agriculture could also relate to people in need and not only to farmers. For the level of agriculture positive issues include that unemployed people could help with the gleaning activities and this could create jobs. People in need could save money which could be used for other urgent purposes together with increasing happiness of that target group. A possible negative impact was seen in a more or less “forced” donation by farmers due to social expectation. For the processing stage only negative impacts were reported including possible damage to brands due to substandard products, unexpected resale of donated products on the black market, lack of traceability of donated products followed by liability problems, decrease of economic benefit and that volunteers are necessary for the work. Except for the last issue all negative benefits are directly related to the processing companies. For the level of wholesale and retail one positive social impact was raised which was the increasing involvement of the staff members with the goals of the company. Negative impacts were seen to be similar to the processing level including less earnings due to donation, possible job reduction and bad image due to better visibility of surplus amount of products. With respect to the HORECA sector only positive impacts were mentioned which were all related to the companies itself. The impacts were better image due to donation activities which also could lead to increasing number of customers. For the recipients of the donated products, the households in need, only three negative impacts were mentioned. The list included a bad image if dependent on donations, the household could be ashamed to receive donations of surplus food and they could face a higher risk related to health issues. Related to level of transport only negative impacts were mentioned targeting the society as increasing environmental costs and ineffective logistic were expected due to intensified transport. The level of waste management bears both positive and negative social impacts. The positive assumption was that the packaging material of the surplus food could be collected by the households in need and sold with economic benefit. Less jobs in waste management due to decreased input material was highlighted as negative impact for the waste management companies. Several positive impacts on society were listed, among them increased inclusion of needy people, decreasing food poverty, improved health due to access to fruit and vegetables, creating further positive inputs related to other issues, reducing punishable offences due to cheap food offer, image building for donors, job creation, improving social networks, decreasing waste disposal costs for donors and release of additional resources in social economy to be used for other purposes than buying food for people in need. Negative impacts related to society in general covered less energy output from food waste utilisation, resale of donated products on the black market and increased demand for surplus food could initiate more food waste generation (rebound effect).

In addition to the experiences of the workshops in Amsterdam and Sardinia, further insights were collected in the course of the review process of this report. S. Juul from Stop Wasting Food, Denmark and M. Buksti from Communique, Denmark mentioned that there are some doubts if a social supermarket will be launched in Denmark, due to logistics problems and strict food safety regulations. There are also worries that due to the social supermarket: 1) food waste will be postponed to the consumer level – consumers will end up thowing food away which they bought at the social supermarket, because they will not be sure whether expired food is edible or not; 2) stigmatization/discrimination of certain parts the Danish society: people with low incomes will be exposed, because they shop at the social supermarket. Finally, there haven't been made any estimates of the impact of food waste reduction by such social supermarket. Furthermore it was stated that food banks are symptom treatment for food waste – they do not eliminate the problem at its roots. Another negative social impact may be that people will become dependent on "free food" and won't get enough incentive to lift themselves out of poverty

**Table 7.6: Results from the workshop in Amsterdam related to social impacts of redistribution activities on different levels of the food supply chain (FSC)**

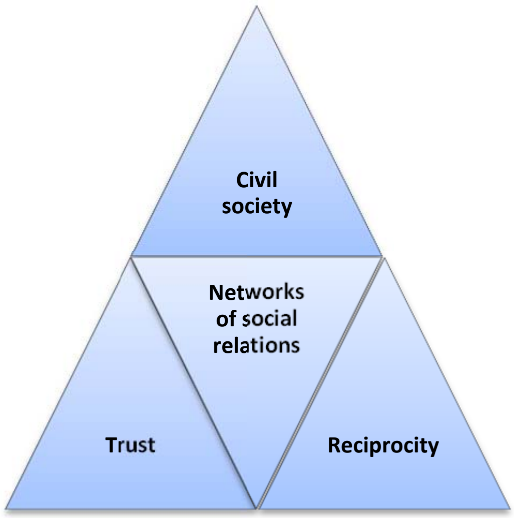
| Level in FSC | Positive social impacts of redistribution on… | Negative social impacts of redistribution on… |
|---|---|---|
| agriculture | - gleaning of fields could integrate unemployed people<br>- if farmers let people come and collect crops that retailers did not want, people would be happy and save the money they would have spent on food and may invest it for some other good purposes | "forced" to donate food products while interest is rising from market to use odd shaped products |
| processing | nothing mentioned | - forwarding substandard food to food banks can lead to brand damage to the food producer<br>- packed food could be resold (black market) outside of the producers control<br>- There is no control on integrity and traceability of donated food making it a liability issue<br>- manufacturers get less money for their donated food products compared to if they sell it like originally intended<br>- voluntary labour is necessary to collect the food, hiring staff will make it too expensive |
| wholesale/retail | - workers get more involved with the firms goals | - less food sold may cause job reduction<br>- retailers get less money for their donated food products compared to if they sell it like originally intended<br>- could get bad image of throwing a lot away<br>- more people gain access to "free food" and buy less at retail prices in the supermarket – loss of profit |
| HORECA | - increase their image by giving what was left<br>- might attract more customers if it is known that they help the needy households | nothing mentioned |
| households | nothing mentioned | - bad image, ashamed<br>- health risk might be higher |
| transport | nothing mentioned | - transportation is needed for redistribution with associated environmental costs<br>- intensification of transport e.g. if food is transported on long distances and then stored, trucks return empty |

| | | |
|---|---|---|
| waste management | - recycling of the packaging material of the donations with returns for the food insecure people | - less input for waste treatment companies = less jobs<br>- jobs will be lost in waste management if there will be less food waste |
| society | - contribution to involvement<br>- demand to be social<br>- meeting place<br>- creates opportunities to other initiatives<br>- social responsibility<br>- surplus food – less hungry people (issue shifted from HORECA to society)<br>- surplus veggies and fruits – better health and nutrition (issue shifted from HORECA to society)<br>- people will not die of hunger<br>- people will not steal in order to survive<br>- integration of target group<br>- image building = charity<br>- job creation – food bank also for disabled or people who are less employable<br>- fewer hungry<br>- more social inclusion<br>- saving lives<br>- job creation in the redistribution sector<br>- redistribution generates activity for food banks and improves social networks<br>- raising awareness might affect own behaviour with respect to wastage when giving food to food bank<br>- social economy has more resources available to invest in e.g. a training course to find a job or education of the children<br>- charities (food banks) save money - savings invested in other goods and service<br>- companies have less wastage costs<br>- society has less waste and less environment impact<br>- food banks have fresh products (high quality) | - less energy production based on food waste<br>- negative impact as the food received may be resold to other people in need by the donations facilities<br>- charities (food banks) sometimes could be too much connected with recovery/waste – they ask for more products – more waste!<br>- food supply chain: more redistribution = discouraging "waste sources" to reduce waste – less awareness about the actual causes of waste and less responsibility<br>- no/less incentives to find a job or be less dependent on the donations from food banks<br>- Imbalance of food supply and offer |

## 7.4.3 Literature review on the concept of social capital

The concept of social capital is characterized by multiple definitions, interpretations, and applications. However in the present report, social capital is intended as the networks of social relations based on social norms of trust and reciprocity. Combined together, these two elements (social norms of trust and reciprocity) represent the foundation of civil society, and drive people to act for mutual benefit (Lochner et al., 1999; Winter, 2000; Stone, 2001; Schneider, 2006; Iyengar, 2012). Stewart-Weeks and Richardson (1998 p. 2) suggest that "the quality of social relationships between individuals […] affects their capacity to address and resolve problems they face in common".
Furthermore, Putnam (2000) argues that social capital is measurable since networks and the associated norms of reciprocity have demonstrable externalities for both individuals and communities.

**Figure 7.2: Social capital**




The concept of social capital has been used also to explore the potential for individuals and communities to drive environmental sustainability (Pretty and Ward, 2001; Jones et al., 2009; Macias et. al., 2012; Rogers et al., 2013). Also, these authors focus their attention on networks, social norms of trust and reciprocity and attempt to investigate the interconnections among the different components of social capital, types of environmental policy instruments and goals of environmental groups. Therefore, a similar approach was used in the current work to investigate the social impacts of food redistribution activities (FRAs).

**Social capital: definitions and key concepts**
Bourdieu (1986), Coleman (1988) and Putnam (1993) define social capital as the result of the different dynamics characterizing social networks. According to Bourdieu (1986 p. 248), "social capital is the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition". Coleman (1988 p. 98) defines social capital by its function that "it is not a single entity, but a variety of different entities having two characteristics in common: they all consist of some aspects of social structures, and they facilitate certain actions of individuals who are within that

structure". Putnam (1993, p. 167) defines social capital as "features of social organizations, such as trust, norms, and networks that can improve the efficiency of society by facilitating coordinated actions" for mutual benefits. Thus network relationships characterized by mutual recognition, trust, and expectations are of critical importance for the creation, conservation, and growth of social capital.

According to Woolcock and Sweetser (2002 p. 26), different types of social capital can be identified depending on the types of networks involved:
- "**bonding social capital** refers to connections with family, relatives, kinship;
- **bridging social capital** refers to connections with people who are not related in some demographic sense;
- **linking social capital** pertains to connections with people in power, whether they are in politically or financially influential positions."

Bonding social capital is the relationship within a homogeneous group and "bridging social capital tends to bring together people across diverse social divisions" (Field, 2003). Bonding and bridging social capital are relevant with Granovetter's (1983) ideas of "strong ties" and "weak ties" respectively. Linking social capital also includes vertical connections to formal institutions (Mayoux, 2001).

A large part of the socio-economic literature (Schneider, 2006; Coffé and Geys, 2007; Schneider, 2009; Hawkins and Maurer, 2012) also emphasizes the potential socio-economic benefits that can derive from social interaction (social networks):

- it helps knowledge transmission, reducing information asymmetry;
- it helps specific knowledge transmission regarding technologies and markets, limiting market failures;
- it favours collective action.

Thus, in accordance with Foxton and Jones (2011), formal and informal networks are central to the concept of social capital. They are the personal relationships which are achieved when people interact with others in families, workplaces, neighbourhoods, local associations and a range of informal and formal meeting places.

The World Bank (Grootaert et al., 2004) proposes a definition of social capital, intended as the set of behavioural norms that increase cooperation and trust, which are essential elements for community welfare.
Therefore social capital is not simply the sum of the institutions and networks that underpin society, but it is also the "glue" that holds them together. It includes the shared values and rules for social conduct expressed in personal relationships, trust, and a common sense of "civic" responsibility that makes society more than a collection of individuals.

In accordance with Durlauf and Fafchamps (2004), the World Bank distinguishes three main underlying features:

1) social capital generates positive externalities for group members;
2) these externalities are achieved through shared trust, norms, and values and their consequent effects on expectations and behaviour;
3) shared trust, norms, and values arise from informal forms of organizations based on social networks and associations.

So the study of social capital is the analysis of network-based processes that generate beneficial outcomes through norms and trust. For these reasons, in this report, the definition provided by the World Bank was used as the reference.

## 7.5 Social impacts of food redistribution

### 7.5.1 Methodology

**Dimension of social capital**
Coherently with the World Bank methodology and taking into account the relevant literature (Grootaert et al., 2004, World Bank, 2004, Harper and Kelly, 2004, Schneider, 2009; Ansari, 2013), 5 key dimensions were identified to apply the concept of social capital at an operational level:

- Groups and networks;
- Trust and solidarity;
- Collective action and cooperation;
- Social Cohesion and Inclusion;
- Information and Communication.

In addition to these five dimensions, the following dimension was added in the course of the assessment:

- Food Safety/Food Security

**Groups and networks.** These are defined as groups of people (family, friends and people involved in the same organization) that share a sense of common identity and regularly interact with one another on the basis of shared expectations. They are seen as important sources of social capital, because they allow for solving problems of common interest. The number and types of interactions between people within the network, and shared identities that arise, can influence the amount of support an individual has, give access to a larger number of help sources, disseminate information, reduce opportunistic behaviour, and facilitate collective decision-making.

**Trust and solidarity.** This dimension measures the amount of trust individuals have in others as well as in formal institutions. When individuals in communities trust each other and the institutions that operate among them, they can reach agreements and conduct transactions more easily. Trust is seen as closely linked to social capital, either as a direct part of it or as an outcome. Solidarity measures people's willingness to co-operate for mutual benefit and is therefore a source of social capital.

**Collective action and cooperation.** It refers to action taken together by a group of people whose goal is to enhance their status and achieve a common objective. The purposes of collective action may differ widely across communities. In some places, collective action primarily consists of activities for the provision and management of public services. In other places, collective action is more politically oriented and used primarily to lobby politicians to provide more services to the community.

**Social Cohesion and Inclusion.** This dimension measures the capacity of a society to ensure the welfare and well-being of all its members, to minimise disparities, to create a sense of belonging and to promote trust. Social cohesion manifests in individuals who are willing and able to work together to address common needs, overcome constraints, and consider diverse interests. Inclusion is understood as a process aimed at creating conditions which enable full and active participation of every person society, by ensuring equal opportunities for all.

**Information and Communication.** Information and communication form the core of social interactions. Downward flows of information from the policy realm and upward flows from the local level are critical components of the development process. Horizontal information flows strengthen capacity by providing civil society a medium for knowledge and idea exchange. Open dialogue fosters a sense of community, while secrecy breeds suspicion and distrust. Enhancing the dissemination of information can build trust and cohesion.

Due to the specific focus of the study and in accordance with the World Bank suggestion to adapt the methodology to the research, a sixth dimension was included in this study - Food Safety / Food Security – as they are crucial issues and a goal of food redistribution initiatives.

**Food Safety/Food Security.** Food security exists when all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2008). In this case, FRAs satisfy both aspects.

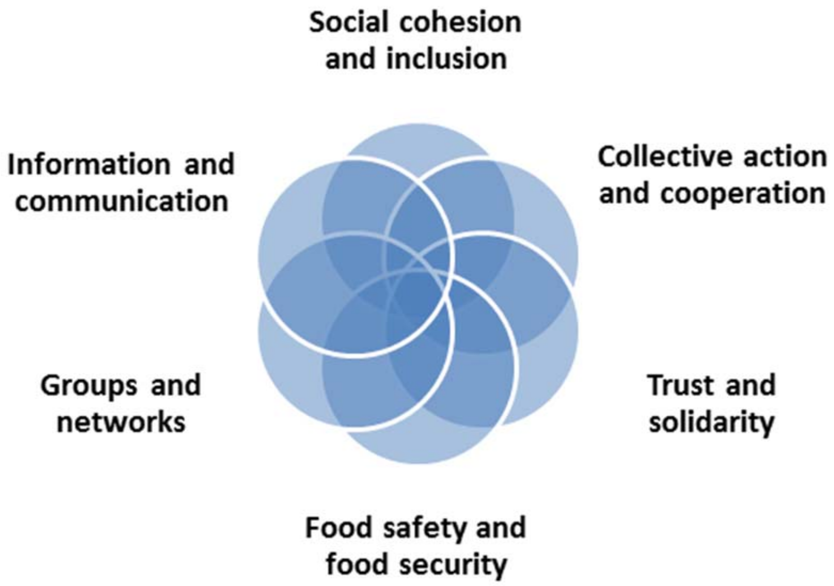
Food safety exists when the handling, preparation, and storage of food are undertaken in ways that prevent foodborne illness. This includes a number of practices that should be followed to avoid potentially severe health hazards. One of the main concerns of food distribution initiatives is precisely to ensure these aspects.

As argued by the World Bank: "The social capital of a society includes the institutions, the relationships, the attitudes, the values and the principles that govern interactions among people and contribute to economic and social development, able to create social wellbeing" (World Bank, 1998). Being fundamental human rights, food safety and food security permit to achieve the pursuit of economic and social development. Thus, it is possible to affirm that they allow to increase social capital for three main reasons:

- Food safety / Food security link the economic, social and political spheres (both macro and micro), allowing the increase of social relations;
- Food safety / Food security can enhance the effectiveness and efficiency of both collective and individual action;
- Ensuring this right can increase the trust of the individual in the community.

Therefore, it is useful to investigate this dimension so to understand its role and weight in contributing to social capital creation.

**Figure 7.3: Social capital dimensions (World Bank, 2004)**




**Testing the methodology**

A pilot study was carried out to assess the applicability of the concept of social capital with indicators developed within section 7.3.1 and 7.3.2 and aimed at evaluating the social impact of food redistribution initiatives. This pilot study is not intended to have any statistical relevance but it aims to test the methodology, to provide specific insights and recommendations for its improvement and to collect preliminary data on the social impact of the surveyed FRAs.The following steps were undertaken:

1. Previously identified positive and negative impacts (see sections 7.4.1 and 7.4.2) were gathered together in the six dimensions: Groups and networks, Trust and solidarity, Collective action and cooperation, Social cohesion and inclusion, Information and communication, Food security/food safety).

**Table 7.7: Most commonly identified impacts within the social capital dimensions**

| GROUPS AND NETWORKS | | |
|---|---|---|
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Local and community oriented aspects* | - local and community-orientation |
| | | - time and effort bind resources |
| | | - network building, advocacy and lobbying |
| | | - possibility to create synergies among non-profit organisations, companies and authorities |
| | *Politics and food poverty* | - dependency on volunteers (their skills and energy) |
| | | - provide data on social marginalisation |
| | *Economic impact* | - effort for coordination of volunteers |
| **People involved in redistribution activities** | *Employment possibility* | - possibility of volunteering for unemployed people |
| | *Psychological impacts* | - feeling of satisfaction, usefulness |
| | | - expected advantages from external effects of volunteering |
| **People in Need** | *Social impacts* | - encouraging competence via additional activities (practical training for cooking or nutritional issues, medical services, information by social workers) |
| **Donors** | *Corporate social responsibility* | - increasing identification of staff with goals of the company |
| | | |
| **TRUST** | | |
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Economic impact* | - can provide extra services if they receive free food |
| | *Local and community oriented aspects* | - dignity and social justice |
| **People involved in redistribution activities** | *Employment possibility* | - raise self-confidence of (long-term) unemployed |
| | | - higher prospects on the labour market |
| | *Psychological impacts* | - feeling of powerlessness (limited supply, quality of distributed food out of their control) |
| | | - concerns (to jeopardize relationships with donors, discomfort selecting permitted foods, fear of reducing total amount of food distributed) |
| | | - self-realisation |
| | | - comply with feeling of spiritual concerns |
| | | - compliance with social or ethical norms |
| **People in Need** | *Social impacts* | - covers existential needs |
| | | - informal access to emergency food programs |
| | *Psychological impacts* | - decrease of social position |
| | | - requires clients to give up their privacy by revealing personal social and economic |

| | | |
|---|---|---|
| | | circumstances. |
| | | - feeling of social injustice |
| | *Economic impacts* | - improved management of household budgets |
| **Donors** | *Corporate social responsibility* | - achievement of corporate social responsibility goals |
| | | - impact on staff moral |
| | | - allows company to be viewed as responsible community partners |
| | | - social expectation to donate |
| | | - corporate pride |
| | | - enhanced customer loyalty |
| | *Psychological impacts* | - positive feedback that their efforts were helpful |
| | | - sense to provide assistance to hungry people |
| | | - positive feeling associated with helping others |
| | | - liability problems |
| | | - concerns about liability |
| | | - sense of satisfaction |
| | | |
| ***COLLECTIVE ACTION AND COOPERATION*** | | |
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Politics and food poverty* | - dependency on goodwill and generosity of volunteers and donors |
| | | - cost savings (reduced disposal costs) |
| | | - permit state to neglect their obligation to protect vulnerable and powerless people |
| | | - indicates prevalence of food poverty and failure of welfare state |
| | | - contribution to solve "excess food production" topic |
| | | - supplement to public welfare |
| | | - reselling of donations on the ‘black’ market |
| | | - ineffective logistics |
| **Donors** | *Economic Impacts* | - tax benefits |
| | *Psychological impacts* | - liability problems |
| | | |

| ***INFORMATION AND COMMUNICATION*** | | |
|---|---|---|
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Local and community oriented aspects* | - Positive public education impact |
| | | - raising community awareness towards food insecurity |
| **People involved in redistribution activities** | *Employment possibility* | - education and training |
| **People in Need** | *Social impacts* | - exchange of information via direct contact |
| **Donors** | *Economic Impacts* | - donation increases awareness about generated food waste, which may lead to a decrease of food waste generation |

| ***SOCIAL COHESION AND INCLUSION*** | | |
|---|---|---|
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Local and community oriented aspects* | - provide food insecure households with a voice |
| | *Politics and food poverty* | - reduce need for income support |
| | *Reduction of crime rate* | - reduction of crime rate |
| **People involved in redistribution activities** | *Employment possibility* | - employment possibility for people with disabilities |
| | | - re-integration of unemployed |
| | | - positive impact of skills |
| | *Psychological impacts* | - social integration |
| | | - self-realisation |
| **People in Need** | *Social impacts* | - number of people reached by charitable food aid |
| | | - overcome individual isolation |
| | | - support integration of socially excluded people |
| | | - feeling part of a community |
| | *Psychological impacts* | - charge of symbolic price supports feeling of self-determination and dignity |
| | | - feeling of degradation (shame, social acceptability, personal values) |
| | | - barriers (access and information) have to be overcome, confusion |
| | | - increase stigmatization |
| | | - "undignified" way to receive food |
| | | - shame |
| | | - lack of independence |
| | | - experience of powerlessness (inability to make choices) |
| | | - expectation of gratitude by volunteers |
| | | - cement the low social status of poor elderly |

| | | |
|---|---|---|
| | | - sense of social alienation |
| | | - self-determination |
| **Donors** | *Corporate social responsibility* | - bad image due to visibility of surplus |
| | *Economic impacts* | - profit from higher purchasing power of food bank clients |
| | | |
| ***FOOD SECURITY / FOOD SAFETY*** | | |
| **Subject** | **Category of impact** | **Impact** |
| **Community and society in general** | *Politics and food poverty* | - dependency on surplus food and donations |
| | | - local short-term non-governmental food aid, emergency response |
| | | - could increase social problems as a separate supply system with missing legal and market basis is established |
| **People involved in redistribution activities** | *Psychological impacts* | - concern about nutritional adequacy |
| | | - difficulties with high demands of clients |
| | | - concerns about food safety |
| | | - Pressure to acquire donations |
| **People in Need** | *Nutrition and health* | - health benefits |
| | | - improve nutritional situation |
| | | - unsuitable food (type, quality) |
| | | - reduce the likelihood of repeated severe food insecurity |
| | | - risk of receiving food which is unsafe to eat |
| | | - have to conform to available - donated products |
| | | - lower food quality |
| | | - ensures some variety to the menu |
| | | - limited choice/ range of products |
| | | - more food available |
| | *Economic Impacts* | - increase purchasing power |
| | | - helps to bridge the gap between - benefit payment and food needs |
| | | - allows some planning, save money for harder times |
| | *Psychological impacts* | - limits clients autonomy |
| | | - conflicts due to limited available products |
| | | - purchasing limits |
| **Donors** | *Psychological impacts* | - concerns about food safety |

2. A multiple choice questionnaire was created to assess identified impacts. For each dimension a certain set of questions (see the questionnaire in the annex 10.3) was prepared to investigate the perceptions of respondents (food redistribution initiatives). Answers were rated from 1 to 6, with 1 representing the lowest score (total disagreement, lower extent, etc.) and 6 the highest (total agreement, maximum extent, etc.).

3. After data collection answers were converted into indexes: for each question related a partial index (PI) was calculated as the weighted average of responses, and then converted into a scale from 0 to 1 (see Table 7.8).

**Table 7.8: Index calculation method (example)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1.1 Please evaluate the following statements with regard to your organization and its food charity activities | | | | | | | |
| a. Companies which donate food to your initiative are responsible community partners | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | TOT |
| Answers | 7 | 20 | 23 | 27 | 25 | 98 | 200 |
| Weighted answers | 7 | 40 | 69 | 108 | 125 | 588 | 937 |
| Weighted average | | | | | | | 4,685 |
| PARTIAL INDEX PI[1] | | | | | | | 0,78 |
| b. Companies which donate food to your initiative improve their reputation among their employees | | | | | | | |
| | 1 | 2 | 3 | 4 | 5 | 6 | TOT |
| Answers | 50 | 41 | 40 | 25 | 23 | 21 | 200 |
| Weighted answers | 50 | 82 | 120 | 100 | 115 | 126 | 593 |
| Weighted average | | | | | | | 2,965 |
| PARTIAL INDEX PI[2] | | | | | | | 0,49 |

4. After processing partial indexes from all questions, for each indicator a synthetic index was calculated as the average of partial indexes (PI): $PI_1 + PI_2 + Pi_n / n$.

**Table 7.9: Synthetic index calculation method (example)**

| | | |
|---|---|---|
| Synthetic personal trust and solidarity index | (PI[1]+PI[2]) / n | (0,78+0,49) / 2 = 0,64 |

As for the interpretation of value of the indexes, it is assumed that the value of 1 corresponds to the maximum positive impact, while 0 corresponds to the maximum negative impact.

5. Synthetic indexes were then plotted on a prism chart.

**Table 7.10: Synthetic indexes (example)**

| **Social capital dimension** | **Synthetic indices** |
|---|---|
| Groups and networks | 0,5 |
| Trust and solidarity | 0,6 |
| Collective action and cooperation | 0,2 |
| Social cohesion and inclusion | 0,1 |
| Information and communication | 1 |
| Food security/ Safety | 0,7 |

## 7.5.2 Results

### 7.5.2.1 Characteristics of the respondents

During the pilot study, a questionnaire was sent to 211 food redistribution initiatives operating in EU, such as food banks, food pantries, soup kitchens, social supermarkets, shelters etc. Food redistribution initiatives were identified among those included in the FUSIONS database, which was created, between June and August 2013. The aim of the database was to create an inventory of European food redistribution initiatives and to collect data about their activities (for more details see section 6.2).

The response rate was about 15% (32 questionnaires out of 211). Completed questionnaires covered 14 countries: 10 from United Kingdom, 5 from Italy, 3 from Ireland, 2 each from Switzerland, Austria, and Finland, 1 each from Belgium, Portugal, Denmark, Estonia, Lithuania, Latvia, Hungary, and Slovenia.

As showed in Figure 7.4, most of the respondents deliver food and grocery products to people in need. Only in a few cases did respondents collect money from donations to buy food and complete food packages, or provide cash / voucher assistance for food purchasing. Moreover 5 respondents provide food to charity organizations which then distribute it to people in need.

**Figure 7.4: Characteristics of the service provided**

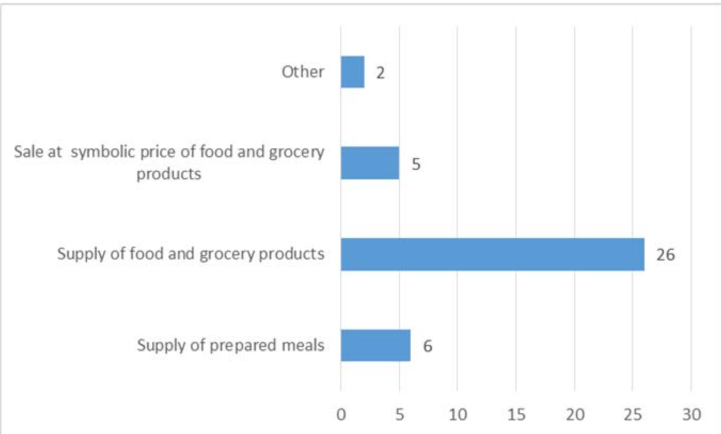
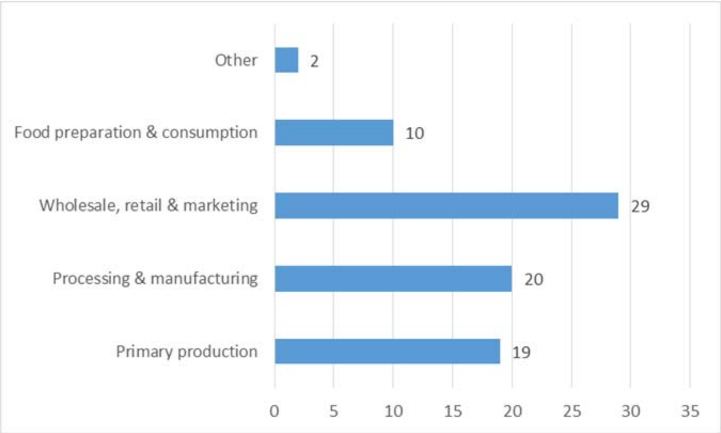



Figure 7.5 shows the breakdown of the 32 initiatives according to the food supply chain segment from where the donated food originated. Most of the initiatives receive food products from upward supply chain segments, as the recovery of prepared food and meals after cooking and serving is usually more difficult to be performed. In 2 cases, respondents declared to receive food only from donations coming from schools, churches and private citizens.

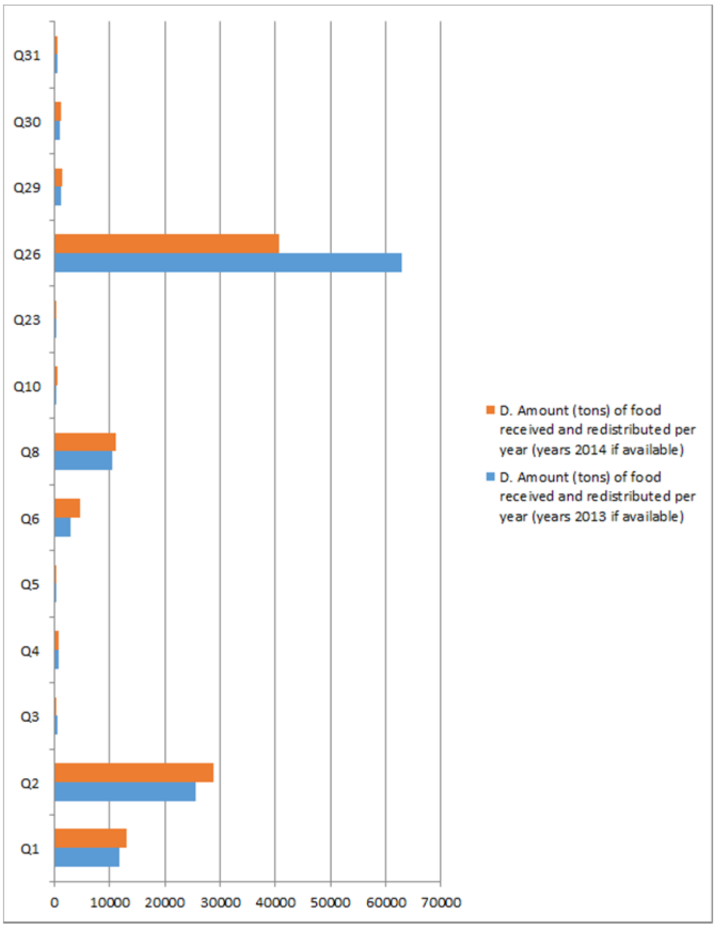
Redistributed food shows significant commonalities. 29 initiatives receive fruit and vegetables, bakery, meat (fresh, dried, tinned), dairy, and grocery products, and 9 FRAs collect prepared meals from canteens. Among the others 2 organizations receive only grocery products and fruit and vegetable and one initiative declared to accept ambient food products.

**Figure 7.5: Origin of the donated food (by sector of the food supply chain)**




Regarding the quantity of food received and redistributed, there is a high variability between organizations that manage small quantities (2 tons of food per year) and those who deal with large amounts (more than 60.000 tons per year). In those cases where data were provided for both the years 2013 and 2014, an increase in the received and redistributed quantity of food was registered on a yearly basis.

**Figure 7.6: Quantity of food received and redistributed in 2013 and 2014**



There is a consistent difference in the number of staff employed in the surveyed organizations: the number of volunteers is usually much higher than employed workers. During 2013 and 2014 surveyed FRAs engaged respectively a total of 2.500 volunteers and 166 employees per year.

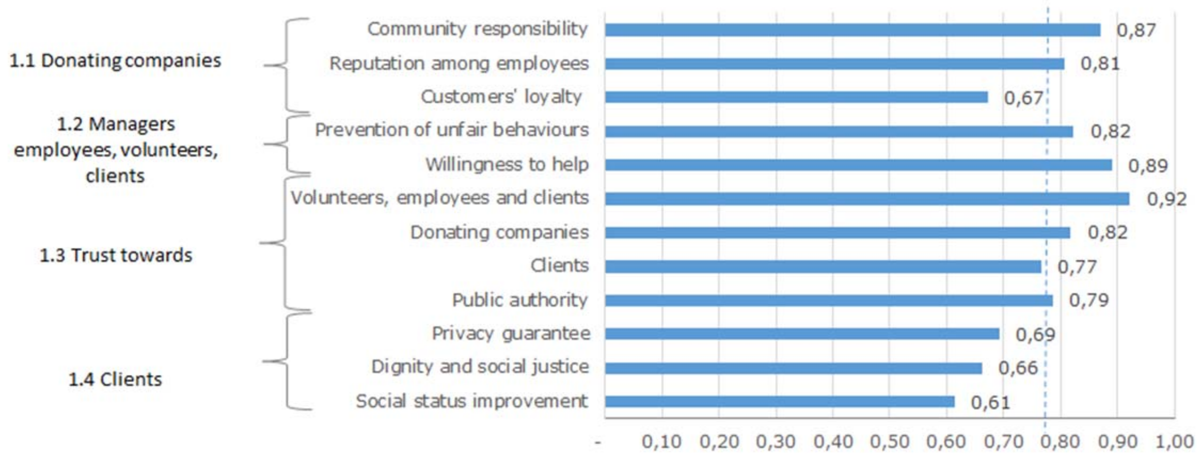
Finally, there is a large variability amongst the sample with regard to the number of assisted people per year. There are small organizations assisting 350 people per year as well as large initiatives assisting up to 2 million people. Overall collected data suggests a slight growth in the numbers of beneficiaries per year between 2013 and 2014.

### 7.5.2.2 Data analysis

**Trust Index**

The trust index shows the degree of trust that respondents have in the relationships in the social networks generated by the FRAs. Furthermore, it also provides an indirect measure of solidarity.

**Figure 7.7: Trust Index**




The average trust index is **0,78**, suggesting that FRAs can have a positive influence in terms of social capital as they tend to forge and reinforce trustful relationships and solidarity mechanisms in the networks covered by their operations.

As mentioned in the previous section, trust is one of the fundamental components of social capital whose consequences are appreciated not only inside the group of close-knit people (family, friends, etc.), but also inside the local community as well as in broader communities (regions, countries or institutions).

Responses suggest a strong deep-rooted trust: question 1.3 emphasizes how respondents manifested a generally high level of trust towards all the subjects involved in FRAs.

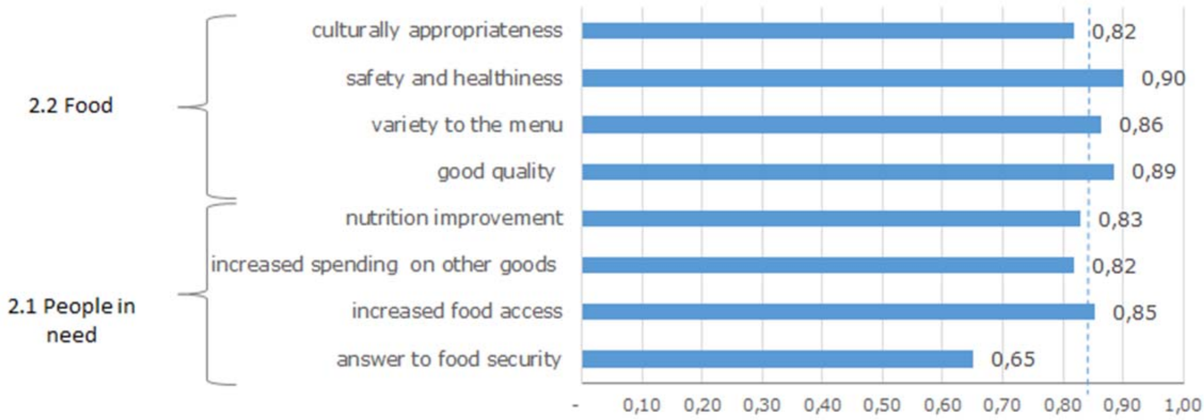
Trust seems higher (PI=0,92) when there is a direct working relationship with workers and volunteers that provide service in food redistribution. Trust tends to decrease when the relationship is with actors external to FRAS it ranges from 0,82 towards donating companies, to 0,79 towards public authorities and 0,77 towards clients of FRAs. It has to be noted how respondents declared that there is a high level of trust among clients, employees, volunteers, which tend to cooperate together when help is needed

However, the involvement of companies in food donations doesn't seem to generate significant benefits in terms of customer loyalty, despite a general improvement of their reputation.

**Food security/food safety Index**

The index of Food security/food safety should synthetically describe to what extent respondents perceive a change in the availability of food (both quantitatively and qualitatively) for people in need, as an effect of their FRAs. In the present study, social capital is linked in a coherent manner to the key topics of trust and reciprocity and with food security and food safety. Thus, the enhancement of this component can contribute to the improvement of physical wellbeing of people in need while at the same time respecting their eating habits.

**Figure 7.8: Food security/food safety Index**




The relatively high score (**0,83**) suggests that FRAs are perceived as having a rather positive influence on the food security/safety of people in need.

Responses highlight how the activity of food redistribution alone does not represent a comprehensive solution to address the food insecurity of people in need (question 2.1a). Respondents almost unanimously credit FRAs with the capacity of distributing good quality food (PI=0,89), improving the accessibility to food for people in need (PI=0,85), allowing them the possibility to prepare varied menus (PI=0,86) and guaranteeing food with high levels of safety and healthiness (PI=0,90) and respecting cultural and religious differences (PI: 0,82). Responses indicate how FRAs might be quite effective in improving the nutritional quality of food (PI: 0,83).

Results suggest that the introduction of the food security and food safety dimension can provide a wide range of potentially interesting insights. For instance the increase of well-being, resulting from the pursuit of food security/food safety, although it is more related to qualitative than quantitative aspects, is remarkable (general index 0,83).

This dimension integrates the findings from the survey conducted on the positive and negative impacts of FRAs (see section 7.4.1) and shows that FRAs can provide a short term answer to the problem of food security although do not represent a comprehensive solution. The survey also provides additional evidence about the role of redistributed food in increasing social welfare and contributing to the enhancement of social capital.

**Groups and networks Index**

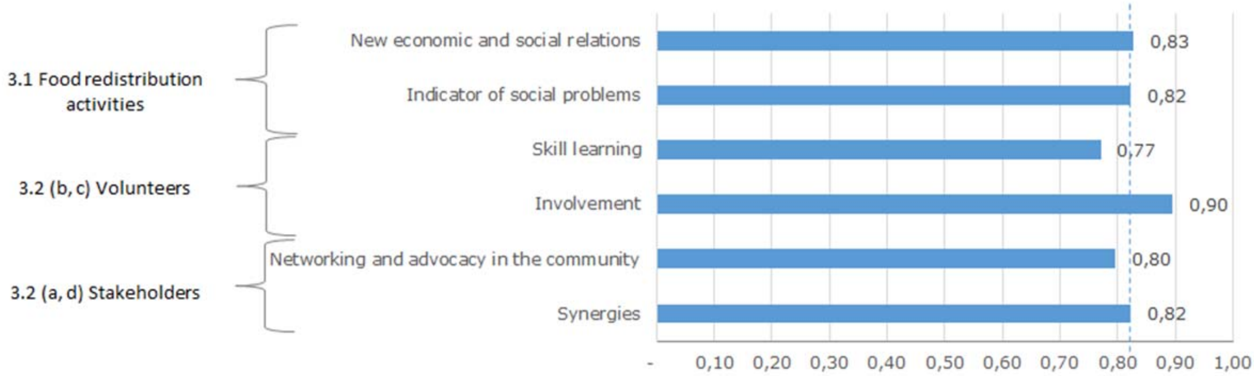
The Groups and networks index shows how and to what degree FRAs allow for forging relationships among all the stakeholders directly or indirectly involved.

The average Groups and networks index is **0,83** suggesting that FRAs generate positive outcomes in terms of social interactions and, consequently also of social capital.

The effectiveness with which the Groups and networks dimension contributes to the formation of social capital depends upon different aspects as:

- the capability to connect different stakeholders;
- the number of relations established;
- the way they function.

**Figure 7.9: Groups and networks Index**




The high value of the index emphasize the success of FRAs, which beside representing an answer to food security, allow an increase in knowledge and information, as well as the creation of strong and collaborative ties among stakeholders that participate in FRAs.

Two results of particular relevance in terms of "capability to connect different stakeholders" and of "number of relations", are those connected to answers 3.1a and 3.2d, where partial indexes register values of 0,83 and 0,82 respectively. This highlights how FRAs bring together different stakeholders (non-profit organizations, companies, public authorities, etc.) and contribute not only to the establishment of economic synergies and relationships among them, but also to a number of other activities beyond the "simple" redistribution of food.

These activities lead to the consolidation of existing networks, the consolidation of new relationship and the strengthening of cooperation. As suggested by the World Bank (2004) the "density of membership" value is high: the higher the number of relationships established among stakeholders by a specific initiative, the higher the value of density membership.

Another interesting aspect is connected to the role of volunteers. The participation of volunteers registers a partial index of 0,9 (question 3.2b) therefore it can be argued that FRAs on one hand attract volunteers but on the other hand depends on them (this emerges also from the descriptive analysis of the sample). However, the strong capacity of involving volunteers does not translate into an equally strong capacity of increasing volunteers' competence. The partial index of question 3.2c (PI=0,77) in fact, is even lower than the previous question. Therefore, the introduction of education programs for volunteers in the FRAs should be considered as a valuable option.

Finally, the high score of the Group and network index suggests that vertical relations (those that arise among different stakeholders: non-profit organizations, companies and public authorities) generated by FRAs are relevant for the enhancement of trust within the community, and for the enhancement of society's ability to respond to its various needs.

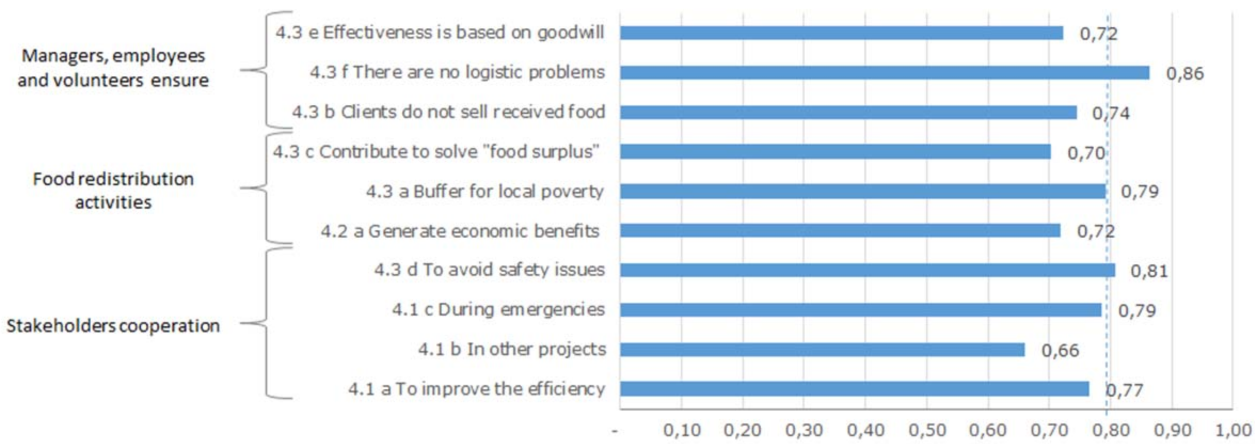
## Collective action and cooperation Index

The Collective action and cooperation index measures respondents' perception of the degree of collaboration inside the network in which they operate their food redistribution activity.

Collective actions, participation and mobility are key elements to enhance social capital. The interaction among various stakeholders engaged in FRAs needs to be reinforced to ensure its benefits in their geographic area. For this reason, the collective action and cooperation dimension aims at collecting three types of information:

- the extent of collective actions;
- the characteristics of the activities undertaken collectively;
- the willingness to cooperate and participate in collective actions.

**Figure 7.10: Collective action and cooperation Index**




The average score is **0,76** showing an overall positive degree of cooperation and collaboration within FRAs therefore with potential positive effects in terms of social capital.

Question 4.1 highlights the goodwill of stakeholders to cooperate in the FRAs to improve the service (question 4.10, PI=0,77) and solve emergencies (question 4.8, PI=0,79), but such values decrease when respondents are asked to cooperate to other initiatives (question 4.9, PI=0,66).

The absence of significant logistical problems (partial index 0,86) suggests a good level of cooperation between managers, employees and volunteers for the coordination of these activities.

The smooth interaction among all these stakeholders leads also to positive results in terms of avoiding food safety liability problems (PI=0,81) and in ensuring that beneficiaries do not sell received food on the 'black' market (PI=0,75).

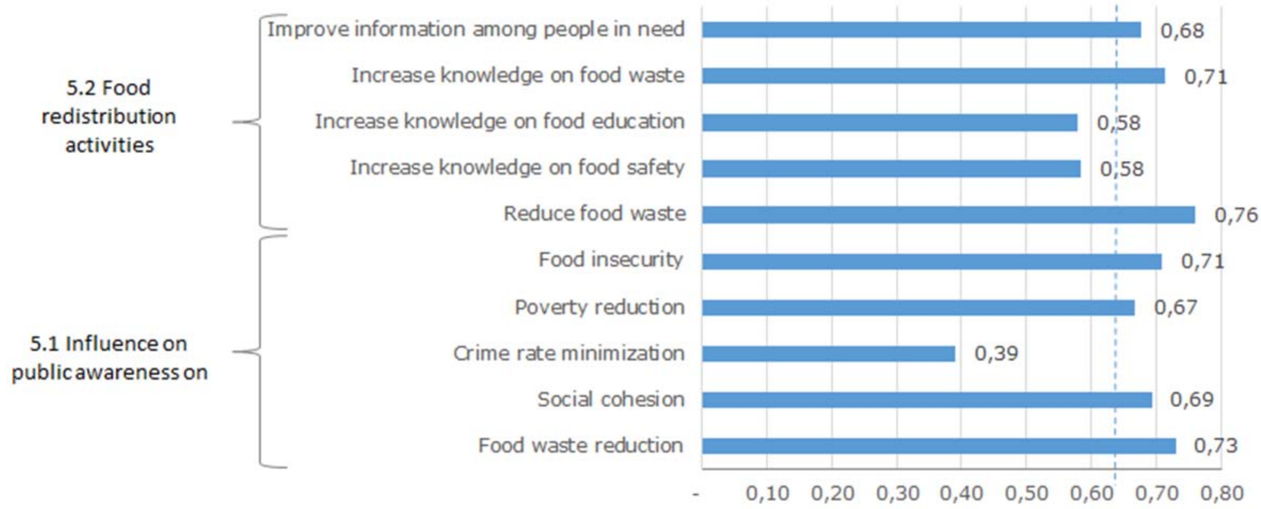
The respondents also emphasized how FRAs do not represent a comprehensive solution to the food surplus challenge (PI=0.70).

Overall it should be noted that the willingness to cooperate is relatively high within FRAs although this appears to be more limited in practice. This evidence is suggesting that there is a significant room for the improvement of the level of cooperation among the various stakeholders suggesting also that in several cases trust is rather limited.

**Information and communication Index**
The Information and communication index highlight the degree of improvement respondents perceive about their knowledge on food waste and food education thanks to the implementation of FRAs and also how the circulation of information influences the improvement of social well-being and the empowerment of local communities.
The average index is **0,65** suggesting a positive but limited influence deriving from FRAs.

The respondents did not recognize that FRAs may be capable of substantially improving the flow of information toward people in need (PI=0,68), nor the community knowledge on food safety education (PI=0,58). Better results were found with regard to the capacity of FRAs to enhance community knowledge on food waste and, consequently, reduce food waste (PI=0,76).

**Figure 7.11: Information and communication Index**



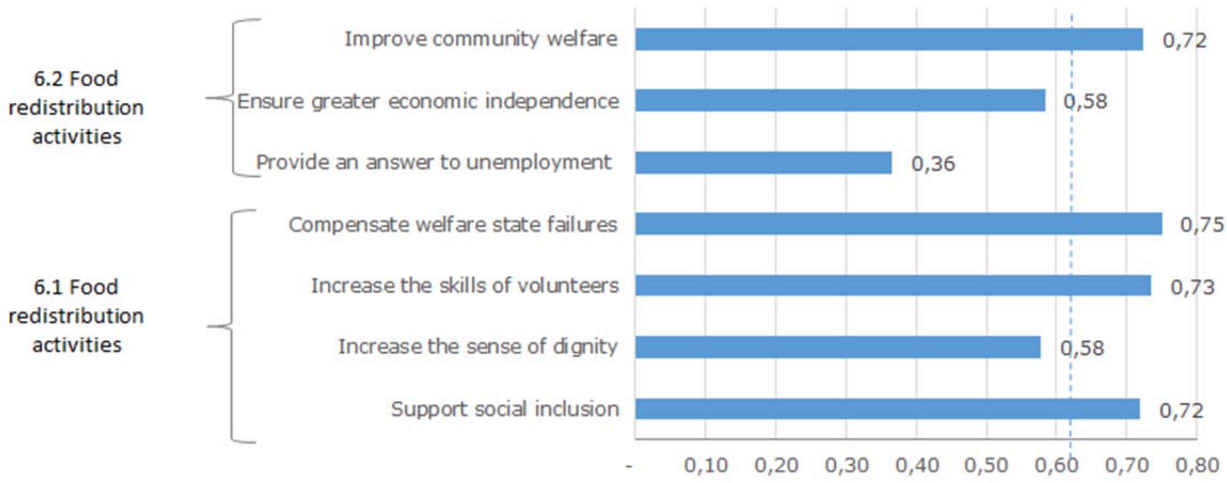

The capacity of FRAs to increase public awareness is considered relatively low with reference to social cohesion (PI=0,69), poverty reduction (PI=0,67) and crime prevention (PI=0,39). Responses suggest also that communication is not considered as a core activity (PI=0,68).

The Information and communication index emphasize a limited capacity of food redistribution initiatives to gather and disseminate information. A more efficient and widespread flow of information could lead not only to enhance social capital but indirectly also to a better access to a greater number of services for the people in need.

**Social cohesion and inclusion Index**
The Social cohesion and inclusion Index summarizes respondents' perception about the degree of improvement of the conditions of people in need, intended as involvement in the local community, thanks to the implementation of FRAs.

The average index is **0,64** representing the lowest rate of all the dimensions. The respondents did not recognize the FRAs as having the capacity to provide an answer to unemployment (PI=0,37, the lowest of the whole questionnaire), nor to improve the life of people in need (PI=0,52). Such activities don't seem to decisively support self-determination, increase the sense of dignity of people in need (PI=0,57) and ensure greater economic independence (PI=0,58). The respondents recognized FRAs as having the capacity to contribute to compensate to welfare state failures (PI=0,75), thus contributing to community welfare (PI=0,72).

**Figure 7.12: Social cohesion and inclusion Index**




The rating of the Social cohesion and inclusion Index suggests that FRAs are recognized almost exclusively for aspects related to their capacity to distribute food and not for other ancillary activities as increasing the skills of volunteers or providing better access to services as employment opportunities.

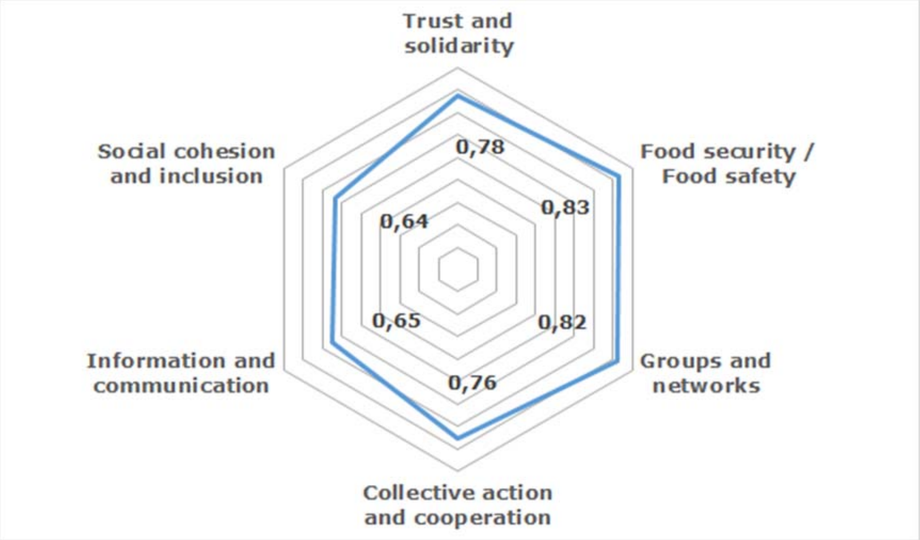
# 7.6 Conclusions and recommendations

The impact of food banks and other initiatives aimed at the food supply of marginalized social groups was quantified using the social capital assessment approach. Social capital is a relatively recent topic in the field of social sciences. Its basic concepts and theoretical understanding are under continued evolution. At the same time, with the application of new methodologies, the ability to measure social capital is increasing. This pilot study represents an attempt to apply an adaptation of the quantitative methodology proposed by the World Bank (2004).

To this end, positive and negative impacts of food redistribution were classified in 6 dimensions (the basic components of social capital): trust, groups and networks, collective action and cooperation, information and communication, social cohesion and inclusion, food security/food safety. Basing on these dimensions, a questionnaire was prepared and sent to food redistribution initiatives operating within the EU, asking for an assessment of the various impacts. Responses were then collected and analyzed to calculate 6 synthetic indicators (Figure 7.13). Results showed that food redistribution can have a rather positive effect on the basic components of social capital, in particular when trust, networks, and cooperation are regarded. Less influence was perceived in terms of information and social inclusion. Obviously, given the specific focus of the initiatives, the largest effect was registered on the food security and safety aspects.

Results suggest that food redistribution activities play a key role not only in improving the food security of marginalized social groups, but also in their integration within the society, increasing their trust towards the third sector, and the social context they live in. A positive effect of food redistribution activities can also be identified in the degree of collaboration between the third sector and other local actors (companies, public administrations, etc.) able to improve the network of local relationships.

**Figure 7.13: Synthetic indexes prism chart**




Moreover a key recommendation arising from the analysis is to strengthen the competencies of volunteers through the introduction of targeted training programs in the food redistribution activities Besides the specific results, the main message emerging from the pilot study is that social impacts of food redistribution can be indirectly measured through an analysis of its effect on social capital. The adaptation of the World Bank methodology and the use of the six dimensions have provided stimulating insights and a reference for this assessment.

At the same time some limitations and opportunities for further improvements can be identified:

- the survey was not integrated with personal interviews to food redistribution initiatives operators. These interviews would allow a deeper investigation of the crucial elements highlighted by the survey, providing additional knowledge of "grey areas";
- the pilot study only provided a snapshot of the situation at a specific time. The periodic repetition of the survey (every 3-4 years) would increase the consistency of the methodology providing the opportunity to derive a dynamic picture of the performances of the social capital six dimensions. Furthermore, the diachronic comparison of data would allow an assessment of the effectiveness of the actions or projects undertaken during the years.
- the size and composition of the sample should be improved by ensuring a more consistent geographical coverage. The current survey covered 14 EU countries but in some cases the number of responses was particularly low preventing a clear understanding of the local specificities. The inclusion of a higher number of food redistribution initiatives would allow to compare results both in homogeneous (e.g. national, regional, local level) and heterogeneous (e.g. comparing different Countries) contexts.

# 8 Assessment of environmental impacts of food waste

## 8.1 Introduction

The work in the FUSIONS project aims to quantify food waste amounts and to identify food waste prevention options along the entire value supply chain of food. The purpose of food is to be eaten by humans or to be part of the value chain for other food products e.g. animal feed. Therefore food waste prevention should improve the efficiency of food production and reduce the associated environmental impact. This chapter covers the assessment of environmental impacts of food waste. The most appropriate way of estimating the environmental benefit of food waste prevention is the application of a methodological approach taking into account all life cycle stages of a product from cradle to grave as given by Life Cycle Assessment (LCA).
In the first phase, goal and scope definition, the most important choices of the study are described i.e. methodological choices, assumptions and limitations, particularly with regards to the system boundaries and allocations. In the second phase, the inventory for FUSIONS LCA is given and in the third phase the results and its interpretation.

## 8.2 Scope and definitions

### 8.2.1 Aim of the environmental assessment within FUSIONS

In 2006, Tukker et al identified that food and drink was responsible for 20-50% of various environmental impacts of private consumption in the EU. Although the methodology allowed double counting of impacts (e.g. impact of cooking was attributed to both homes and food), it nonetheless attributed 31% of EU consumption based greenhouse gas emissions to food and drink, and of these over 80% are attributed to meat and dairy produce (Weidema et al 2008).

Following up this work, Monier et al (2010) suggested average greenhouse gas emissions per life cycle stage for food products. A similar approach has also been undertaken by WRAP (WRAP, 2013a) and others (Defra, 2009). FAO's Food Wastage Footprint Model also gives input to greenhouse gas emissions on global level (FAO, 2013).

The present work for FUSIONS is to provide a common methodology for the environmental assessment of food waste along the value chain in Europe.

The work on the methodology considers the following framework conditions:

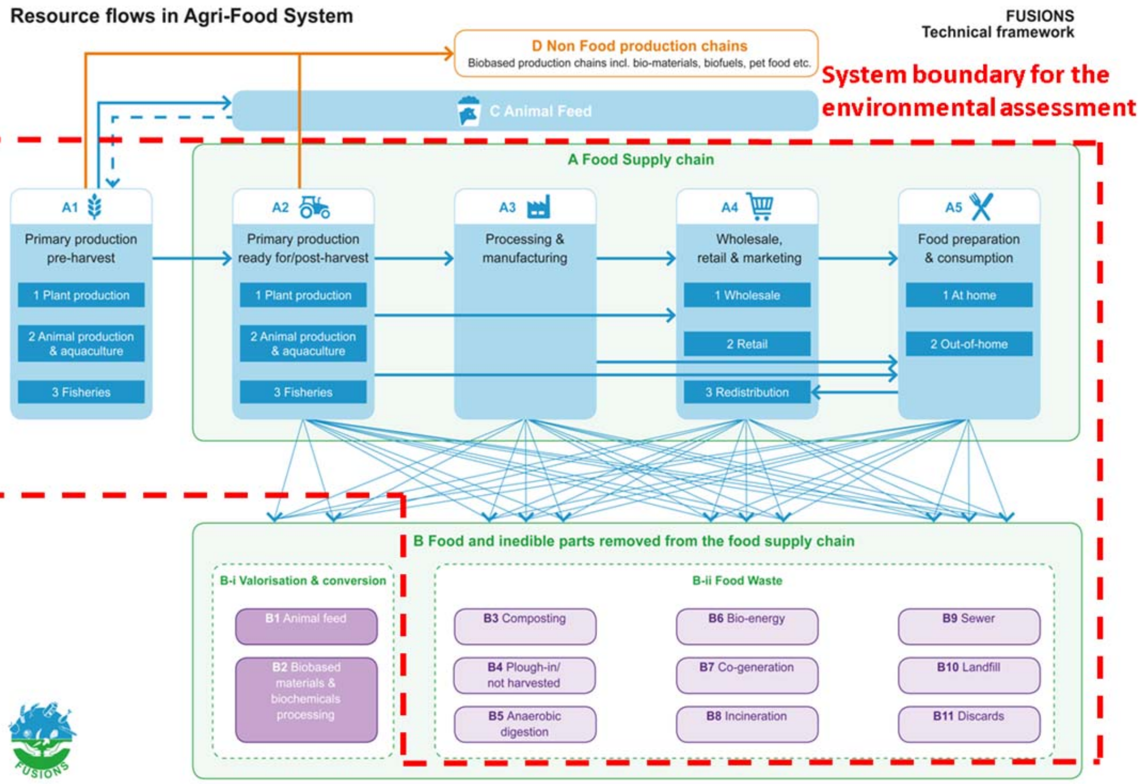
- to go beyond existing studies (e.g. Monier et al., 2010)
- to enable testing and comparison of different approaches (e.g. bottom up and top down)
- to consider information gathered in other tasks of this WP regarding the availability of additional existing data sources of food waste amounts, composition and treatment options in Europe
- to be reproducible, expandable and adaptable
- to be as simple as possible and detailed as necessary
- to enable the work with existing data from literature whenever possible
- to identify data gaps and data uncertainty which have to be improved in the future for more precise results

Thus, there is not the requirement to undertake an entire food waste life cycle assessment in this task which could be interpreted reading the title. The focus lies on the common methodology for a Euopean environmental assessment of food waste and the identification and publication of existing data gaps. The results shall also serve as a shortlist of measures for decision makers to improve the validity of environmental impact estimations of food waste in the future.

### 8.2.2 System boundaries and functional unit

The calculation of the environmental impact of food waste can be seen differently. On the one hand there could be the idea of getting an impression of the End of Life (EoL) effects of food waste. Therefore solely waste management processes would be taken into account showing the relative importance of the environmental impact of treating food waste. On the other hand there is the way of showing the environmental effects of food waste from cradle, from production of the food, to grave, the EoL stage.

**Figure 8.1: System boundaries**




The current study is focusing on food waste prevention meaning that each ton of prevented food waste does not only reduce the environmental impact from waste management efforts. It includes also the prevention of all other life cycle stages from cradle to grave. It can be concluded that a full life cycle has to be considered to calculate the environmental benefits of food waste prevention. The system boundaries for both approaches are given in Figure 8.1 on the example of the FUSIONS definitional framework. Therefore all emissions starting from primary production and ending with the recovery and disposal of food waste are covered, excluding the animal feed production and the valorization and conversion of food and inedible parts removed from the food supply chain.

The system boundaries are set in relation to the current available studies on environmental emissions and to the availability of quantitative data on food and inedible parts leaving the food supply chain. Quantitative inventory data for this study derives from the FAO study (Gustavsson et al., 2011 and 2013) and food waste data elaborated within FUSIONS. The first is taken as data basis for the food waste shares to produce data on product level, the latter is considered to link the results to the findings within FUSIONS (see annex 10.1). Data on food and inedible parts removed from the food supply chain to valorisation and conversion (incl. animal feed) is lacking and is therefore beyond the system boundaries of this assessment. Additionally the high complexity of all waste flows cannot be covered during the FUSIONS project and simplifications have to be applied. Nevertheless for future studies on e.g. the valorisation of food waste these flows have to be covered in more detail.

The allocation methodology (e.g. market value in the case of economic allocation) is dependent on the literature sources used. If in the literature emissions are given for 1 kg food, it was assumed that emissions are related to this 1 kg. Emissions allocated to by-products coming from food production (e.g. leather, bonemeal, starch, fisheries by-catch) and to food residues which are fed to animals or are going another valorization step are therefore not included. This means that also credits which may be related to these products due to system expansion are also not covered in this assessment.

Another important basic setting for LCA studies is the functional unit. This indicator unit expresses the purpose of the considered product. Food waste prevention means that food is eaten instead of being wasted. Thus, it was agreed by the project partners to apply following functional unit for FUSIONS:

**1 kg food product utilized by the consumer**

### 8.2.3 FUSIONS impact categories

The LCA literature found for the selected indicator products was assessed for reported information on thirteen environmental impact categories as follows: global warming potential (GWP); eutrophication potential (EP); acidification potential (AP); photochemical ozone creation potential (POCP); ozone depletion potential (ODP); human toxicity potential (HTP); ecotoxicity potential (ETP); abiotic resource depletion (ARD); biotic resource depletion (BRD); reported energy (RE); land use (LU); biodiversity (BD); water use (WU).

The data was collated and scored according to the following key to indicate its apparent quality and robustness.

**Table 8.1: Assessment criteria for evaluating quality and robustness of environmental attribute data (mostly from LCA) for selected food products**

| | | |
|---|---|---|
| GREEN | | Good evidence, (>3) "robust" papers / reports with good agreement / consensus in reported values |
| ORANGE | <br>*or*<br>*or* | Some evidence / limited evidence (2-3) papers.<br>Different approaches / methodology may exist.<br>Disagreement in reported values. |
| RED | <br>*or* | Single study or attribute not covered.<br>Different approaches / methodology may exist. |

The summary of the collated evidence can be seen in the following diagram:

**Table 8.2: Assessment of quality and robustness of environmental attribute data (mostly from LCA) for the proposed food products (Source: Defra 2011 plus updated references as at 30 September 2015)**

| Attribute | Food product | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Apples (non-organic) | Tomatoes, loose (non-organic) | Potatoes (non-organic) | Bread (non-organic) | Milk (conventional / non-organic) | Pork (conventional / non-organic) | Beef (conventional / non-organic) | Chicken (conventional / non-organic) | White fish (wild caught) |
| GWP | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| EP | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| AP | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| POCP | Green | Green | Green | Amber | Green | Green | Amber | Green | Amber |
| ODP | Amber | Green | Green | Red | Green | Amber | Amber | Amber | Amber |
| HTP | Amber | Amber | Amber | Red | Green | Amber | Amber | Red | Amber |
| ETP | Amber | Amber | Amber | Red | Green | Amber | Amber | Amber | Amber |
| ARD | Amber | Green | Green | Red | Green | Amber | Amber | Green | Amber |
| BRD | Red | Red | Red | Red | Red | Red | Red | Red | Red |
| RE | Green | Green | Green | Green | Green | Green | Green | Green | Green |
| LU | Green | Green | Green | Green | Green | Green | Green | Green | Amber |
| BD | Red | Red | Amber | Red | Green | Red | Amber | Red | Amber |
| WU | Amber | Green | Green | Amber | Amber | Red | Amber | Red | Red |

Abbreviations: GWP, global warming potential; EP, eutrophication potential; AP, acidification potential; POCP, photochemical ozone creation potential; ODP, ozone depletion potential; HTP, human toxicity potential; ETP, ecotoxicity potential; ARD, abiotic resource depletion; BRD, biotic resource depletion; RE, reported energy; LU, land use; BD, biodiversity; WU, water use.

It can be seen that there is sufficient reported information covering at least part of the food supply chain for four of the environmental impact categories (GWP, EP, AP & RE) for all nine of the selected indicator products. Global warming potential is undoubtedly the most widely reported impact category probably reflecting the huge public and media interest in climate change. The initial calculations of the environmental impact of food waste in the EU will focus mainly on GWP with some attention to EP % AP.

There is also reasonable information on the following two attributes: POCP & LU for all nine indicator products.

Biotic resource depletion (BRD) and biodiversity (BD) were found to receive little or no attention in the LCA literature of the selected indicator products.

It should also be noted that most LCA studies use the farm gate as the system boundary with increasingly less information reported as the product moves along the food supply chain chain.

## 8.3 Methodological approach

The methodological approach is the core output of this task. As allowed by the framework conditions to reach this goal a bidirectional approach is applied which combines top-down and bottom up methods. The methodology used for both approaches is Life Cycle Assessment (LCA). It is a technique for assessing the potential environmental impacts associated with a product (or service), by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with those inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the objectives of the study. The actual LCA process is iterative by its nature.

The results of both approaches, top-down and bottom-up, are extrapolated to show the contribution of environmental impacts of food waste to the entire food supply chain and then compared. Differences are shown and recommendations are finally drawn.

### 8.3.1 Bottom up approach

The bottom-up approach is starting on a product level calculating the environmental impact of each selected indicator product. The approach is literature based which makes a comprehensive literature research necessary to cover different production schemes or waste management options. Literature data is screened in detail to enable a data collection on a life cycle stage level. This is compiled in a FUSIONS bottom-up database which provides a sortable data structure for the collected data e.g. by means of production, by country or by year.

After data collection, gaps and uncertainties can be easily highlighted. Data gaps may be filled by own calculations whereas uncertainty management has to be applied through the use of data quality rules. If literature data is only showing aggregated results for all product life cycle stages, an estimation for a segregation by life cycle stage can be considered in proportion to the other references for the same product providing data for each life cycle stage.

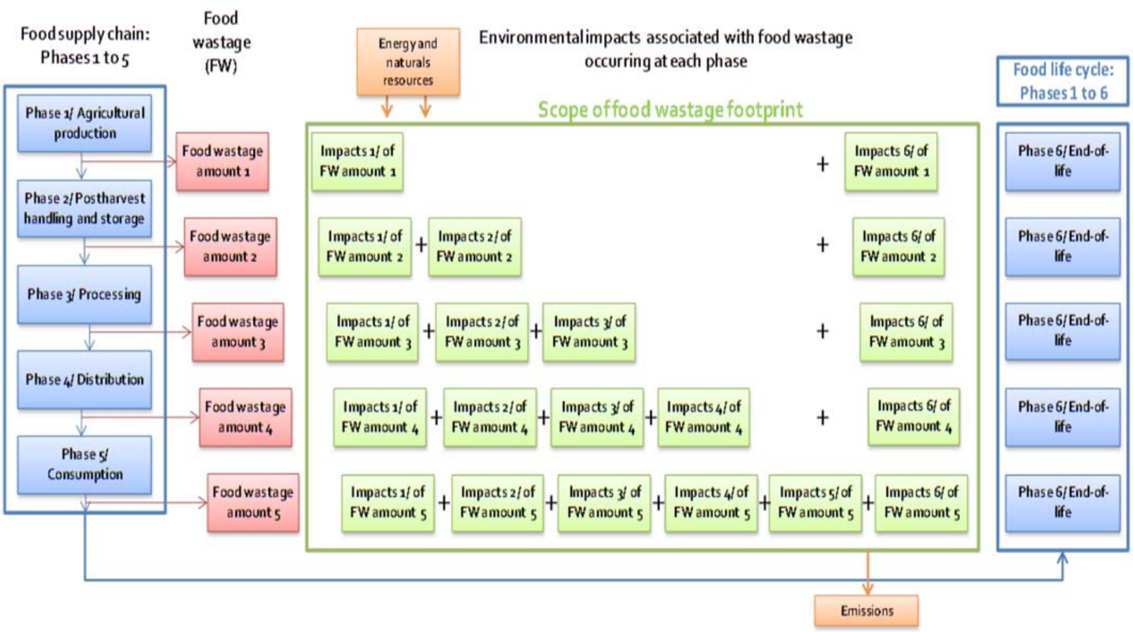
The European level is reached by applying estimated European averages for waste amounts and composition, production schemes and waste treatment technologies.

The strength of the bottom-up approach is the high level of detail and the traceability due to high transparency. Additionally the approach allows for the inclusion of additional products if the availability of LCA data increases in the future. However, the necessary data detail as well as the data quality may also be a weakness of this approach. After data issues, the estimations for a European average may also introduce high uncertainty due to weak statistics or data gaps.

The EoL stage covers all operations for the food waste disposal and recovery, which are composting, plough-in/not harvested, anaerobic digestion, bio-energy, co-generation, incineration, sewer, landfill and discards according to the FUSIONS definitional framework. Operations involved in the valorisation and conversion process (e.g. animal feed) in the food supply chain are not included in the EoL stage.

The modelling of the EoL stage includes the collection of data on different waste management routes in EU-28, the allocation of data to the food supply chain and the environmental impacts of each. Data needs to be collected for each indicator product and for each waste management operation underlined in the FUSIONS framework. The strength of the bottom up approach is that all food waste related emissions can be detected from production to end of life stage. Figure 8.2 shows a figure of a FAO study on the Environmental footprint of Food Waste on how to account environmental impacts of food wastage to each stage of the food supply chain. Results in the bottom-up approach will be shown according to this scope, which is referred to as "polluter-pays principle".

**Figure 8.2: Food wastage and associated environmental impacts, at each phase of supply chain (FAO, 2013)**




## 8.3.2 Top down approach

The top-down approach builds on previous work, including that by Tukker (2006) and Monier et al (2010) by illustrating the contribution of selected food and drink products to the total impact of consumed and wasted food in Europe. This will also allow comparison of the environmental profile of selected indicator products compared to the average environmental profile of food and drink in terms of consumption mix and waste mix.

Whilst the EU are pursuing development of methodologies for consistent quantification of the environmental impacts of a product or organisation, there is currently no internationally agreed method for national environmental impact calculation. In addition, data is not available in a consistent format which would allow a common approach to be taken to quantifying the impacts of food and drink at every life cycle stage. There are two potential approaches to attributing impacts to the consumption of goods and services, including food and drink: input-output analysis and material flow analysis. Input-output analysis uses economic information (e.g. trade values) and multipliers (impacts per unit) derived impacts associated with specified goods and services. This was used, for example, in DEFRA (2009) to quantify the footprint of UK food and drink consumption.

Material flow analysis uses physical information (e.g. trade volumes in combination with process life cycle coefficients (impacts per unit). The co-efficients may be derived on a per unit basis (e.g. in a typical LCA) or for all activity within a sector (e.g. energy use reported by the food and drink manufacturing sector).

The top-down approach applied in this study uses material flow analysis in combination with co-efficients to derive the impact of an average impact per unit of food and drink in the EU-28. This requires data on the quantity of food and drink consumed within the EU, the origin of these items, and the environmental impacts associated with each life cycle stage. Whilst material flows are available for the system as a whole (i.e. the amount of food produced and consumed is known) the proportion of food which passes through each stage (e.g. manufacturing, wholesale) is not known. The average presented therefore divides emissions for every stage by the total quantity of food and drink as though it all passed through each stage.

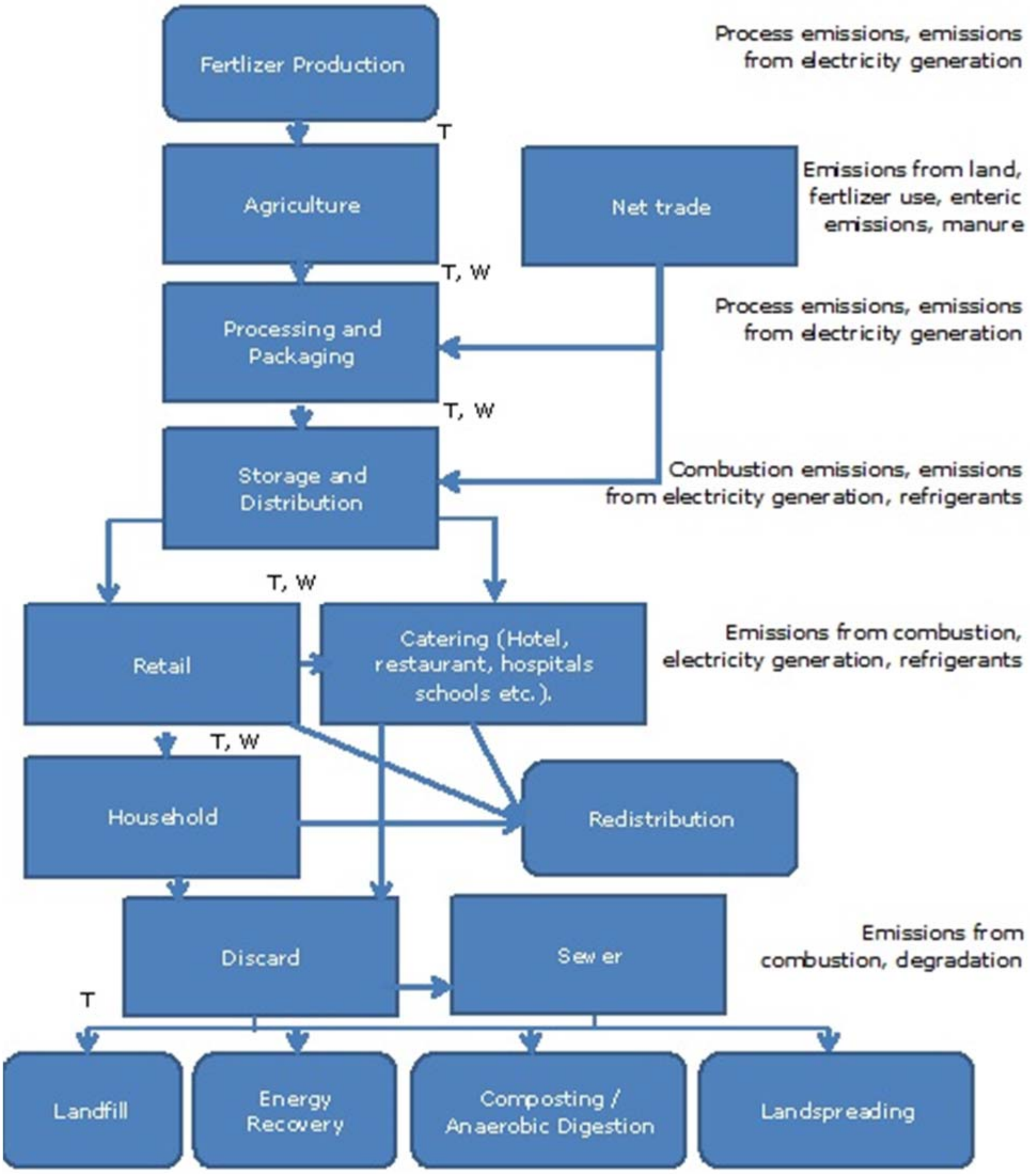
A top down approach has a number of strengths and weaknesses. By capturing all data from a sector (e.g. food and drink manufacturing), a top-down approach allows a comprehensive view of the impacts of a system. As the assessment is based on total food supply, there is also no need to allocate emissions to specific supply chains (e.g. retail or restauarant). However, it is constrained by the availability of data in a suitable format. For example, data may be available for the sector "food and beverages", or for "food beverages and tobacco", which will lead to an overestimate of impacts. Inferences and assumptions are also required to sub-divide activities (e.g. household travel) to identify the relevant emissions.

The life cycle stages considered in the top down approach are summarised in Figure 8.3. Between each of these stages is transportation (T), and at each stage is waste disposal (W), which has the same options as those shown for waste at end of life. Transport stages include extra-EU trade.

A data hierarchy will be used within the top down approach. In the first instance, data will be identified where possible for the EU-28 for a common year (2012). Official statistics (e.g. Eurostat, European Environment Agency) information will be preferred in the first instance. Where such data are not available, data from official national sources will be sought and weighted to the EU-28. If this cannot be found, data from peer reviewed sources will be identified and utilised. Finally, if this is not available, data from non-peer reviewed sources may be used to support the development of estimates.

The inventory and data sources used are covered in section 8.3.

**Figure 8.3: Stages of the food supply chain covered in the top-down approach (T = Transport, W = Waste)**




## 8.3.3 Data representativeness and quality

Whilst it is accepted that "robustness" of the data is perhaps a subjective assessment given that time did not allow a detailed assessment of all the literature found. "Robust" assessments were considered by the authors to be those that have included the general elements required by ISO14044 Environmental management - Life cycle assessment - Requirements and guidelines (2006), with good detail provided on the methodology including references to primary and secondary data sources, and a good level of transparency and reporting of results, compared to the studies reviewed in general, including uncertainties in results was also considered an extra indicator of robustness.

Peer reviewed articles in respected journals (*International Journal of Life Cycle Assessment* and *Journal of Cleaner Production*), were also considered an indication of robustness.

# 8.4 Life cycle inventory

## 8.4.1 Bottom up inventory

### *8.4.1.1 Process data*

**System characterization**
The study consisted of a comprehensive literature review using both scientific literature and general sources to search for evidence and data, guidance and metrics to define the environmental impacts of the selected indicator products. Sources have included Google, Web of Science, Scirus, scientific journals and reviews (both peer and non-peer reviewed), book chapters and company information / websites.

Life cycle assessment results for the selected indicator products were recorded along with other data on:

- An exact description of the food product;
- The kind of production system;
- The functional unit reported;
- The data source and country of study;
- The extent of the food chain covered;
- Any data covering waste management for the production, supply and consumption of the food product;
- The reported results and metrics of environmental impact.

Where possible the impacts reported were converted to common units of impact characterisation and scaled to functional units of 1kg of food product eaten by the consumer.

Aggregated environmental impact data reported over the whole or some parts of the supply chain were disaggregated where possible in proportion to the remaining data identified for the appropriate indicator product.

**Results**

The outcome of the literature study was a database of GWP values for each stage of the food supply chain. The arithmetic average, median value, first quartile and third quartile as well as the standard deviation were calculated to detect the data correlations within each indicator product. If major discrepancies between data within indicator products occurred then a weighting was applied to the values. In case of the potato major differences appeared between fresh and semi-prepared products. As a consequence a weighting was carried out according to the UK retail value sales of the potato market in

2011 (63% fresh, 33% frozen, 2% chilled and 2% canned/dehydrated) to adjust the data.

Extreme values where no explanation could be given were excluded for further calculations. This was true for the case of apple and bread where, for each product, the single value found for consumption-related emissions appeared unexpectedly high.

Instead the database needed to be extended in the consumption section to cover all fields within the system boundaries. Most of the costumer based activities were not covered in literature (e.g. cooking, consumer travel) and had to be added with simplified assumptions by the authors of this report.
For the consumer travel a transport of on average 10 kg of food by passenger car over a distance of 5 km was assumed.
The cooking behaviour of consumers is different for some of the indicator products. The considered assumptions are each stated in the table below.

For further calculations within the bottom up approach the median values were considered, which are shown in Table 8.3. Please see also the references in Annex 10.5.

**Table 8.3: Median value for the GWP for each life cycle stage in kg $CO_2$ eq /kg (n = number of literature sources related to the given median value)**

| Indicator product | Unit | Primary production | Food Processing | Transport (average) | Retailing & Distribution | Packaging | Food consumption | Assumptions taken by the authors |
|---|---|---|---|---|---|---|---|---|
| Apple | Median value | 0.10 | 0.03 | 0.12 | 0.02 | 0.04 | 0.09 | Three data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 16 | 9 | 9 | 3 | 2 | 0 | |
| Tomato (GH vs. Field) | Median value Field | 0.25 | 0.10 | 0.22 | 0.02 | 0.09 | 0.11 | Eleven data sources covering more than one chain step were disaggregated to provide additional results. Retail and Packaging from greenhouse tomato was considered for field tomato as well. Consumption covers storage in a refrigerator with similar emissions to milk storage. |
| | n | 7 | 3 | 3 | 1 | 1 | 0 | |
| | Median value Greenhouse | 2.15 | 0.10 | 0.04 | 0.02 | 0.09 | 0.11 | |
| | n | 17 | 12 | 12 | 3 | 2 | 0 | |
| Potato | Median value Fresh | 0.15 | 0.00 | 0.05 | 0.04 | 0.03 | 0.69 | Twenty-six data sources covering more than one chain step were disaggregated to provide additional results. Consumption: Assumed 1kg fresh potatoes are boiled for 30 min on 1500W hob, therefore 0.75kWh $CO_2$eq/kg Assumed 1kg chipped / prepared potato products are oven cooked for 25 min in 2000W oven, therefore 0.83kWh $CO_2$eq/kg |
| | n | 25 | 15 | 17 | 6 | 3 | 2 | |
| | Median value Frozen | 0.25 | 0.53 | 0.05 | 0.13 | 0.04 | 0.92 | |
| | n | 3 | 3 | 3 | 3 | 1 | 1 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Median value Chilled | 0.44 | 0.79 | 0.14 | 0.42 | 0.02 | 0.29 | Assumed 1kg mashed potato is heated in 1500W microwave oven for 8 minutes, therefore 0.2kWh $CO_2$eq/kg |
| | n | 15 | 15 | 15 | 13 | 13 | 13 | |
| Bread | Median value | 0.55 | 0.14 | 0.06 | 0.05 | 0.02 | 0.09 | Five data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 12 | 12 | 10 | 9 | 6 | 0 | |
| Milk | Median value | 1.12 | 0.08 | 0.02 | 0.05 | 0.06 | 0.11 | Five data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 55 | 12 | 9 | 7 | 7 | 3 | |
| Pork | Median value | 5.85 | 0.20 | 0.15 | 0.27 | 0.22 | 1.13 | Fourteen data sources covering more than one chain step were disaggregated to provide additional results. Packaging: was taken from beef. Consumption stage: Assumed oven cooked for 90 min at 180C in 2000W oven, therefore 3kWh equiv to 1.38kg $CO_2$eq/kg Assumed 1kg minced pork/sausages is fried/cooked for 30 min on 1500W hob, therefore 0.75kWh $CO_2$eq/kg. Waste Management includes manure management. Assumed bacon is fried for 10 min on 1500W hob, therefore 0.25kWh $CO_2$eq/kg Assumed tenderloin is oven cooked for 60 min at 180C in 2000W oven, therefore 2kWh equiv to 0.92kg $CO_2$eq/kg. Waste |
| | n | 33 | 16 | 13 | 9 | 3 | 2 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Management covers manure management. |
| Beef | Median value | 27.77 | 0.49 | 0.11 | 0.15 | 0.18 | 1.32 | Five data sources covering more than one chain step were disaggregated to provide additional results. Consumption: Assumed oven cooked for 80 min at 180C in 2000W oven, therefore 2.66kWh equiv to 1.23kg. Waste Management covers Manure Management. |
| | n | 31 | 8 | 5 | 2 | 0 | 0 | |
| Fish | Median value | 2.62 | 0.16 | 0.28 | 0.55 | 0.11 | 0.40 | Six data sources covering more than one chain step were disaggregated to provide additional results. Packaging of 4 sources is included in upper supply chain steps. |
| | n | 14 | 14 | 14 | 6 | 6 | 2 | |
| Chicken | Median value | 2.99 | 0.21 | 0.02 | 0.38 | 0.06 | 1.05 | Seven data sources covering more than one chain step were disaggregated to provide additional results. Consumption: Assumed oven cooked for 75 min at 180C in 2000W oven, therefore 2.5kWh equiv to 1.15kg |
| | n | 15 | 11 | 7 | 5 | 5 | 2 | |

The LCA literature examined often stated that waste management was included in the calculations. However, this mostly covered manure management. Next to manure management, waste management activities were often not transparent and it remained difficult to separate out emissions associated with wastes from the manufacture, preparation and consumption of the product.

**Data uncertainty and data gaps**

The results indicated that each of the selected indicator products had a (often considerable) range of data, highlighting problems in making general comparisons between different studies. The range of data was due to a number of factors. For instance, the main variation in reported burdens within the meat food chains were often due to differences in life cycle assessment methodology and boundaries, (for example economic allocation of GWP emissions to expensive cuts of meat at the retail stage, whilst other studies include methodologies for soil emissions not commonly included in other studies). In addition, there are wide differences in reported burdens between different types of meat & meat products. Whilst in fruits and vegetables, very high GWP resulted from production system characteristics (e.g. specialist on-the vine tomatoes vs. classic loose tomatoes).

In addition, variation was also due to the differences in the goals and scopes of the different studies, the methodological approaches, the setting of boundaries and assumptions as well as data quality & availability. It is likely that the studies were not designed with such comparative evaluation with other studies of similar or different food products in mind.

Other review papers have compared different lifecycle assessments, often highlighting methodological differences. Transparency of studies, data and methods were also an issue in this respect – many studies did not give enough details to allow studies to be repeated. This is partly because of the widespread use of commercial databases but also because journals do not always provide enough space for all details. In addition, some data are provided by commercial operators on a confidential basis.

Further differences arise between studies according to whether they apply attributional or consequential analysis. Attributional (or "accounting") LCA describes an existing supply chain; it is used, for example, in estimating the "carbon footprint" of a product. Consequential (or "prospective") LCA attempts to explore the system effects of changes in economic activities; a conspicuous use of consequential LCA is in exploring the effects of changes in land use due to switching from production of food to fuel crops in one location, compensated by increased food production elsewhere. The methodological differences between the two forms of LCA are a matter of current debate but, for food products, consequential LCA usually gives significantly higher impacts, particularly for climate change, because it includes changes in carbon stock resulting from indirect land use change.

Notwithstanding the above uncertainties over data quality, there is good agreement in the reported values by selecting the first and third quartile points to represent the range of data around the median value.

#### *8.4.1.2 Waste data*

**System characterization**

Food waste is often disposed together with other waste fractions such as residual household waste, so that the waste treatment options are very varied and often depend on the waste stream where food waste ends up. Furthermore there are differences in the disposal of animal containing food waste and vegetal waste. Due to a lack of data on European level on recovery and disposal operations for food waste, data needed to be abstracted from existing statistics and literature on biodegradable waste. Additionally information on some waste disposal options (e.g plough-in; bio-energy) mentioned in the FUSIONS definitional framework is only available in form of single data sources such as country reports or master theses or not available at all. Assumptions are taken to specify the data set to build a more realistic picture for the environmental assessment of food waste recovery and disposal. As a consequence the presented relative and absolute amounts on recovery and disposal operations come with certain uncertainties, but shall only serve as a basis for assessing the environmental effects.

Three main data sources were used for the data inventory of the EoL stage:

- Data collected within FUSIONS
- Eurostat (served as a basis for waste management routes)
- Other national statistics, research studies and articles from scientific journals to underline assumptions for filling data gaps

Within the FUSIONS project (in Task 1.6 "Estimation of EU data on food waste") an Excel matrix was prepared to collect food waste data from different member states. Representatives of each MSs Government responsible for the collection of waste statistics were contacted. Data on the destination for food waste was also requested. The output of this survey concerning waste management options was unfortunately poor. Only 6 countries presented some data. Countries reporting from waste management practices of food waste were Malta, United Kingdom, Greece and Sweden as well as the candidate countries Macedonia and Serbia. The difficulty of the national reports is that there is no common definition on waste treatment option and therefore hard to allocate to the options within FUSIONS definitional framework. For example mentions Serbia that most of the food waste from processing goes to animal feeding (80% from processing stage and 90% from food service), which is a valorisation option within FUSIONS and not an option for food waste in this sense. This valorisation step is not covered in the assessment due to lack of data (see chapter 8.2.2). Yet, the example of Serbia shows the high importance of the feed stream in quantitative terms which would demand more investigations.
Most of the data was communicated for the food preparation and consumption stage. Sweden reported that most of it is incinerated (89% from hotels and restaurants, 55% from catering, 67% from households). United Kingdom reported that food waste from food service sector is disposed of via residual waste stream, not mentioning how the residual waste stream is disposed of. For summing up the reported data it is therefore too heterogeneous. Specific statements can only be taken to compare it with findings from literature. So is the fact confirmed, that countries with a well developed waste management structure, such as Sweden, dispose their food waste to incineration or recycling and countries with a less developed infrastructure, such as Greece and Macedonia, report from landfilling most of the food waste. Yet, also food waste from

United Kingdom and Ireland is reported to be mostly landfilled. As shown in Table 8.6, the share of food waste disposed of to landfill in 2012 across the EU-28 was 25%.

As the data collected within FUSIONS does not provide the necessary inventory for the bottom-up approach other data sources needed to be considered. Eurostat was used as a basis, but doesn't provide all information to life cycle stages and waste management routes. Data in Eurostat is separated into five treatment operations on the basis of the Waste Framework Directive 2008/98/EC (European Commission, 2008). In Table 8.4 those treatment operations were collated to food waste management options in the FUSIONS definitional framework. It can be seen that the recovery option in Eurostat can be collated to two possibilities in FUSIONS, namely composting and anaerobic digestion. For disaggregation of results a literature survey was carried out to detect the proportion of composting to anaerobic digestion in the view of their installed capacities. For this purpose information was used from various national reports of the European Compost Network, ECN (2015) and the report of Saveyn, H. and Eder, P. (2014). For the option land treatment/release into water also three possibilities exist in FUSIONS, namely plough-in/not harvested, discards and sewer. A distinction between these waste streams was not conducted due to lack of data. The environmental consequences were though analysed exemplarily.

**Table 8.4: Waste treatment operations according to Eurostat and to FUSIONS definitional framework**

| Eurostat[27] | FUSIONS framework |
|---|---|
| Recovery (excluding energy recovery): operations R2 to R11; | composting, anaerobic digestion |
| Energy recovery: R1; | co-generation, bio-energy |
| Incineration: D10 | incineration |
| Disposal on land: D1, D5, D12 | landfill |
| Land treatment/release into water: D2, D3, D4, D6, D7 | plough-in/not harvested, discards, sewer |

The allocation of waste streams to specific life cycle stages is also not possible with data from Eurostat. Assumptions had to be taken to model the waste streams in life cycle stages. Waste streams in Eurostat which contain food waste are

- animal and mixed food waste from agriculture, forestry and fishery, food preparation and products, biodegradable kitchen and canteen waste, edible oils and fat, and
- vegetal waste from agriculture, forestry, food preparation and products, biodegradable kitchen and canteen waste, edible oils and fat (also containing green waste), and
- household and similar waste (mixed municipal waste, bulky waste, street cleaning waste, kitchen waste, household equipments, where the main amount comes from private households, but also similar wastes from commerce (not including separated collected biodegradable waste).

Food waste from all steps such as production, processing, wholesale, logistics, food preparation and consumption are included in above mentioned waste streams. For a matter of allocation the following assumptions were set:

[27] A description to the categories can be found in Eurostat (2013)

- Food waste in the production, processing stage can be allocated to animal and mixed food waste and vegetal waste depending on the type of waste (animal containing or vegetal)
- Food waste in the wholesale, logistics, retail and marketing can be allocated to animal and mixed food waste (in practice no separation is done for vegetal waste as most of the products are contaminated with animal containing food)
- Food waste in the food preparation and consumption stage can be allocated to household and similar waste (under consideration of separate collection of biodegradable waste).

For the consideration of the extent of separate collection of biodegradable waste in EU-28, information of national reports of the ECN (2015) and the report of Saveyn, H. and Eder, P. (2014) were taken as a basis. It revealed that 14 European countries have a separate collection installed, but the extent varies considerably. While in the Netherlands 90% of the households are covered by separate collection of waste, in some Eastern European countries there is a separate collection installed only for big housings or in some pilot projects. For further calculations it was assumed that 65% of the EU member states have a separate collection installed with a participation rate of 40% of housholds. The extent of it remains a crucial factor and the effects on the overall results will be calculated in a sensitivity analysis.

**Results**

The primary data source was Eurostat, which provides recovery and disposal options for food waste relevant waste streams for European Member States. The data source was extended with additional information on separate collection of biodegradable waste and the capacities for aerobic and anaerobic digestion plants from literature.
Results are based on the following assumptions:

1. Food waste from agriculture, production, processing is allocated to the Eurostat-Category: Animal and mixed food waste as well as Vegetal wastes
2. Food waste from wholesale, logistics & retail is allocated to the Eurostat-Category Animal and mixed food waste
3. Food waste from food consumption is allocated to Eurostat-Category Household and similar wastes
4. 65% of the EU member states have a separate collection for biodegradable waste installed with an estimated averaged participation rate of 40% of households.
5. Recovery is allocated to 80% composting and 20% anaerobic digestion (based on the installed capacities reported in ECN country reports)
6. Food service is at the same extent effected from separate collection of biodegradable waste as households (some MS reported that biodegradable waste from food service is collected separately, therefore the assumptions together with the given estimated shares seems to be explainable)
7. Backfilling[28] is shown separately although it is not part of the FUSIONS definitional framework but part of Eurostat

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[28] Backfilling means a recovery operation where waste is used in excavated areas (such as underground mines, gravel pits) for the purpose of slope reclamation or safety or for engineering purposes in landscaping and where the waste is substituting other non-waste materials which would have had to be used for the purpose. This includes:
• the use of waste for stowage of mines and quarries;
• the use of waste for recultivation, land reclamation or landscaping;
Backfilling does not have a clear assignment to the R-codes. Depending on the wastes used for backfilling it may be assigned to R5 or R10. In both cases backfilling operations build a sub-set of the respective recovery operations. However, as mentioned earlier, in order to produce data in compliance with the recycling definition of the Waste Framework Directive, Item 3b 'backfilling' has been introduced as a separate reporting item. (Eurostat, 2013)

8. Bio-energy and energy recovery are aggregated, as a distinction was not possible from literature data.
9. Plough-in /not harvested, discard to sea or to crop and the disposal via sewer are summed up, as an allocation is not possible due to lack of data.

**Table 8.5: Estimated proportion of recovery and disposal operations for different waste categories, related to EU-28 in 2012**

| Waste category | B3: Composting | B5: Anaerobic digestion | B7: Co-generation, (B6: Bio-energy) | B8: Incineration | B10: Landfill | B4: Plough-in/not harvested, B9: Sewer, B11: Discard | Backfilling |
|---|---|---|---|---|---|---|---|
| Animal containing food waste | 67.3% | 16.9% | 5.7% | 2.1% | 7.3% | 0.6% | 0.1% |
| Vegetal food waste | 74.5% | 18.7% | 3.4% | 0.4% | 2.8% | 0.1% | 0.0% |
| Household and similar wastes with consideration of sep. coll. biodegradable waste | 27.9% | 7.0% | 17.0% | 11.2% | 36.9% | 0.0% | 0.1% |
| Separate collected biodegradable waste | 79.9% | 20.1% | - | - | - | - | - |

**Table 8.6: Estimated amounts of food waste per supply chain and recovery and disposal operations in 1000 tonnes in EU-28 in 2012, related to FUSIONS food waste data set from Oct 2015**

| Supply chain | B3: Composting | B5: Anaerobic digestion | B7: Co-generation, (B6: Bio-energy) | B8: Incineration | B10: Landfill | B4: Plough-in/not harvested, B9: Sewer, B11: Discard | Backfilling | FUSIONS food waste data set from Oct 2015[29] |
|---|---|---|---|---|---|---|---|---|
| Production | 18897.00 | 4752.93 | 960.27 | 171.49 | 871.06 | 44.56 | 2.70 | 25700.00 |
| Processing | 12308.01 | 3095.68 | 669.59 | 139.39 | 647.61 | 36.72 | 3.01 | 16900.00 |
| Wholesale, logistics, retail & marketing | 1282.78 | 322.64 | 781.59 | 514.29 | 1695.47 | 0.50 | 2.97 | 4600.25 |
| Food preparation & consumption | 15783.82 | 3969.91 | 9616.97 | 6328.00 | 20861.67 | 6.10 | 36.58 | 56603.05 |
| **Sum** | **48271.61** | **12141.16** | **12028.42** | **7153.16** | **24075.81** | **87.88** | **45.26** | **103803.30** |
| Relative share | 46.5% | 11.7% | 11.6% | 6.9% | 23.2% | 0.1% | 0.0% | |

[29] Due to differences in rounding of Eurostat data there are differences in the decimals.

**Table 8.7: GWP of recovery and disposal operations – processes used for assimilated environmental assessment of food waste**

| Recovery and disposal operation | GWP in kg $CO_2$-Equivalents per kg biodegradable waste | Data source | Process description and assumptions |
|---|---|---|---|
| B3: Composting | -0.0095 | BOKU | Enclosed composting of biodegradable waste (substitution of fertilizer and peat) |
| B5: Anaerobic digestion | -0.0328 | BOKU | Anaerobic digestion of biodegradable waste with enclosed composting of the digestate incl. spreading of digestate (substitution of fertilizer and peat, and of electricity from the grid mix and heat from fossil fuels) |
| B7: Co-generation, (B6: Bio-energy) | -0.1401 | GaBi 6.0 | Waste incineration of biodegradable waste fraction in municipal solid waste. (substitution of electricity from the grid mix and heat from fossil fuels) |
| B8: Incineration | 0.0491 | GaBi 6.0 | Waste incineration of biodegradable waste fraction in municipal solid waste. No use of energy output |
| B10: Landfill | 0.7585 | GaBi 6.0 | Landfill of biodegradable waste |
| B4: Plough-in/not harvested (B11: Discard) | 0.0583 | BOKU | Rotting process of the open windrow composting of biodegradable waste (assimilation process) |
| B9: Sewer | 0.0006 | GaBi 6.0 | Waste water treatment (contains organic load) |
| Backfilling | Not assessed | Not assessed | Not assessed |

Table 8.7 shows the GWP values taken for the specific waste recovery and disposal operations. Values are partly taken from GaBi 6.0 database of ThinkStep (former PE International GmbH) and partly from BOKU's own investigations. Negative GWP results indicate an environmental benefit, as the operations substitute e.g. fertilizer, fossil fuels (e.g. the efforts to produce compost from biodegradable waste has minor emissions than the production of fertilizer and peat). Positive GWP results indicate an environmental burden (e.g. the incineration of biodegradable waste without using the energy output result in emissions to the environment only; as the energy is not used, no credits can be applied).

It needs to be mentioned that biodegradable waste and not food waste is covered as input material in the GWP values of recovery and disposal operations shown above. Biodegradable waste may contain also green waste and structural material which is not part of food waste in FUSIONS Defintional Framework. Food waste may therefore behave differently to biodegradable waste in certain operations. Differences are not investigated in this project.

### Data uncertainty and data gaps

Although European countries are subject to the Landfill Directive (1999/31/EC) which restricts the landfilling of organic substances, it is still common practice. In countries where no separate collection of biodegradable waste is installed, food waste still ends up in the household or similar waste fraction. As around half of the household / similar waste is going to landfill (50% in EU-28 in 2012), the environmental effects are considerable in this point. The critical factor for the environmental analysis in this study is to assume the extent of food waste entering this waste stream and therefore ending up mostly at landfills. Another issue is the extent of home composting, which may reduce the amount accounted for by landfilling.

Emissions from waste treatment of organic substances in the inventory are based on a mixture of biodegradable material. The differences between rotting processes or incineration of animal containing products or vegetal products couldn’t be evaluated within this project. To test their behaviour and to see if major differences occur, laboratory tests under standard conditions need to be carried out. Although the behaviour in theory and in practice may differ when a mixture of input material is treated.

### 8.4.2 Top down inventory

The following section provides additional detail on how greenhouse gas emissions are identified for each life cycle stage for the top down assessment.

**Fertilizer**

Fertilizers Europe (2014a, b) provide GHG emission data for 2011 for both fertilizer production and fertilizer use, alongside data for fertilizer use in the EU-27 in 2011 / 12, broken down by different formulations. FAOStat also present data on consumption of fertilizers by nutrients, by country, but data is not available for 2012 broken down by different formulations. The formulations in Fertilizers Europe (2014a) are assumed to be representative of the EU28. Table 8.8 applies the Fertilizer Europe formulation splits and greenhouse gas emissions to the consumption data from FAOStat to infer that total fertilizer production emissions associated with EU-28 fertilizer use were 48 million tonnes $CO_2$equivalent in 2012. This excludes in-use emissions, which are reported in agriculture statistics (See the next section).

**Table 8.8: Fertilizer production greenhouse gas emissions associated with EU-28 consumption, 2012 (Sources: FAOStat, 2015, Fertilizers Europe 2014a,b)**

| | Ammonium Nitrate | Calcium Ammonium Nitrate | Ammonium Nitrosulphate | Calcium Nitrate | Ammonium Sulphate | Ammonium Phosphates | Urea | Urea ammonium Nitrate | NPK 15-15-15 | Triple Superphosphate | Muriate of Potash |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EU-28 Consumption (tonnes nutrients) | 2236611 | 2769137 | - | 1065053 | - | 833378 | 2023600 | 1278063 | 2550503 | 431312 | 2734083 |
| kg $CO_2$ eq per kg nutrient, production only | 3.52 | 3.70 | 3.20 | 4.38 | 2.76 | 4.05 | 1.98 | 2.73 | 5.06 | 0.54 | 0.43 |
| total tonnes $CO_2$ eq based on product | 7883103 | 10245808 | 0 | 4668907 | 0 | 3377480 | 4001188 | 3492257 | 12894457 | 232589 | 1175656 |
| Total | 47971446 | | | | | | | | | | |

**Agriculture**

The European Environment Agency (2014) reports that in 2012, agricultural greenhouse gas emissions for the EU-28 were 461 million tonnes $CO_2$ equivalent. This includes emissions from the use of fertilizer. Whilst it is acknowledged that a proportion of these emissions are incurred in the production of non-food and drink items (e.g. biofuels), for the purposes of the top down screening all emissions are attributed to food and drink production.

**Food and Drink Processing (Manufacturing )**

Eurostat (2014a) provides data on the direct greenhouse gas emissions from different industrial sectors. For the EU-28 food and beverage sector in 2012, these are reported as 44.7 million tonnes $CO_2$ equivalent.

In the same inventory, emissions associated with electricity generation are associated with the producing sector, and are quantified as 1220 million tonnes $CO_2$ equivalent. It is therefore necessary to attribute emissions from electricity consumption to the food and beverage sector.

Eurostat (2014b) provides final energy consumption statistics for the EU-28 for electricity and derived heat. Assuming that the average intensity of emissions for electricity consumed by the food, beverage and tobacco sector is the same as the average intensity of production (i.e. the industry is proportionately spread actoss the EU-28), this suggests that 44.6 million tonnes $CO_{2}$-equivalent were associated with electricity use by the sector in 2012.

**Table 8.9: Energy consumption and greenhouse gas emissions from electricity use in the EU-28 food, beverage and tobacco sector, 2012**

| | Electricity in kt-oe | Derived heat in kt-oe | Total heat and electricity in kt-oe | Public electricity and heat generation GHG emissions (Mt $CO_2$ eq.) |
|---|---|---|---|---|
| **Final energy consumption, EU-28** | 240609 | 48266 | 288875 | 1220 |
| **Industry** | 86668 | 15766 | 102434 | 433 |
| **Of which Food Beverage and tobacco** | 9457 | 1096 | 10553 | 44.56 |
| **Transport** | 5508 | 0 | 5508 | 23 |
| **Other sectors** | 148433 | 32499 | 180932 | 764 |
| **Of which Commercial and Public Services** | 72647 | 9095 | 81742 | 345 |
| **% total of which Food beverage and tobacco** | 4% | 2% | 4% | |

The proximity of these two figures suggests the possibility that they represent the same energy use. However, Eurostat (2014b) suggests that alongside 10553 ktoe of electricity and derived heat, the sector also consumes 16564 ktoe energy directly from fossil sources. This is approximately a 40:60 split. It is therefore plausible that the greenhouse gas emissions from these delivered electricity and direct combustion of fossil fuels are similar.

## Packaging

Although data is available at an EU level on the weight of packaging placed on the market, the proportion of this packaging which is associated with food and drink is not identified. The Global Packaging Alliance (2014) suggest that food and drink comprises 60% of packaging market by value in Europe. In this report, we have therefore also assumed that 60% of all packaging impacts are associated with food and drink.

Eurostat (2015a) suggest that in 2012 79 million tonnes of packaging were place on the market, of which 60% is assumed to relate to food and drink. Table 8.10 presents data on the amount of packaging has been taken from Eurostat (2015a) and GHG emission factors have been taken from WRAPs factors for the Courtauld Commitment 3 (WRAP 2014)

**Table 8.10 GHG emissions associated with food and drink packaging**

| | Material | Food and drink packaging in Mt[1] | GHG emissions in $CO_2$eq per tonne (WRAP 2014) | Mt $CO_2$eq |
|---|---|---|---|---|
| **Implied Food and Drink Packaging (EU 28)** | **Paper and cardboard packaging** | 18.9 | 0.8 | 15.3 |
| | **Plastic packaging** | 9.1 | 3.7 | 34.1 |
| | **Wooden packaging** | 7.2 | 0.4 | 3.0 |
| | **Metallic packaging** | 2.7 | 4 | 10.4 |
| | **Glass packaging** | 9.4 | 0.7 | 6.7 |
| | **Total** | 47.5 | | 69.4 |

[1] modified from Eurostat 2015a

There are a number of sources of uncertainty in these figures. Firstly, the approach taken does not account for the difference in value of primary and transit packaging, which may mean that the economic cost does not reflect the volume of packaging. In addition, the 60% split is unlikely to apply to all packaging evenly, with materials such as glass almost exclusively used in food and drink packaging. However, in the absence of a material-specific data set, the split has been applied across all packaging. Including all glass would change the estimated GHG emissions, but not the magnitude of the figure.

## Food Net Trade

Comext (2014) provides import and export data for food products for the EU-28 in both weight (100kg units) and financial value (Euros). Data from Comext has been used for all food and drink trade, excluding live animals and some animal feed. Animal feeds are exluded where they are by-products or waste from food production (e.g. husks) as this is otherwise accounted for in the impact of food. Including separate calculations for all animal feed therefore leads to the potential for double counting. Imported live animals also become domestically-produced animal products, and again there is potential for double counting of impacts.

Data on the greenhouse gas emissions associated with agriculture and food production overseas has been sourced from a range of published academic literature. Average values have been taken for each item in as much detail as possible.

Use of net trade statstics avoids double counting EU-28 agricultural emissions associated with the export of food. This suggests that in 2012 EU28 net trade was associated with emissions of 323 Mt $CO_2$ eq.

### Distribution

Eurostat provide data on goods transported by rail and road by group of products. This covers movements of food through various stages in the supply chain, from farm to processor, to storage and to retail or catering. It is anticipated that this may also include home-delivery of internet-based food shopping. Food, beverages and tobacco are classified as one group and transport factors provided. This level of detail is not provided for air, sea and inland waterways. Greenhouse gas conversion factors for heavy goods vehicles (HGVs) have been used, and these are considered representative of the EU, as emission standards are set at the EU. In the absence of EU-specific emissions for rail transport, UK averages have been used, based on DEFRA DECC (2014). Table 8.11 provides an overview of the emissions associated with this sector.

**Table 8.11: Distribution of Food, Beverages and Tobacco, EU-28 2012**

| **Method of transport** | **Mtkm** | **Kg $CO_2$eq per tkm** | **Mt $CO_2$eq** |
|---|---|---|---|
| **Road** | 286758 | 0.1232 | 35.3 |
| **Rail** | 8244 | 0.02831 | 0.2 |
| **Total** | | | 35.6 |
| **Reference** | Eurostat (2014d, e) | DEFRA DECC (2014) | |

### Retail

Unlike manufacturing, data on energy use by the retail sector is not made publically available through Eurostat. It is therefore necessary to estimate greenhouse gas emissions through use of other existing data.

Tassou et al (2011) carried out a survey of UK food retailers covering 2570 stores from all major store categories (convenience stores, superstores, supermarkets, hypermarkets). This identified that collectively UK supermarkets and superstores (6578 stores covering 73% sales by value) consumed 8385 GWh electricity and 2477 GWh gas per annum, with associated emissions of 4 million tonnes $CO_2$eq. The source data (DEFRA 2006) suggested that at the time there were 102537 grocery retail stores. This is significantly above the Eurostat figure of 61 000 for 2008. The classifications used in DEFRA (2006) and Eurostat (2014g) do not align, and it is unlikely that these cover the same premises. This suggests that although the estimate of greenhouse gas emissions covers 73% of sales, it covers only 6%-11% of food and beverage retail enterprises. If extrapolating from this data source, there is therefore potential to underestimate the emissions associated with food and drink retail. Alternative methods were therefore investigated.

Food and drink may be retailed through specialised stores, non-specialised stores, stalls, markets, and via the internet. Tackett (2014) highlights that different countries within the EU have different blends of shopping channels, with hypermarkets in France and discounters in Germany having strong market shares respectively. However, all countries appear to sell principally through hypermarkets, superstores, supermarkets and discount stores.

Food sold through stalls and markets is assumed to have negligible energy and carbon impacts as markets are typically outdoors in unheated locations, and account for a relatively small proportion of retail by value. The focus is therefore is on quantifying emissions associated with specialised and non-specialised stores.

Data on business populations and employment are available via Eurostat. Table 8.12 shows the number of food and drink retail enterprises in 2012 (Eurostat 2014g), collectively employing around 4.5 million full-time equivalent (FTE).

**Table 8.12: Number of Food and Drink Enterprises in the EU-28, 2012**

| Geographical Area | Retail sale of food, beverages and tobacco in specialised stores | Retail sale in non-specialised stores with food, beverages or tobacco predominating | Retail sale via stalls and markets of food, beverages and tobacco products | Total |
|---|---|---|---|---|
| EU-28 | 457126 | 429820 | 117199 | 1,004,235 |

Two hybrid approaches are considered. The first of these is to use economic allocation of emissions in conjunction with data on the business population, and secondly to use economic allocation in conjunction with the number of FTE employees.

Although energy use data is not available for EU retail, energy use in UK retail is available from DECC (2014). This covers the energy use in retail associated with catering, computing, cooling and ventilation, hot water, heating, lighting and other uses. The energy use, expressed in Million tonnes oil equivalent (Mtoe), is converted into $CO_2$eq using the DEFRA DECC (2014) conversion factors. Table 8.13 shows the greenhouse gas emissions associated with UK retail, excluding catering. To estimate the emissions associated with food and drink retail, economic allocation has been used. This means that the proportion of consumer expenditure on food and drink has been taken to represent the proportion of retail emissions associated with food and drink.

Greenhouse gas emissions associated with retail of food and drink in Germany is also available in Bleher (2013). This is also shown in Table 8.13, and is similar in magnitude to the UK.

**Table 8.13: Retail greenhouse gas emissions in the UK, 2012**

| Retail excl catering | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|
| **Electricity (Mt $CO_2$eq)** | 10.12 | 9.84 | 9.75 | 9.61 |
| **Natural Gas (Mt $CO_2$eq)** | 2.24 | 2.18 | 2.23 | 2.41 |
| **Oil (Mt $CO_2$eq)** | 0.19 | 0.21 | 0.20 | 0.19 |
| **Solid fuel (Mt $CO_2$eq)** | | | | |
| **Heat Sold (Mt $CO_2$eq)** | | | | |
| **Bioenergy and Waste (Mt $CO_2$eq)** | | | | |
| **All (Mt $CO_2$eq)** | **12.57** | **12.22** | **12.17** | **12.22** |
| **Proportion of UK household final consumption expenditure on food and drink as a subset of shopping. Current prices, seasonally adjusted (ONS 2014)** | 0.537384 | 0.540382 | 0.541929 | 0.536053 |
| **Inferred emissions associated with the retail of food and drink, specialised and non-specialised (Mt $CO_2$eq)** | 6.75 | 5.58 | 5.58 | 5.52 |
| **Emissions associate with the retail of food and drink Germany, heating and electricity only (Mt$CO_2$eq)** | 6.89 | | | |

Eurostat (2014g) suggests that in the UK in 2012 there were 28 613 non-specialised stores predominantly selling food and beverages, and 30 205 specialised food and beverage stores. Table 8.14 combines information on the total greenhouse gas emissions with data on the population of active stores retailing food and beverages to suggest a range of emissions for food retail at an EU-28 level.

**Table 8.14: Number of Retail stores and inferred greenhouse gas emissions, 2012**

| Geographic Area | Population of specialised stores for retail sale of food, beverages and tobacco | Population of non-specialised stores with retail of food, beverages or tobacco predominating | Greenhouse Gas Emissions, if allocated to specialist stores on FTE basis (Mt $CO_2$eq) | Greenhouse Gas Emissions, if allocated to specialist stores only (Mt $CO_2$eq) | Greenhouse Gas Emissions, if allocated to all stores (Mt $CO_2$eq) |
|---|---|---|---|---|---|
| **UK** | 30,910 | 30,205 | 5.58 | 5.58 | 5.58 |
| **EU-28** | 457126 | 429820 | 159 | 90 | 82 |

Bleher (2013) suggests that in 2010 greenhouse gas emissions from food specialist stores in Germany were around 7 million tonnes CO2eq, excluding refrigerant losses. This aligns well with the estimate based on the lower assessment based on greenhouse gas emissions allocated to both specialist and non-specialist stores, and suggests that use of FTE employees as an indicator of retail emissions is not appropriate. The assessment therefore suggests that 82-90 million tonnes $CO_2$eq are associated with retail of food and drink. The estimate is lower when both non-specialist and specialist stores are considered due to the differing composition of retail enterprises in different EU member states.

In addition, 4% of food and drink sales in the UK by value were via the internet (IGD 2014). The impact of this is not calculated separately here as the background infrastructure is assumed to be similar for both retail and internet-based routes, and transport emissions are captured in general transport data (see transport section).

The limitations to this approach are numerous. Firstly, no distinction is made between retail in different climates. Whilst energy consumption per retail unit may be broadly similar across Northern Europe, there are likely to be differences to Southern Europe due to differing temperature regimes (Emerson Technologies 2010). Furthermore, there will be differences between countries depending on the prevalence of different diets (e.g. consumption of produce which can be stored at ambient temperatures or chilled).

The approach uses economic allocation to identify the proportion of retail emissions associated with food and drink. This assumes that the energy intensity per unit of spend is equal across products. However, products obviously have a range of values, and whilst all other products can be sold and stored at ambient temperatures, food and drink may either be heated or cooled. All of these factors indicate that in order to better estimate the impact of food and drink retail, additional data would be required in future.

## Catering

In 2011 there were 1,551,476 food and beverage service enterprises in the EU-28 (Eurostat 2014g), including restaurants, mobile catering and event catering. The same approach has been taken to catering as waste taken to retail, with UK data per active enterprise extrapolated to the EU.

**Table 8.15: Greenhouse gas emissions associated with EU catering, 2012**

| Geographic Area | Population of food and beverage service enterprises, 2012 | Greenhouse Gas Emissions, (Mt $CO_2$eq) |
|---|---|---|
| **UK** | 148285 | 6.51 |
| **EU-28** | 1551476 | 68.1 |

The assessment suggests a figure of 68.1 million tonnes $CO_2$eq associated with catering. As with retail, there are a number of limitations to this assessment based on the climate in different countries and dietary choices.

## Consumer Transport.

Whilst information on the modal split of passenger transport across the EU is collected on a regular basis by Eurostat (2014h), the purpose of these journeys is not collated. This means it is not possible to use this data source for estimates of the impact of consumer shopping. A literature review was therefore carried out for National Travel Surveys across EU Member States. Seven surveys were identified containing data on travel associated with shopping measured in distance, and a further two contain data covering the percentage of travel. The output of these studies is covered in Table 8.16.

The population for each of the countries identified is also recorded, and the average distance travelled by an EU citizen has been estimated using a population-based weighted average for the countries listed in Table 8.16. This suggests that the average EU citizen travels over 1900 km per year for shopping.

As with retail emissions, an economic allocation has been taken. As 54% of expenditure on shopping is associated with food and drink, it has been assumed that 54% of all journeys by all modes of transport are for the purchase of food and drink. This suggests that around 69 million tonnes $CO_2$eq are emitted through travel for food and drink shopping in 2012.

There are a number of limitations to this method. Firstly, the methods used for average shopping may not reflect food and drink shopping, as this may be more local than shopping for items such as clothing and electrical products. Secondly it is based on a limited number of travel surveys which may not represent other EU member states with differing population densities.

**Table 8.16: Consumer travel for shopping in the EU**

| Country | Reference | Year of data | Unit | % of all journeys | Walk | Bicycle | Car | M.cycle | Bus | Train | Other | Annual Total | Popn (million) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | BMVIT (2012) | 2011 | % | 17% | 12% | 10% | 67% | | 1% | | | | 8.4 |
| | | | Km p.a. | | 257 | 214 | 1626 | | 21 | | | 2119 | |
| Belgium | BELDAM (2012) | 2009 | % | 12% | 21% | 9% | 64% | | 5% | | 1% | | 10.7 |
| Finland | Liikennevirasto (2012) | 2011 | % | 18% | 4% | | 72% | 4% | 19% | | | 2701 | 5.3 |
| | | | Km p.a. | | 108 | | 1945 | 108 | 513 | | | | |
| Germany | Follmer et al (2010) | 2008 | % | 21% | 28% | 11% | 49% | | 7% | | | | 82 |
| | | | Km p.a. | | 756 | 297 | 1323 | | 189 | | | 2566 | |
| Italy[30] | ISFORT (2013) | 2010 | % | 29% | 20% | 2% | 71% | 1% | 7% | | | | 60 |
| | | | Km p.a. | | 451 | 48 | 1613 | 23 | 154 | | | 2288 | |
| Malta | PriceWaterhouseCoopers (2010) | 2010 | % | | 4% | | 16% | | 77% | | 2% | | 0.4 |
| Netherlands | Statistics Netherlands (2013) | 2012 | % | 9% | 5% | 14% | 72% | 1% | 2% | 5% | 2% | | 16.4 |
| | | | Km p.a. | | | | | | | | | | |
| Sweden | Official Statistics of Sweden (2014) | 2012 | % | 13% | 3% | | 94% | | 5% | | 3% | | 9.2 |
| | | | Km p.a. | | 37 | | 1301 | | 72 | | 35 | 1378 | |
| United Kingdom | Department of Transport (2013) | 2011 | % | 20% | 3% | <1% | 82% | <1% | 8% | 4% | 1% | | 61.7 |
| | | | Km p.a. | | 40 | 3 | 1040 | 3 | 103 | 55 | 18 | 1262 | |
| EU-28 Population | | | % | | 20% | 6% | 65% | <1% | 7% | 1% | <1% | | 504 |

[30] Family business here interpreted as including shopping

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weighted Average | | | | | | | | | | | | | |
| | | | Km p.a. | | 389 | 120 | 1257 | 9 | 143 | 14 | 6 | 1938 | |
| $CO_2$eq emissions per km | | | | | 0 | 0 | 0.19 | 0.12 | 0.10 | 0.05 | 0.10 | | |
| EU-28 Million Tonnes $CO_2$ eq emissions, all shopping | | | | | 0 | 0 | 119.9 | 0.5 | 0.7 | 0.3 | 0.3 | 128 | |
| Of which associated with food and beverages (by final consumption expenditure) | Eurostat (2014f) | | | 54% | | | 64 | 0.3 | 0.4 | 0.2 | 0.2 | 68.9 | |

## Home-related impacts

Lapillone and Pollier (2014) suggest that in 2011, households in the EU-27 used 18Mtoe (million tonnes oil equivalent) of energy for cooking, 67 TWh for refrigeration and 34 TWh for freezers. In addition, a further 24 TWh were associated with dishwashers.

No EU statistics are available for greenhouse gas emissions per kWh since 2009. Therefore, the same approach has been taken for home related impacts as manufacturing impacts to convert the figures from Lapillone and Pollier into greenhouse gas emissions.

Eurostat (2014b) provides final energy consumption statistics for the EU-28 for electricity and derived heat. Assuming that the average intensity of emissions for electricity and derived heat consumed by households is the same as the average intensity of energy use by manufacturing, this suggests that per Mtoe final energy consumption, 4.4 million tonnes CO2eq were produced. Table 8.17 summarises the energy use and associated greenhouse gas emissions associated with activities in the home.

**Table 8.17: Emissions associated with home energy use.**

| Household activity | TWh | Mt | Mt $CO_2$ eq |
|---|---|---|---|
| **Cooking** | | 18 | 76 |
| **Refrigeration** | 67 | 5.76 | 24 |
| **Freezer** | 34 | 2.92 | 12 |
| **Total** | | 26.68 | 113 |

## Disposal

Estimated shares of food waste to different recovery and disposal operations has been taken from Table 8.6. Average European performance characteristics to each management route have then been applied based upon Gibbs et al (2014). (e.g. the proportion of landfill gas captured, the efficiency of energy recovery). The results of this assessment are presented in Table 8.18. Please note that a credit is given for avoided fossil fuels in energy recovery and anaerobic digestion.

**Table 8.18: Disposal Routes and Greenhouse gas emissions for food waste**

| Recovery and disposal operations | Estimated shares (see Table 8.6) | Food waste in Mt | Conversion Factor (t $CO_2$eq per tonne of waste) | GHG emissions in Mt $CO_2$eq |
|---|---|---|---|---|
| **Composting** | 46.5% | 48.3 | -0.039 | -1.9 |
| **Anaerobic digestion** | 11.7% | 12.1 | -0.111 | -1.3 |
| **Co-generation** | 11.6% | 12.0 | -0.089 | -1.1 |
| **Incineration** | 6.9% | 7.2 | 0 | 0.0 |
| **Landfill** | 23.2% | 24.1 | 1.105 | 26.6 |
| **Discard to land/sea/backfilling** | 0.1% | 0.1 | 0.0222 | 0.003 |
| **Total** | | 103.8 | | 22.3 |

**Data uncertainties and data gaps**
There are a number of data uncertainties in the top down approach. Where national inventory data is available for a sector, this should be considered as being of good quality. However, in many instances, the data available does not fit the food and drink supply chain perfectly. For example, it contains tobacco, or covers an activity, within which the contribution of food and drink must be estimated. Furthermore, data on consumer transport and household energy use in particular are derived from ad-hoc data sources which may not be replicable. However, data was identified for all stages being considered and the exercise suggests that this is replicable, and that data uncertainties could be reduced.

# 8.5 Results

## 8.5.1 Bottom up results

**Results for each indicator product - polluter pays principle**
The bottom up approach is based on GWP values of specific indicator products. Food products strongly vary in their GWP values. Especially strong variations can be observed between vegetal and animal containing food products. In the following pages, vegetal indicator products are shown in Figure 8.5 and animal containing products are shown in Figure 8.6. The figures are scaled differently as the GWP emissions from animal containing products are generally higher than those from vegetal products.

The results show the emissions on an actor based perspective allocating the waste to the step in the step responsible for it (polluter pays principle). It means, food which is wasted in the consumption stage is responsible for the emissions of their production, processing, transport, retail and consumption (see Figure 8.2 for food wastage and its associated environmental impacts). The emissions are related to 1 kg of consumed food.

When interpreting the results, it is interesting to see how emissions related to food wastage can affect the overall results within each steps of the supply chain considerably. As most of the food is wasted in the consumption stage, emissions related to this food wastage are accounted to this stage. Therefore not only emissions from cooling and cooking, which are typical for the consumption stage, but also emissions from the production, processing, transport and retail are found in this stage. It increases the total emissions in this step considerably and underlines the importance of applying food waste prevention activities in this stage.

**Figure 8.4: Background information for interpretation of results in the following figures**

Example:

1.3 kg apples need to be produced to receive 1 kg for consumption (0.3 kg are wasted in different steps of the supply chain)

1 kg out of 1.3 kg apples are consumed

*… Emissions related to this 1 kg are shown in grey bars.*

0.11 kg out of this 1.3 kg apples are wasted in the production phase

*… Emissions related to this food wastage are shown in patterned blue colours.*

0.01 kg out of 1.3 kg are wasted each in the processing and retail phase

*… Emissions related to this food waste from the production are shown in patterned blue colours in the specific steps of the supply chain.*

*... Emissions related to this food waste from the processing are shown in patterned orange colours.*

*... Emissions related to this food waste from the retail phase are shown in light blue colours.*

0.17 kg out of 1.3 kg are wasted in the consumption phase

*… Emissions related to this food waste from the production are shown in patterned blue colours in the consumption phase .*

*....*

TRANSPORT: Emissions deriving from transports between production, processing and retail are shown in the red bar. There is no food waste deriving from this phase. Yet, food which becomes waste in each step of the supply chain was transported before, therefore also patterned red bars are shown in this relation. Consumer travel is covered in the consumption phase and not shown extra.

END OF LIFE: EoL related emissions are shown in green colours and are attributed to the phase which is responsible for the food waste.

**Figure 8.5: Global Warming Potential in kg $CO_2$-Equivalents per kg consumed indicator product for all life cycle stages – Vegetal products**

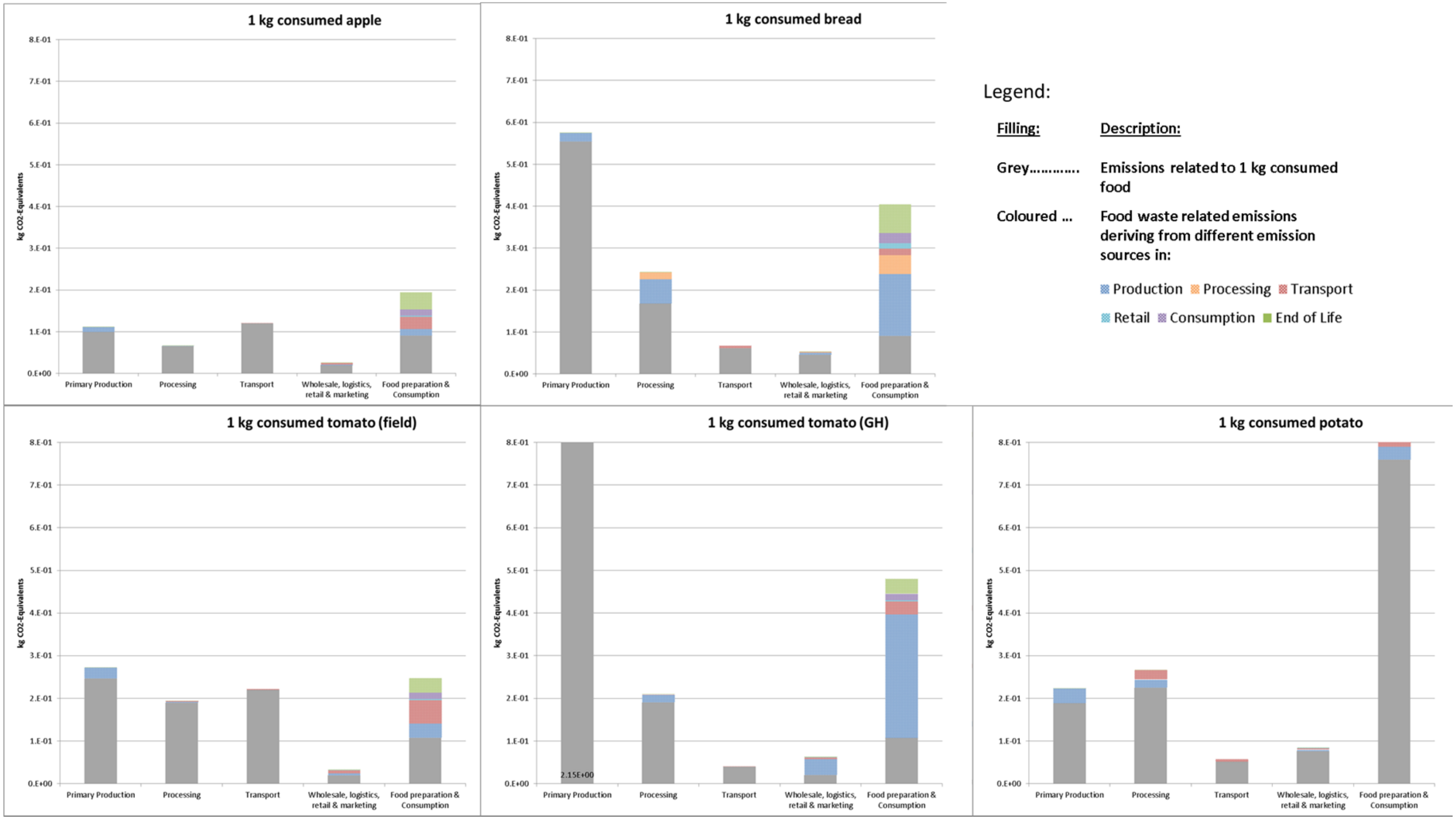
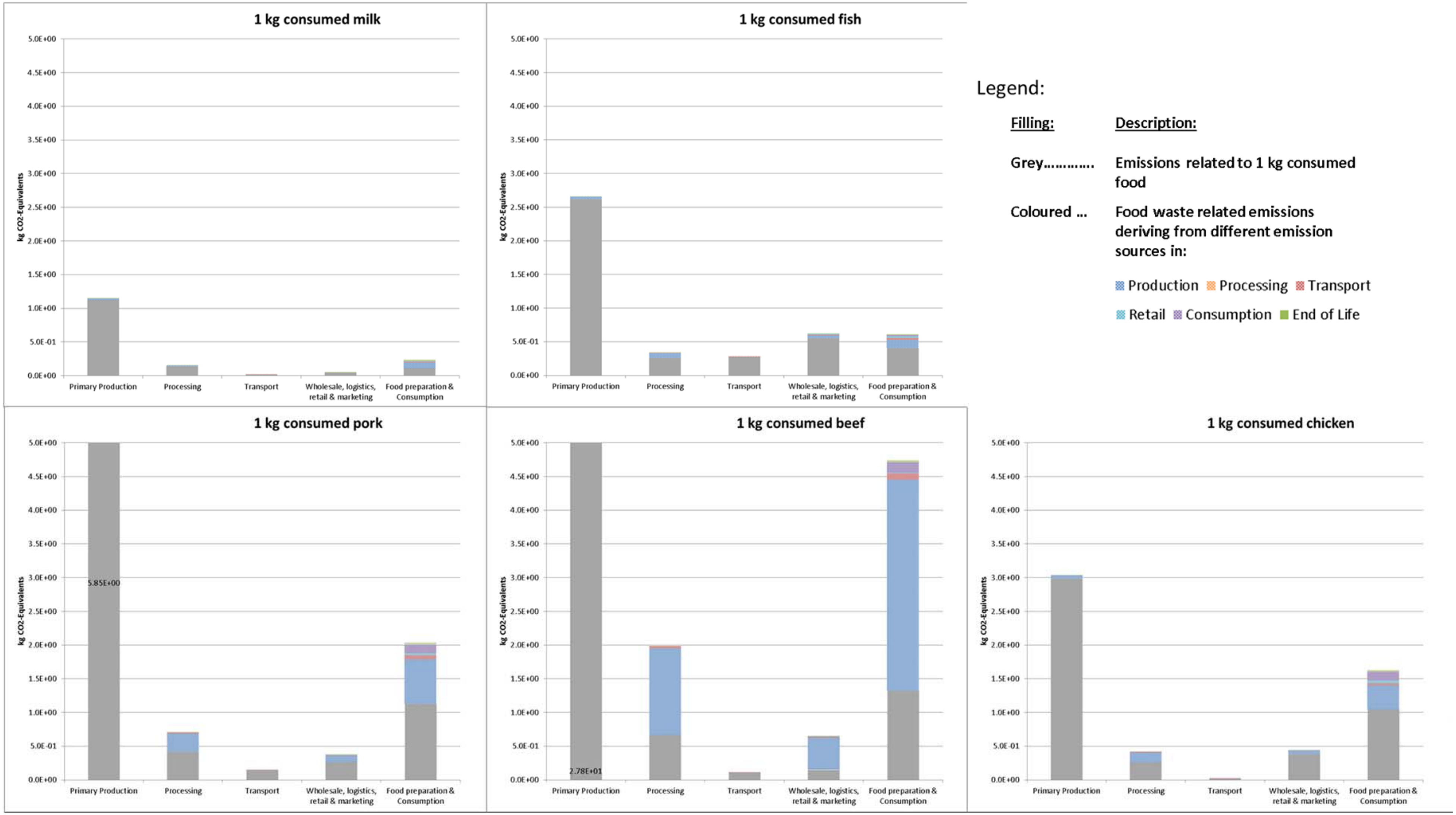


**Figure 8.6: Global Warming Potential in kg $CO_2$-Equivalents per kg consumed indicator product for all life cycle stages – Animal containing products**



**Extrapolation of results**

The above results for each indicator product reveal the hotspots of GWP if only the product itself is looked at. For an extrapolation of results to the consumer diet level the GWP per indicator product is summed up according to the composition of domestic food utilization in EU 2011 (see Table 4.2). The remaining food products which are not represented by the indicator products, are scaled up with the same factor as the indicator product composition.

The results show that the Global Warming Potential (GWP) of food waste in EU is estimated to be around 227 Mt $CO_2$ eq. This is 16% of the total GWP of domestic food utilization in Europe (absolute amount: 1,382 Mt $CO_2$ eq.).

When interpreting the results the following biases need to be considered:

- The results are only estimates of the current situation on food waste
- Food waste data is currently not available on product level. Therefore the approach of Gustavsson et al (2013) was used for estimating the shares of food products.
- Indicator products were chosen which are most relevant by mass of utilized food. A further investigation of the most relevant products by environmental impacts is essential.
- Valorisation opportunities of food which is removed from the food supply chain (e.g. animal feed) was not considered due to lack of data on mass flows. An inclusion would lower the total impacts of food removed from the supply chain, but not of food waste.

Food waste related emissions are shown in two ways: one from the perspective of the polluter (polluter-pays principle) and one from the perspective of the emitter (emission origin based). Figure 8.7 shows it from the perspective of the polluter. As the consumption stage produces most of the food waste, this also reflects the situation that most of the environmental impacts are accounted to this consumption stage with 153.27 Mt $CO_2$ eq (68%). Emissions which are attributed to the production, processing and retail stage show a much lower amount than in the consumption stage. Emissions from End of Life (EoL) operations are not displayed in addition here. EoL emissions are attributed to the stage of the supply chain where food waste occurs.

The composition by indicator products is only shown for utilized food (a composition by indicator products for food waste would not reflect the real situation): 30% beef, 20% pork, 21% milk, 10% bread, 6% potato, 6% chicken, 4% fish, 2% tomato and 1% apple. The total mass of indicator products represents 66% of the total food utilization in the EU in 2011.

**Figure 8.7: Estimation of GWP of current consumed and wasted food in EU in Mt $CO_2$ eq with disposition of emissions from consumed food by indicator products (left) and food waste related GWP on the polluter pays principle (right)**

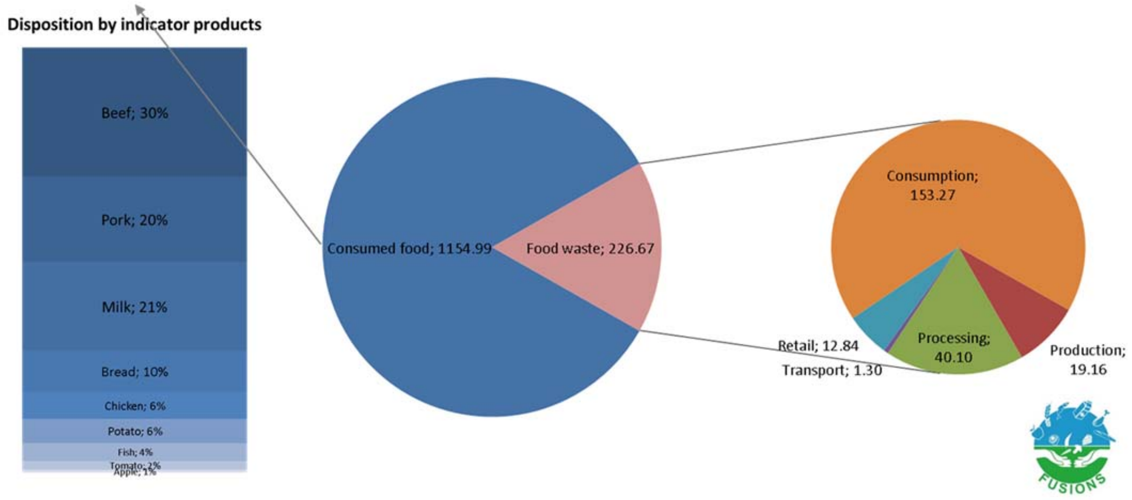
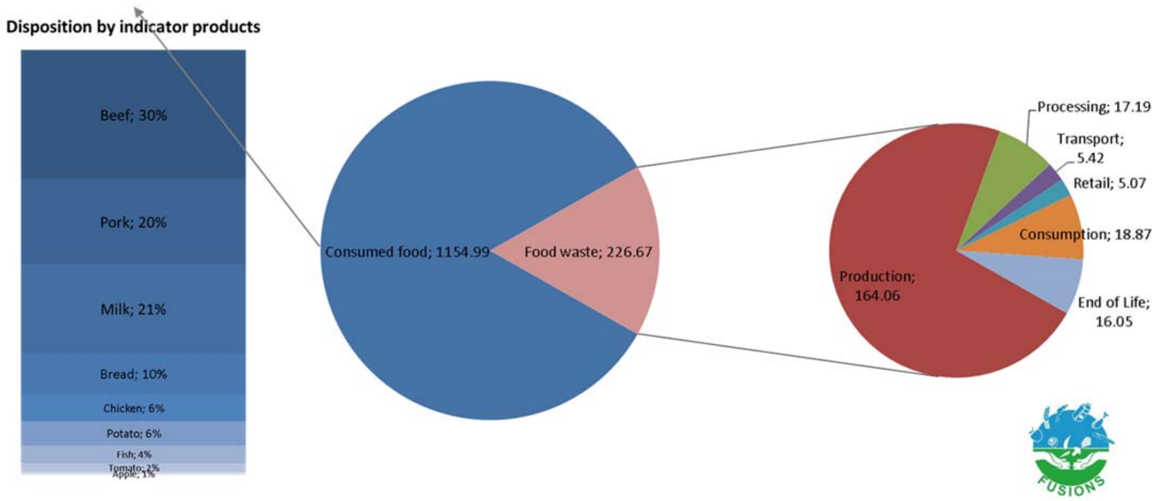



Figure 8.8 shows the results based on the origin of emissions. Most of the emissions (72.4%) derive from the production stage, as this stage is very resource and energy demanding. The consumption stage of the food supply chain accounts for 8.3% of the total GWP of food waste, this is related to consumer travel and cooking habits of the consumers. 7.6% derive from the processing stage and 7.1% from the waste handling in the end of life (EoL) stage. Most of the emissions from the EoL can be attributed to landfill associated emissions, as this is currently the most used operation for food waste at consumer level. Transport and retail activities account for only 2.4% and 2.2% respectively of the food waste related emissions.

**Figure 8.8: Estimation of GWP of current consumed and wasted food in EU in Mt CO2 eq with disposition of emissions from consumed food by indicator products (left) and food waste related GWP on the view of the emission origin (right)**



**Acidification and Eutrophication Potential**

As mentioned previously in the methodology section, other environmental impact categories than the GWP are considered within the bottom-up approach to obtain a fuller picture of overall environmental impacts. A data base was created for the acidification potential (AP) and the eutrophication potential (EP) of the indicator products similar to the database with GWP values (the values can be found in Annex 10.6 and 10.7).

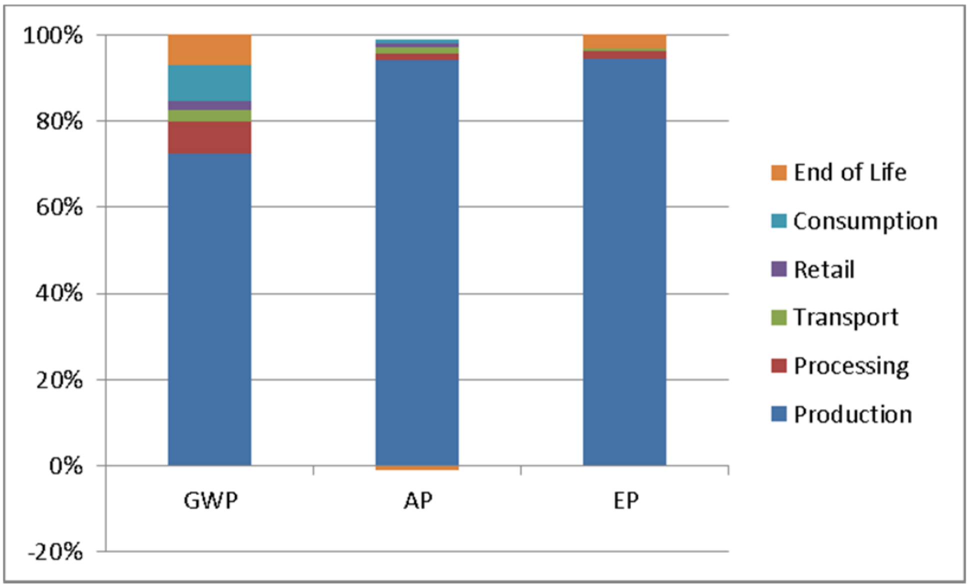
The environmental impacts of the total food supply chain and the food waste itself for GWP, AP and EP are shown in Table 8.19.

**Table 8.19: Absolute results of GWP, AP and EP**

| Environmental impact categories | Total emissions (food consumed and food waste) | Food waste related emissions |
|---|---|---|
| GWP in Mt $CO_2$ eq | 1377.10 | 212.19 |
| AP in Mt $SO_2$ eq. | 13.29 | 2.04 |
| EP in Mt $PO_4$ eq. | 6.00 | 0.96 |

The impacts in each stage of the food supply chain are shown in Figure 8.9. It can be seen that the share of the production stage on the total emissions is higher in the AP and EP. Furthermore it can be seen that emissions from the End of Life stage show negative results in the AP, meaning that there are in total environmental benefits from EoL operations. For a further interpretation of results, the results need to be looked at in more detail. Therefore these results are only a starting point for further investigations.

**Figure 8.9: GWP, AP and EP emissions on food waste (emission origin perspective)**



**Sensitivity analysis**

The research for the bottom up inventory data revealed certain data uncertainties and data gaps. To identify the potential effects on the overall results, a sensitivity analysis should be carried out for the following parameters:

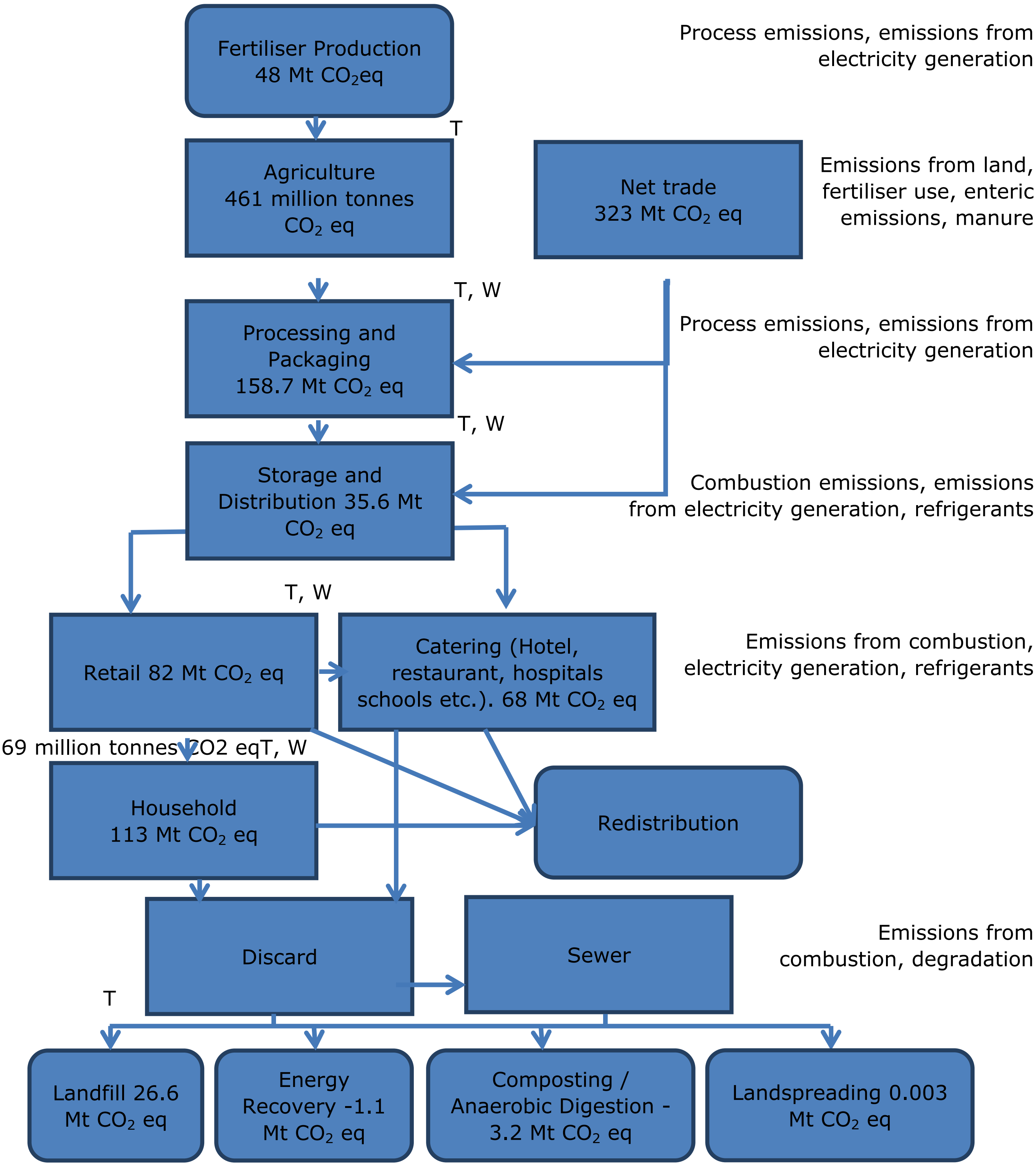
1. Variances in the food waste quantities (variances of The FUSIONS data set from Oct 2015)
2. Weighting within indicator products (change in consumption behaviour)
3. Uncertainties of GWP database
4. Variances in the transport sector
5. Variances in the EoL stage

Due to time limitations within this task, a selection of above mentioned sensitivity analyses needed to be done. As the transport and EoL stage are in the view of environmental impacts not so relevant compared to production and consumption steps, these analysis were neglected. The change in consumption behaviour is also difficult to predict and would demand a deeper research on further literature on this topic. Uncertainties of the GWP database would also demand more research on this topic and also on other indicator products – however, the database represents a comprehensive collection of current LCA studies of the indicator products.

The sensitivity analysis within this task covers therefore only variances of food waste quantities, as this is one of FUSIONS major outputs. As preliminary data on food waste quantities is used and changes of this data are expected to be within the variances, the results of the environmental assessmen are also adapted to these variances. It shows that the overall share of food waste related emissions on the total emissions is 16% ±3%.

### 8.5.2 Top down results

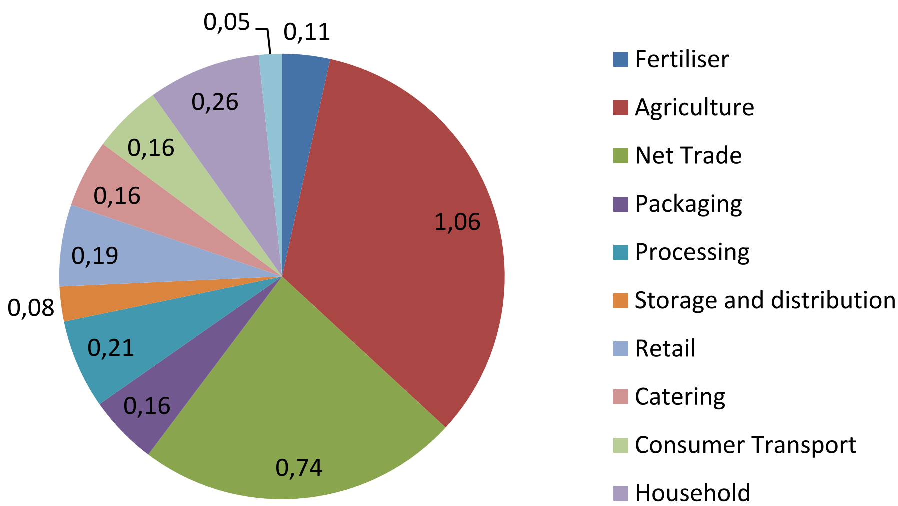
**Figure 8.10: GWP per stage of the food supply chain (T = Transport, W = Waste)**




The average impact per tonne has been allocated using the food waste data set from FUSIONS (Status from Oct 2015).

The results were divided by the total amount of domestic food utilization in EU 2011, and suggest that the average GWP of a tonne of food and drink consumed in the EU-28 is estimated to be around 3 tonnes $CO_2$eq per tonne. The composition of this is shown in Figure 8.11. Although these are for different years, the difference in food utilization from one year to the next is unlikely to vary significantly and so the results are not considered to be sensitive to this.

**Figure 8.11: Composition of GWP of an average kilogram of food purchased by a consumer (kg $CO_2$eq).**




At an EU level, the GWP of food and drink is dominated by on-farm impacts, both within the EU and overseas followed by household emissions. All other life cycle stages contributing a broadly similar quantity of greenhouse gas emissions each.

### 8.5.3 Comparison of results

The results of both approaches, bottom-up and top-down, are shown again in Table 8.20 for a direct comparison. Results for the total greenhouse gas emissions associated with food consumed in the EU in 2011 arrive at a very similar figure for both approaches. Although the share of food waste related emissions is different in the two approaches used. The top-down approach shows a share of 22% of food waste related emissions from the total emissions and the bottom-up approach resulted in 16%.

As many of the data points used for the top-down approach are single sources, it is not possible to identify the statistical uncertainty associated with this approach. It is therefore not possible to say whether the difference in the results from the two approaches is statistically significant.

The emissions per tonne of waste arising, accounting for the point in the supply chain at which the waste arises is also shown in Table 8.20. This is a different functional unit. The average GWP of a tonne of food waste across the whole life cycle of food in the top-down approach is 2.9 tonnes $CO_2$eq. The average GWP of a tonne of food waste arising at a household is 5.4 tonnes $CO_2$eq. This figure is higher for two particular reasons. Firstly, because emissions accumulate through the supply chain as further processing / activity is undertaken with the food. Secondly whilst less than 5% of food waste from production and processing goes to landfill, 37% of food waste from food preparation and consumption is estimated to go to this destination. Landfill is the waste management route with the highest emissions per tonne, and over six times as much food waste from preparation and consumption enters landfill as all previous stages combined.

For food waste, the top down approach reallocates the emissions associated with waste from the point at which the waste arises to the point at which the emissions were incurred. For example, food wasted in storage and distribution will have also been associated with emissions from agriculture, processing and packaging.

Both approaches used different methods for allocating the emissions to the stages of the food supply chain. Furthermore different data sources were used for the assessment. Therefore it is clear, that variations occur when results are compared in detail. The methodologies used for the environmental assessment in FUSIONS shall give an estimation on food waste related emissions. The individual data sources still come with certain uncertainties, which need to be considered with further research. These results present a starting point and recommendations for further investigations. Nevertheless, they provide a useful indication of the scale of the environmental impact of food waste within the EU's food supply chain.

**Table 8.20: Global Warming Potential of food consumed in Mt $CO_2$ eq in EU 2011 – Comparison of Top-down and Bottom-up approach**

| **Life cycle stages in Mt $CO_2$ eq** | **Top-down approach** | | **Bottom-up approach** | | |
|---|---|---|---|---|---|
| | **Total (Consumed food and food waste)** | **Food waste only** | **Total (Consumed food and food waste)** | **Food waste only (emission origin based)** | **Food waste only (polluter-pays principle)** |
| Fertiliser Production | 48.00 | 11.47 | | | |
| Agriculture | 461.00 | 110.26 | | | |
| Net trade | 323.00 | 77.25 | | | |
| Total production | 832.00 | 198.99 | 882.22 | 164.06 | 19.16 |
| Processing and Packaging | 158.70 | 32.67 | 125.62 | 17.19 | 40.10 |
| Storage and Distribution | 35.60 | 6.30 | 26.13 | 5.42 | 1.30 |
| Retail | 82.00 | 11.56 | 49.85 | 5.07 | 12.84 |
| Catering | 68.00 | 8.87 | | | |
| Household | 113.00 | 23.74 | | | |
| Total consumption | 182.00 | 32.61 | 281.79 | 18.87 | 153.27 |
| Redistribution | | | | | |
| Discard | | | 0.005 | 0.005 | |
| Sewer | 0.01 | 0.003 | | | |
| Landfill | 27.10 | 26.6 | 18.26 | 18.26 | |
| Energy Recovery | -1.1 | -1.1 | -1.69 | -1.69 | |
| Incineration | | | 0.35 | 0.35 | |
| Composting/Anaerobic digestion | -2.9 | -3.2 | -0.85 | -0.85 | |
| Other | 0.003 | | | | |
| End of Life | 22.3 | 22.3 | 16.05 | 16.05 | |
| **Total** | **1379.97** | **304.43** | **1381.66** | **226.67** | **226.67** |
| **Share of food waste related emissions** | | **22%** | | **16%** | **16%** |

## 8.6 Discussion and Conclusions

Both approaches show a result of around 3.2 kg $CO_2$-Equivalents per kg consumed food. Food waste related emissions estimated at 16% to 22% of the total emissions of consumed food in the bottom-up approach and the top-down approach respectively. Most of the emissions can be attributed to the production stage, followed by the food consumption stage. Distribution and End of Life play a rather insignificant role. When it comes to an attribution of emissions to the polluter pays principle, the consumption stage shows the most impacts.

The top down approach has identified that regularly updated information is available to allow the calculation of emissions associated with fertilizer production, agriculture, manufacturing and distribution of food and drink. These account for just under half of the estimated emissions above. Regularly updated information is also available on international trade in food and drink, the number of retail and catering premises, but emissions associated with these activities can only be inferred using other literature. These account for approximately a third of the emissions above. Data on packaging, consumer transport and household energy use is not available on a regular basis. These account for around one fifth of the emissions above. It would therefore be challenging to update the full assessment of the GWP of EU-28 food and drink on a regular basis.

The bottom-up approach shows emissions associated in two ways: emissions deriving from each stage of the supply chain and based on the polluter pays principle. It can be noticed that most of the emissions can be attributed to the production phase, but when it comes to level of food waste arisings, the consumption phase shows the most significance.

The advantage of the bottom-up approach is that results are available on product level. This enables the setting of exact waste prevention measures. Results show that most of the emissions can be attributed to the consumer stage, but also the beef in the wholesale stage shows very high impacts for food waste related emissions. Thus, if measures are set on this product or even product category, the environmental emission reduction in this step of the food supply chain would be significant. The advantage of the top-down approach is that relatively few data sets are required, and official statistics provide most of the key data. However, the data gaps identified mean that replication on a regular basis is challenging.

The additional insight from using both approaches at the same time is to consider how well the results align. Though it is not possible to state the level of uncertainty around the results, and therefore the statistical confidence, the two approaches can give an estimation of the food waste related emissions. As a comparator, the top down approach therefore suggests that it is possible to use selected products as indicative of the greenhouse gas emissions associated with wider product categories.

The most crucial point when interpreting the results from the top-down and the bottom-up approach is that a major material flow, which is food and inedible parts removed from the food supply chain going the conversion and valorisation step, is not covered in the assessment. Credits given via system expansion of food which is converted or valorised may change the overall emissions considerably. Yet, the absolute results which are based on food waste only would remain the same. Only the given share of food waste on the total emissions might be underestimated.

## 8.7 Recommendations

Out of the findings of the top down and bottom-up approach the following recommendations can be made:

- Representative products can be identified within wider product categories and used as proxies to identify environmental impacts, with little overall difference between the top down and bottom up approaches. The level of detail required on the composition of food waste may therefore be relatively high in order to estimate the environmental impacts
- It is necessary to take a detailed look at variances of emissions originating in the production sector for specific products for each product category. The present work showed that sufficient data is available for the indicator products. Other products may have an important role in terms of environmental impacts and should therefore be investigated and set in relation to the total consumed food.
- A top-down approach appears to offer a rapid way of approximating the GWP of food and food waste. However, in order for this assessment to be updated and be made more precise, a number of regular and more detailed data sets would be required. In particular, greater detail on the nature of energy use in retail, catering and households.
- A top-down and bottom up approach can be used to assess the results of an assessment of the environmental impact of food waste in the absence of statitistical uncertainty.
- A bottom-up approach from the perspective of the polluter pays principle can give valuable background information for setting detailed and specified waste prevention strategies and also predict the possible effect of such strategies
- A bottom-up approach from the perspective of the emission origin can give valuable input to the actual operations where the emissions are coming from.
- Next to environmental indicators, it is necessary to deepen the knowledge about food waste amounts specifically on product level or at least at product category level
- In respect of food waste valorisation, a deeper understanding of the End of life step of the supply chain needs to be carried out as many data gaps are still present there.

The following data gaps were identified for further research in order to receive a more accurate picture of the GWP of food waste in the entire EU's food supply chain:

- Food waste data on product category level. More data on food waste shares on product category level can support and update the findings of Gustavsson et al. (2013) – FAO FLW data
- Data on recovery and disposal options for food waste (Not biodegradable waste). Information is existing for recovery and disposal options for biodegradable waste. Food waste and food residues are handled in a different way and shall therefore be evaluated differently. Focus shall also be given at amounts for home composting and separate collected kitchen waste from food service and households.
- Data on food and inedible parts removed from the food supply chain going to valorisation and conversion in EU.

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# 10 ANNEX

## 10.1 Food waste along the value chain on product level

In this part food waste and losses in EU were evaluated. Food waste and losses in the EU are considered here to be food waste and loss volumes that occur inside the borders of the EU. This includes all value chain steps inside the EU borders where food waste and losses occur (e.g. food waste during agriculture and postharvest in the EU and food waste in households within the EU).

**Data and methodology**
FUSIONS food waste data set from October 2015 showed data on aggregated level. As the approaches used in the assessment in FUSIONS demand data on product level, data needed to be retrieved from literature sources. The following data sources were used to derive an educated guess on the food waste amounts on product level:

- Approach by Gustavsson et al (2013) to estimate food waste for different product groups (calculation formulas; including allocation - and conversion factors presented in the report)
- Weight percentages of food losses and waste (in percentage of what enters each step) by Gustavsson et al. 2011 to receive data on product level (Table 10.1)
- Food Balance Sheets:
    - Food production in EU in 2011 (Excl. alcohol) according to FAOSTAT to add a weighting to the agriculture and post-harvest categories (Table 10.2)
    - Domestic utilizations in EU in 2011 (Excl. alcohol) according to FAOSTAT to add a weighting to the production, retail and consumption categories (Table 10.2)
- Quantified FUSIONS food waste data set (from Oct 2015) to include the amounts on aggregated level

To estimate absolute and relative shares of food waste in each step of the food chain we used the approach by Gustavsson et al (2013). In common with their approach, we used Food Balance Sheet data, whilst, the data in our study was from 2011 and the area was the EU. Additionally, whereas Gustavsson et al include most of the food categories they have not included all food categories. We included the biggest missing categories: sugar crops, nuts, offal and animal fat. The approach for sugar crops was same as for oil crops; the approach for nuts was same as for pulses; and the approach for offal and animal fat was same as for meat.

The use of the approach by Gustavsson et al (2013) is demonstrated below: "Example of the use of approach by Gustavsson et al (2013)" with an example of "Roots & tubers". We used the same approach (more detailed approaches for each category are presented in Gustavsson et al 2013) for all food categories and calculated the total waste sums for all steps of the food chain: the steps of the food chain in the FUSIONS data set from Oct 2015 are "Production, Processing, Wholesale and retail, Food services and Households" and in Gustavsson et al the steps are "Agriculture, Postharvest, Processing, Distribution, Consumption" we created four final steps: "Production" (where we combined waste from "Agriculture" and "Postharvest")", "Processing", "Distribution" (is seen same as "Wholesale and retail") and "Consumption" (where we combined waste from "Food services" and "Households").

We compared the food losses/waste amounts of different food categories (calculated using the approach by Gustavsson et al 2013) within each step to estimate the relative shares of food losses/waste for each food category (Table 10.5). For instance the food losses/waste of "Roots & tubers" in "Production" is estimated to be 17 393 thousand tonnes (see example) and the total food losses/waste in "Production" is an estimated 67 817 thousand tonnes[31]. Therefore, the relative share of food losses/waste of "Roots & tubers" in "Production" is 26 % (Table 10.5).
Furthermore, we used these relative food loss/waste shares i.e. "allocation factors" of product categories (Table 10.5) to divide the total of FUSIONS food waste data set (from Oct 2015). As an example: 26 % of "Production waste" is estimated to be "Roots & tubers" and the total losses/waste of "Production" is estimated as 25 700 million tonnes in FUSIONS. Therefore, we used the following formula: *0.26 * 25 700 (Food waste (million tonnes) in Production*, Table 10.4*) =6 591.* Consequently, 6 591 million tonnes of "Roots & tubers" is lost/wasted during production.

Moreover, indicator product specific food loss/waste estimates were calculated simply by using the information on the indicator product's representativeness in its product category and assuming the same losses/waste for all products within same product categories. For instance, "potato" represents 99.9 % of production of "Roots & tubers" and thus the losses/waste of potato production is 6 591 * 0.999 = 6 582.

[31] The methodologies and system boundaries of the FUSIOSNS food waste data set and Gustavsson et al 2013 are different, and due to these differences the food waste levels are higher when Gustavsson et al 2013 is used in comparison food waste data set of FUSIONS.

**Table 10.1: Percentages of food losses and waste in different steps of the value chain in EU. Gustavsson et al 2013(in percentage of what enters each step), m= milling, p=processed, f=fresh**

| Product category | Agriculture | Postharvest | Processing | Retailing | Consumption |
|---|---|---|---|---|---|
| Cereals | 2.0 % | 4.0 % | 0.5 %(m), 10.0 %(p) | 2.0 % | 25.0 % |
| Root & tubers | 20.0 % | 9.0 % | 15.0 % | 7.0 %(f), 3.0 %(p) | 17.0 %(f), 12.0%(p) |
| Oil crops & pulses | 10.0 % | 1.0 % | 5.0 % | 1.0 % | 4.0 % |
| Fruits & vegetables | 20.0 % | 5.0 % | 2.0 % | 10.0 %(f), 2.0%(p) | 19.0 %(f), 15.0%(p) |
| Meat | 3.2 % | 0.7 % | 5.0 % | 4.0 % | 11.0 % |
| Fish | 9.4 % | 0.5 % | 6.0 % | 9.0 %(f), 5.0%(p) | 11.0 %(f), 10.0%(p) |
| Dairy | 3.5 % | 0.5 % | 1.2 % | 0.5 % | 7.0 % |
| Eggs | 4.0 % | - % | 0.5 % | 2.0 % | 8.0 % |

**Table 10.2: Food production and Domestic utilization, EU 2011 (excl. alcohol). 1000 tons**

| Product category | Production in EU 2011 (excl. alcohol) | Domestic utilization in EU 2011 (excl. alcohol): food | Domestic utilization in EU 2011 (excl. alcohol): food manufacture[2] |
|---|---|---|---|
| Cereals | 293 091 | 63 367 | 18 606 |
| Roots & tubers | 62 383 | 36 549 | 2 156 |
| Oil crops/oil, sugar crops/ sugar&sweeteners, pulses, & nuts[1] | 172 976 | 35 286 | 482 |
| Fruits & vegetables | 130 353 | 109 511 | 24 599 |
| Meat, offal & animal fat | 58 675 | 49 761 | 460 |
| Fish & seafood | 6 735 | 11 597 | |
| Dairy & eggs | 162 410 | 127 927 | |
| TOTAL | **886 766** | **433 998** | **46 303** |

[1] Production: Oil crops, sugar crops, pulses and nuts. Domestic utilization: Vegetable oils, oil crops (excl. food manufacture), sugar & sweeteners, pulses and nuts

[2] Domestic utilization figures are only used for modelling food waste using the approach of Gustavsson et al.

**Table 10.3: Food production and Domestic utilization of indicator products, EU 2011 (excl. alcohol). 1000 tons**

| Product category | Production in EU 2011 (excl. alcohol) | Domestic utilization in EU 2011 (excl. alcohol): food | Domestic utilization in EU 2011 (excl. alcohol): food manufacture[1] |
|---|---|---|---|
| Apples and products | 11 717 | 9 302 | 1 839 |
| Tomatoes and products | 16 261 | 13 918 | |
| Potatoes and products | 62 298 | 36 473 | 2 153 |
| Cereals - Excluding Beer | 293 091 | 63 367 | 18 606 |
| Milk - Excluding Butter | 155 527 | 121 839 | |
| Bovine Meat | 8 059 | 7 947 | |
| Pigmeat | 23 374 | 20 489 | |
| Poultry meat | 12 285 | 11 003 | |

| | | | |
|---|---|---|---|
| White fish (Demersal) | 1 897 | 3 663 | |
| Indicator product TOTAL | **584 509** | **288 001** | **22 598** |

[1] Domestic utilization figures are only used for modelling food waste using the approach of Gustavsson et al. 2013

### Results

Results on food waste amounts are given for different steps of the value chain in the EU using the approach of Gustavsson et al. 2013 and data on production and domestic utilization amounts of FAOSTAT (Food Balance Sheet, EU 2011 (excl. alcohol)).

**Table 10.4: Food waste on product category level in 1000 tonnes, EU 2011 (based on the FUSIONS data set from Oct 2015)**

| Product category | Production | Processing | Retailing | Consumption | Total |
|---|---|---|---|---|---|
| Cereals | 2 348 | 6 577 | 527 | 16 907 | 26 360 |
| Roots & tubers | 6 591 | 3 600 | 497 | 4 152 | 14 840 |
| Oil crops/oil, sugar crops/ sugar&sweeteners, pulses, & nuts | 1 747 | 1 459 | 147 | 1 528 | 4 882 |
| Fruits & vegetables | 11 411 | 1 253 | 2 082 | 17 770 | 32 516 |
| Meat, offal & animal fat | 891 | 2 322 | 822 | 5 685 | 9 720 |
| Fish & seafood | 170 | 309 | 212 | 563 | 1 254 |
| Dairy & eggs | 2 541 | 1 380 | 312 | 9 996 | 14 229 |
| TOTAL (the FUSIONS data set from Oct 2015) | **25 700** | **16 900** | **4 600** | **56 600** | **103 800** |

**Table 10.5: Relative shares, "allocation factors", of food waste on product category level in each step of the food chain in EU[32]**

| Product category | Production | Processing | Retailing | Consumption | Total |
|---|---|---|---|---|---|
| Cereals | 9 % | 39 % | 11 % | 30 % | 25 % |
| Roots & tubers | 26 % | 21 % | 11 % | 7 % | 14 % |
| Oil crops/oil, sugar crops/ sugar&sweeteners, pulses, & nuts | 7 % | 9 % | 3 % | 3 % | 5 % |
| Fruits & vegetables | 44 % | 7 % | 45 % | 31 % | 31 % |
| Meat, offal & animal fat | 3 % | 14 % | 18 % | 10 % | 9 % |
| Fish & seafood | 1 % | 2 % | 5 % | 1 % | 1 % |
| Dairy & eggs | 10 % | 8 % | 7 % | 18 % | 14 % |
| TOTAL | **100 %** | **100 %** | **100 %** | **100 %** | **100 %** |

[32] It is assumed that the relative shares, "allocation factors", of food waste on product category level are proportional to the destinations of food waste. This is a strong assumption since Gustavsson et al. (2013) do not include the destinations of food loss and waste and thus the differences in boundary conditions in the FUSIONS approach and the approach of Gustavsson et al. (2013) cannot be fully taken into account.

**Table 10.6: Food waste on the level of indicator products in 1000 tonnes, EU 2011**

| Indicator product | Production | Processing | Retailing | Consumption | TOTAL |
|---|---|---|---|---|---|
| Apples and products | 1 026 | 103 | 175 | 1 479 | 2 783 |
| Tomatoes and products | 1 423 | 116 | 245 | 1 877 | 3 661 |
| Potatoes and products | 6 582 | 3 593 | 496 | 4 143 | 14 814 |
| Cereals - Excluding Beer | 2 348 | 6 577 | 527 | 16 907 | 26 360 |
| Milk - Excluding Butter | 2 432 | 1 352 | 259 | 9 460 | 13 504 |
| Bovine Meat | 122 | 367 | 137 | 898 | 1 524 |
| Pigmeat | 355 | 948 | 336 | 2 320 | 3 958 |
| Poultry meat | 186 | 527 | 187 | 1 291 | 2 192 |
| White fish (Demersal) | 48 | 98 | 67 | 178 | 391 |
| Indicator product TOTAL waste | **14 524** | **13 681** | **2 429** | **38 553** | **69 187** |
| Indicator product TOTAL waste / TOTAL waste (Status data set: Oct 2015) | **57 %** | **81 %** | **53 %** | **68 %** | **67 %** |

## Limitations of the study

There are several limitations that affect the food waste and loss estimates presented above. These include:

1) Food waste data is generated from secondary sources (FUSIONS food waste data set from Oct 2015 and Gustavsson et al 2013) and there are a few issues that should be noted:
    a. The methodologies and system boundaries of the secondary sources (FUSIONS food waste data set and Gustavsson et al 2013) are different, and therefore the results based on these two sources are not totally comparable. Due to these differences the food waste levels are higher when Gustavsson et al 2013 is used in comparison of food waste data set of FUSIONS.
    b. It is assumed that the relative shares, "allocation factors", of food waste on product category level (Table 10.5) are proportional to the destinations of food waste. This is a strong assumption since Gustavsson et al. (2013) do not include the destinations of food loss and waste and thus the differences in boundary conditions in the FUSIONS approach and the approach of Gustavsson et al. (2013) cannot be fully taken into account.Therefore, it is not evident that the allocation factors for the product categories (based on Gustavsson et al 2013) are reflecting the true waste shares of the waste amounts of FUSIONS food waste data set, but these allocation factors can be treated as "the best available guess" before we have more detailed FW data. Thus, it should be noted that the methodology used here is not sufficient enough to replace actual FW data on different food items, and therefore, more empahisis is needed to attain actual FW data in future.
2) The chosen indicator food products may differ from domestic utilization datasets (used in this study). E.g. one indicator product is 'apple' whereas in FAOSTAT the category is 'apples and products'.

## Example of the use of approach by Gustavsson et al (2013), "Roots & tubers"

*We estimated the losses/waste of roots and tubers using the percentages of food losses/waste in different steps (*Table 10.1*) of roots and tubers.*

*In agriculture losses/ waste were calculated to occur before the production and thus we used formula:*
*0.2/(1-0.2) * 62 383 (production of roots and tubers in EU in 2011) = 15 596*
*Where, 0.2 is 20 % food losses/waste of roots and tubers in agriculture (*Table 10.1*)*
*Furthermore, a conversion factor was used to estimate the fraction of primary product volumes that is edible.*
*0.82 * 15 596 = 12 789*
*Where, 0.82 is 82 % of roots and tubers is estimated to be recovered after peeling (Gustavsson et al 2013)*
*Total food losses/waste of roots and tubers in agriculture: 12 789*
*In postharvest losses/waste were calculated using the following formula:*
0.09 * *62 383 (production of roots and tubers in EU in 2011) = 5 614*
*Where, 0.09 is 9 % food losses/waste of roots and tubers in postharvest (*Table 10.1*)*
*Furthermore, a conversion factor was used to estimate the fraction of product volumes that is edible.*
*0.82 * 5 614 = 4 604*
*Where, 0.82 is 82 % of roots and tubers is estimated to be recovered after peeling (Gustavsson et al 2013)*
*Total food losses/waste of roots and tubers in postharvest: 4 604*
*Total food loos /waste in the "Production step" : 12789 + 4604=17393*

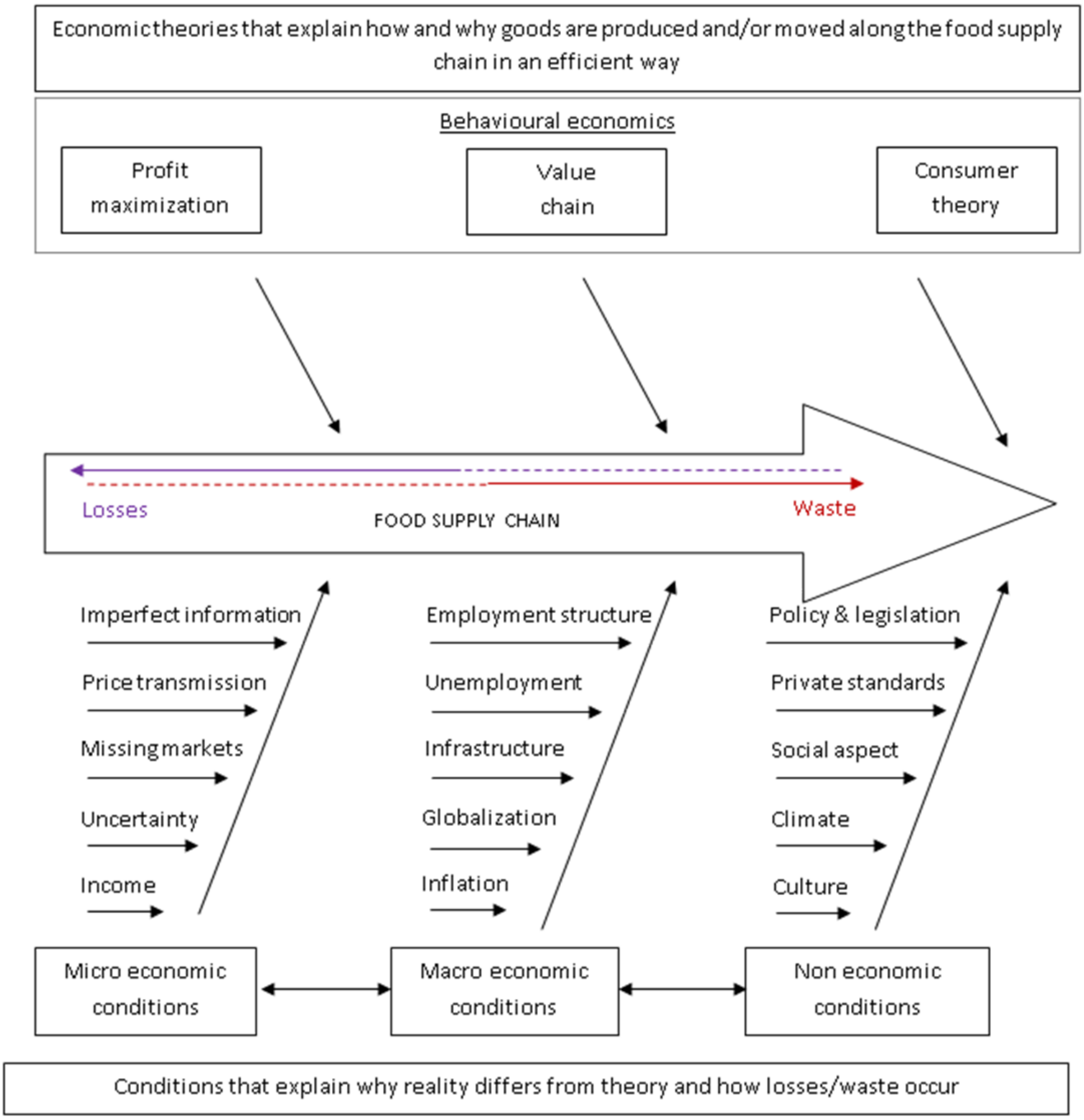
*In processing losses/waste were calculated using the following formula:*
*0.15 * ((36 549 (Domestic Utilization: Food, roots and tubers in EU in 2011)) * 0.73) + 2 156 (Domestic Utilization: Food Manufacture, roots and tubers in EU in 2011)) = 4 326*
*Where, 0.15 is 15 % food losses/waste of roots and tubers in processing (*Table 10.1*)*
*Where, 0.73 is 73 % roots and tubers is estimated to be processed (Gustavsson et al 2013)*
*Furthermore, a conversion factor was used to estimate the fraction of product volumes that is edible after industrial peeling.*
0.9 * *4 326 (production of roots and tubers in EU in 2011) = 3 893*
*Where, 0.9 is 90 % of food losses/waste of roots and tubers estimated to be recovered after industrial peeling in postharvest (Gustavsson et al 2013)*
*Total food losses/waste of roots and tubers in processing: 3 893*

*In distribution losses/waste were calculated using the following two formulas:*
*Processed: 0.03 * ((36 549 * 0.73) + 2 156 - 4 326) = 735*
*735 * 0.9 = 662*
*Where, 0.03 is 3 % food losses/waste of processed roots and tubers in distribution (*Table 10.1*), Where, 0.9 is 90 % of roots and tubers estimated to be recovered after industrial peeling (Gustavsson et al 2013)*
*Fresh: 0.07 * (36 549 * 0.27) = 691*
*691 * 0.74 = 511*
*Where, 0.07 is 7 % food losses/waste of fresh roots and tubers in distribution (*Table 10.1*)*
*Where, 0.74 is 74 % of roots and tubers estimated to be recovered after peeling by hand (Gustavsson et al 2013)*
*Total food losses/waste of roots and tubers in distribution: 662 + 511 =1 173*

*In consumption losses/waste were calculated using the following two formulas:*
*Processed: 0.12 * ((36 549 * 0.73) + 2 156 - 4 326 - 662) = 2 853*
*2 853 * 0.9 = 2 568*
*Where, 0.12 is 12 % food losses/waste of processed roots and tubers in consumption (*Table 10.1*), Where, 0.9 is 90 % of roots and tubers is estimated to be recovered after industrial peeling (Gustavsson et al 2013)*
*Fresh: 0.17 * ((36 549 * 0.27) - 511 = 1 560*
*1 560 * 0.74 = 1 155*
*Where, 0.17 is 17 % food losses/waste of fresh roots and tubers in consumption (*Table 10.1*)*
*Where, 0.74 is 74 % of roots and tubers is estimated to be recovered after peeling by hand (Gustavsson et al 2013)*
*Total food losses/waste of roots and tubers in consumption: 2 568 + 1 155 = 3 722*

## 10.2 Formation of food losses and waste

**Figure 10.1: Basic conditions that explain the formation of food losses and waste**




**Source:** Segrè et al., 2014

## 10.3 Questionnaire to food redistribution organisations

**GENERAL INFORMATION**

| | |
|---|---|
| **Characteristics of the service provided to people in need (please mark the correct answer)** | |
| - supply of prepared meals | |
| - supply of food and grocery products | |
| - sale to symbolic price of food and grocery products | |
| - Other: (please specify) | |
| | |
| **Origin of the food. Sector of the food chain (please mark the correct answer)** | |
| - Primary production | |
| - Processing & manufacturing | |
| - Wholesale, retail & marketing | |
| - Food preparation & consumption | |
| - Other: (please specify) | |
| | |
| **Kind of food received (please mark the correct answer)** | |
| - Fruit and vegetable | |
| - Bakery | |
| - Meat | |
| - Dairy | |
| - Grocery products | |
| - Prepared meals from canteens | |
| - Other: (please specify) | |
| | |
| **Amount of food recovered and distributed per year (years 2013 and 2014 if available) (tons)** | |
| **Number of volunteers involved in the food redistribution activities** | |
| **Number of employees involved in the food redistribution activities** | |
| **Number of people in need helped per year (years 2013 and 2014 if available)** | |

## TRUST AND SOLIDARITY

| 1.1 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements with regard to your organization and its food charity activities:? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Companies which donate food to your initiative are responsible community partner | | | | | | |
| b. Companies which donate food to your initiative improve their reputation among their employees | | | | | | |
| c. Companies which donate food to your initiative increase customer loyalty | | | | | | |

| 1.2 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements, concerning the people who are involved (clients, employees, volunteers) in your food redistribution activities? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| | | | | | | |
| a. Managers, employees and volunteers involved in the food redistribution activities play a key role in ensuring that some clients don't take unfairly advantage from food redistribution activities | | | | | | |
| b. Clients, employees, volunteers are willing to help if necessary. | | | | | | |
| | | | | | | |

| 1.3 On a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent, how much do you trust different types of people involved in your food redistribution activities? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Volunteers, employees and clients engaged in food redistribution | | | | | | |
| b. Donors / donating companies engaged in food redistribution | | | | | | |
| c. Clients of the food redistribution activities | | | | | | |
| d. Officials/employees of public authority | | | | | | |

| 1.4 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements, concerning people in need involved in your food redistribution activities? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. People are not required to give up their privacy by revealing personal social and economic circumstances | | | | | | |
| b. Food donations give them dignity and social justice | | | | | | |
| c. Food donations improve their social position | | | | | | |

**FOOD SECURITY/SAFETY**

| 2.1 On a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent, how much do your food redistribution activities help to achieve the goals listed in the table below? | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Food donations provide an answer to the problem of food security of people in need | | | | | | |
| b. Food donations increase food accessibility (physical access to food) of people in need | | | | | | |
| c. Food donations help people in need to increase their spending capacity on other goods and services (bills, rents, etc.). | | | | | | |

| 2.2 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements, concerning the quality of food distributed by your food redistribution initiative? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Good food quality | | | | | | |
| b. Ensures some variety to the menu | | | | | | |
| c. Improves nutritional situation | | | | | | |
| d. Food is safe and healthy | | | | | | |
| e. Food offered to clients allows to respect their food habits | | | | | | |

## GROUPS AND NETWORKS

| 3.1 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. The food redistribution activities connect different stakeholders. This allows to establish new economic and social relations | | | | | | |
| b. Food redistribution activities are an indicator of social problems such as social marginalization and poverty | | | | | | |

| 3.2 On a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent, how much do your food redistribution activities help to achieve the goals listed? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Create networks and advocacy at the local community | | | | | | |
| b. Involve volunteers | | | | | | |
| c. Increase volunteers skills | | | | | | |
| d. Create synergies among non-profit organizations, companies and public authorities | | | | | | |

## COLLECTIVE ACTION AND COOPERATION

| 4.1 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements, concerning the stakeholders involved in your food redistribution activities? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Stakeholders cooperate with each other to improve the efficiency of the recovery intervention | | | | | | |
| b. Stakeholders cooperate with each other also in other projects | | | | | | |
| c. When there is an emergency related to food redistribution activities, stakeholders cooperate to solve the problem | | | | | | |

| 4.2 On a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent, what do you think about the following statement, concerning the companies that donate food? | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Food redistribution activities help to create economic benefits | | | | | | |

| 4.3 On a scale of 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| | | | | | | |
| a. Food redistribution activities compensates for local food poverty situation | | | | | | |
| b. Managers, employees and volunteers involved in the food redistribution activities play a key role in ensuring that clients don't sell food received on the black market | | | | | | |
| c. Food redistribution activities contributes to solve "excess food production" problems | | | | | | |
| d. Cooperation among all stakeholders involved in the food redistribution activities plays a key role in ensuring that there are no food safety liability problems | | | | | | |
| e. Cooperation among all stakeholders involved in the food redistribution activities plays a key role in ensuring that there are no dependency problem on good will of volunteers and donors | | | | | | |
| f. Managers, employees and volunteers involved in the food redistribution activities play a key role in ensuring that there are no logistics problems in the food redistribution activities | | | | | | |

## INFORMATION AND COMMUNICATION

| 5.1 Rate the influence of your food redistribution activities in the public information on the issues listed below on a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Minimization of food waste | | | | | | |
| b. Social Cohesion | | | | | | |
| c. Minimization of criminality | | | | | | |
| d. Minimization of poverty | | | | | | |
| e. Community awareness on food insecurity | | | | | | |
| f. Other: (please specify) | | | | | | |

| 5.2 On a scale from 1 to 6, where 1 means a very small extent and 6 means a very great extent, how much do your food redistribution activities help to achieve the goals that are listed in the table below? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Reduce food waste | | | | | | |
| b. Increase community knowledge on food safety | | | | | | |
| c. Increase community knowledge on food education | | | | | | |
| d. Increase community knowledge on food waste | | | | | | |
| e. Improve the flow of information among people in need | | | | | | |

## SOCIAL COHESION AND INCLUSION

| 6.1 On a scale from 1 to 6, where 1 means strongly disagree and 6 means strongly agree, what do you think about the following statements? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Food redistribution activities support the integration of the socially excluded people | | | | | | |
| b. Food redistribution activities don’t increase stigmatization of people in need | | | | | | |
| c. Food redistribution activities support feeling of self-determination and dignity of | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| people in need | | | | | | |
| d. Food redistribution activities increase skills of volunteers | | | | | | |
| e. Food redistribution activities compensates welfare state failures | | | | | | |

| 6.2 On a scale of 1 to 6, where 1 means a very small extent and 6 means a very great extent, how much do the food redistribution activities help to achieve the goals that are listed in the table below? **(give your opinion for each statement)** | | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| a. Provide an answer to the unemployment problem | | | | | | |
| b. Ensure greater economic independence to people in need | | | | | | |
| c. Improve the welfare of your community | | | | | | |

## 10.5 References of environmental categories for indicator products

| Author | GWP | AP | EP | Apple | Potato | Tomato | Bread | Milk | Pork | Beef | Fish | Chicken |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Acosta-Alba et al., 2012 | x | | | | | | | x | | | | |
| AEA, 2008 | | x | x | x | | | | | | | | x |
| Alaphilippe et al., 2012 | x | | | x | | | | | | | | |
| Alaphilippe et al., 2013 | | x | x | x | | | | | | | | |
| Allied Bakeries | x | | | | | | x | | | | | |
| Almeida et al., 2014 | x | | | | | x | | | | | | |
| Anderson & Ohlsson, 1999 | x | x | x | | | | x | | | | | |
| Antón et al., 2005 | x | x | x | | | x | | | | | | |
| Arias et al., 2012 | | x | x | | | | | | | x | | |
| Audsley et al., 2009 | x | | | x | | | | | | | | |
| | | | | | | | | | | | | |
| Basset-Mens and van der Werf, 2005 | x | x | x | | | | | | x | | | |
| Basset-Mens C. and van der Werf H.M.G., 2006 | | x | x | | | | | | x | | | |
| Bonesmo et al., 2012 | x | | | | | | | | x | | | |
| Bonesmo et al., 2013 | x | | | | | | | x | | x | | |
| Braschkat, J. et al., 2003 | x | x | x | | | | x | | | | | |
| Broekema R., & Kramer G., 2014 | | x | x | | | | | x | | | | |
| Buchspies et al., 2011 | x | | | | | | | | | | x | |
| Cappelletti G.M. et al., 2010 | x | | | | | x | | | | | | |
| Carlsson-Kanyama, 1998 | x | | | | x | | | | x | | | |
| Casey and Holden, 2005, 2006 | x | | | | | x | | x | | x | | |
| Castanheira et al., 2010 | x | x | x | | | | | x | | | | |
| Cederberg and Darelius, 2002 | x | x | x | | | | | | x | | | |
| Cederberg and Mattsson, 2000 | x | x | x | | | | | x | | | | |
| Cederberg and Stadig, 2003 | x | x | x | | | | | x | | | | |
| Cederberg et al., 2009 | x | | | | | | | x | x | x | | x |
| Cellura et al., 2012x | x | x | x | | | x | | | | | | |
| Cerealia | x | x | x | | | | x | | | | | |
| CLEEN, 2012 | | x | x | | | | x | | | | | |
| D'Arcy, 2010 | x | x | x | | x | | | | | | | |
| Dalgaard et al., 2007 | x | x | x | | | | | | x | x | | x |
| Danish LCA food database | x | x | x | | x | x | x | | x | x | x | x |
| Davis et al., 2011 | x | | | x | | x | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dawson, 2010 | x | | | | | | | | | x | | |
| de Boer, 2003 | x | x | x | | | | | x | | | | |
| DEFRA, 2007 | x | x | x | | | | | x | | | | |
| DEFRA, 2008 | x | | | | | | | | | | | x |
| DEFRA, 2009 | x | | | x | x | x | x | x | x | x | | x |
| DEFRA, 2012 | x | x | x | | x | | | | | | | |
| Del Prado et al., 2013 | x | | | | | | | x | | | | |
| Djekic et al., 2014 | x | x | x | | | | | x | | | | |
| Dollé et al., 2012 | | x | x | | | | | x | | | | |
| Dolman et al., 2012 | | x | x | | | | | | x | | | |
| EBLEX, 2009 | x | | | | | | | | | x | | |
| Ecoinvent | x | | | | x | | | | | | | |
| Edwards-Jones et al., 2009 | x | | | | | | | | | x | | |
| Eide, 2002 | x | x | x | | | | | x | | | | |
| Environmental Resources Management Ltd, 2009 | x | x | x | | | | | | x | | | |
| Espinoza-Orias et al., 2011 | x | | | | | | x | | | | | |
| Fantin et al., 2012 | x | x | x | | | | | x | | | | |
| FAO, 2010 | x | | | | | | | x | | | | |
| Flysjö et al., 2011 | x | | | | | | | x | | x | | |
| Flysjö et al., 2014 | x | | | | | | | x | | | | |
| Fuentes et al., 2006 | x | | | | | x | | | | | | |
| Fulton, 2010 | x | | | | | | | | | | x | |
| González et al., 2011 | x | | | x | x | x | | | x | x | | x |
| González et al., 2012 | | x | x | | | | | | x | | | |
| González-Garcia et al, 2015 | | x | x | | | | | | x | | | |
| González-García et al., 2013 | | x | x | | | | | x | | | | |
| González-García et al., 2014 | x | x | x | | | | | | | | | x |
| Guerci et al., 2012 | | x | x | | | | | x | | | | |
| Guerci et al., 2013a | x | x | x | | | | | x | | | | |
| Guerci et al., 2013b | x | x | x | | | | | x | | | | |
| Guttormsdóttir, 2009 | x | | | | | | | | | | x | |
| Hospido et al., 2003 | x | x | x | | | | | x | | | | |
| Jungbluth, 2013 | x | x | x | | | | | x | | x | | |
| Kanyarushoki et al., 2008 | x | x | x | | | | | x | | | | |
| Katajajuuri, 2007 | x | | x | | | | | | | | | x |
| Kool et al., 2009 | x | | | | | | | | x | | | |
| Korsaeth et al., 2012 | x | x | x | | | | x | | | | | |
| Kristensen et al., 2011 | x | | | | | | | x | | x | | |
| Kulak et al., 2015 | x | | | | | | x | | | | | |
| | | | | | | | | | | | | |
| Leinonen et al., 2012 | x | x | x | | | | | | | | | x |
| Lesschen et al., 2011 | x | | | | | | | x | x | x | | x |
| Lillywhite et al., 2007 | x | x | x | x | x | | | x | | | | |
| Lovett et al., 2008 | x | | | | | | | x | | | | |
| MacLeod et al., 2013 | x | | | | | | | | x | | | x |
| Mattsson and Wallen, 2003 | | x | | | x | | | | | | | |
| McLaren et al., 2010 | x | | | x | | | | | | | | |
| Meneses et al., 2012 | x | x | | | | | | x | | | | |
| Milà i Canals et al., 2006 | x | x | x | x | x | | | | | | | |
| Moudrý Jr et al., 2013 | x | | | | x | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mouron et al., 2006 | x | x | x | x | | | | | | | | |
| Nemecek et al., 2011a | x | x | x | x | x | x | | | | | | |
| Nemecek et al., 2011b | x | | | | | | | x | | | | |
| Nguyen et al., 2010 | x | x | x | | | | | | | x | | |
| Nguyen et al., 2012 | x | x | x | | | | | | | x | | |
| Nguyen et al., 2013a | x | x | x | | | | | x | | | | |
| Nguyen et al., 2013b | x | | | | | | | x | | | | |
| Nilsson et al., 2011 | x | | | | x | | | | | | | |
| O'Brien et al., 2012 | x | x | x | | | | | x | | | | |
| Payen et al., 2015 | | x | x | | | x | | | | | | |
| Prudencio da Silva et al., 2014 | x | x | x | | | | | | | | | x |
| Reckmann and Krieter, 2012 | | x | x | | | | | | x | | | |
| Reckmann et al., 2013 | x | x | x | | | | | | x | | | |
| Refsgaard et al., 2012 | x | | | | x | | | x | | x | | |
| Roer et al., 2013 | x | x | x | | | | | x | | x | | |
| Röös et al., 2010 | x | | | | x | | | | | | | |
| Rugani et al., 2012 | | x | x | | | | | | x | | | |
| Schmidinger and Stehfest, 2012 | x | | | | | | | x | | x | | |
| Sessa et al., 2014 | | x | x | x | | | | | | | | |
| Sheane et al., 2011 | x | | | | | | | x | | | | |
| Smith et al., 2005 | x | | | | | x | | | | | | |
| Strid Eriksson et al., 2004 | x | | | | | | | | x | | | |
| Strid Eriksson et al., 2005 | | x | x | | | | | | x | | | |
| Svanes et al., 2011 | x | x | x | | | | | | | | x | |
| Taylor et al., 2010 | x | | | | | | | | | x | | |
| Tesco, 2012 | x | | | | x | | | x | | | | |
| Thomassen et al., 2008a | x | x | x | | | | | x | | | | |
| Thomassen et al., 2008b | x | x | x | | | | | x | | | | |
| Thomassen et al., 2009 | x | x | x | | | | | x | | | | |
| Torrellas et al., 2012a | x | x | x | | | x | | | | | | |
| Torrellas et al., 2012b | x | x | x | | | x | | | | | | |
| Tuomisto, 2010 | x | | | | | | | x | | | | |
| Uni, 2007 | x | | | x | x | | | x | x | x | | |
| Usva et al., 2012 | | | x | | | | | x | x | x | | |
| van der Werf et al., 2009 | | x | x | | | | | x | | | | |
| Vázquez-Rowe et al., 2011 | x | x | x | | | | | | | | x | |
| Veysset et al., 2014 | x | | | | | | | | | x | | |
| Wallén et al., 2004 | x | | | x | x | x | x | x | x | x | x | x |
| Webb et al., 2013 | x | | | x | x | x | | | | x | | |
| Weidema et al., 2008 | x | | | | | | | | x | x | | x |
| Weiss and Leip, 2012 | x | | | | | | | x | x | x | | |
| Williams et al, n.y. | | x | x | | | | | | | x | | |
| Williams et al., 2006 | x | x | x | | x | x | | x | x | x | | x |
| Williams et al., 2008 | x | x | x | | | x | | | | | | |
| Williams et al., 2010 | x | x | x | | x | | | | | | | |
| Winther et al., 2009 | x | | | | | | | | | | x | |
| Yan et al., 2013 | x | | | | | | | x | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zehetmeier et al., 2014a | x | | | | | | | x | | | | |
| Zehetmeier et al., 2014b | x | | | | | | | x | | | | |
| Zhu and van Ireland, 2004 | x | x | x | | | | | | x | | | |
| Ziegler et al., 2003 | x | x | | | | | | | | | x | |

# 10.6 Acidification potential database on product level

**Figure 10.2: Median value of the acidification potential for each life cycle stage in g $SO_2$ eq /kg (n = number of literature sources related to the given median value)**

| Indicator product | Unit | Primary production | Food Processing | Transport (average) | Retailing & Distribution | Packaging | Food consumption | Waste Management | Total | Assumptions/Limitations |
|---|---|---|---|---|---|---|---|---|---|---|
| Apple | Median value | 0,42 | 0,00 | 0,90 | 0,00 | 0,04 | 0,05 | | 1,55 | Consumption was assumed to be stored in a refrigerator with similar emissions to milk |
| | n | 8 | 3 | 3 | 1 | 1 | | | 8 | |
| Tomato (GH vs. Field) | Median value Field | 1,35 | 0,00 | 1,25 | 0,00 | 0,33 | 0,05 | | 2,98 | Three data sources covering more than one chain step were disaggregated to provide additional results. Consumption was assumed to be stored in a refrigerator with similar emissions to milk. |
| | n | 4 | 1 | 2 | | 1 | | | 4 | |
| | Median value Greenhouse | 2,78 | 0,00 | 0,90 | 0,00 | 0,33 | 0,05 | 0,012 | 3,98 | |
| | n | 5 | 2 | 2 | | | | | 5 | |
| Potato | Median value Fresh | 1,53 | 0,00 | 0,17 | 0,38 | 0,13 | 0,19 | | 2,40 | Five data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 11 | 6 | 6 | 3 | 1 | 1 | | 11 | |
| Bread | Median value | 4,16 | 0,50 | 0,34 | 0,06 | 0,10 | 0,00 | #BEZUG! | 6,27 | Three data sources covering more than one chain step were disaggregated to provide additional results. Consumption: assumed ambient storage with no |
| | n | 7 | 7 | 7 | 5 | 5 | | | 7 | |
| Milk | Median value | 12,81 | 0,12 | 0,18 | 0,23 | 0,15 | 0,05 | 0,03 | 14,04 | One data source covering more than one chain step was disaggregated to provide additional results. |
| | n | 28 | 10 | 7 | 6 | 5 | 2 | | 28 | |
| Pork | Median value | 81,50 | 0,54 | 0,70 | 1,30 | 0,02 | 2,26 | included | 88,29 | Five data sources covering more than one chain step were disaggregated to provide additional results. Packaging: was taken from beef. Retail & |
| | n | 17 | 9 | 5 | 4 | 1 | 1 | | 17 | |
| Beef | Median value | 327,30 | 0,54 | 0,70 | 0,90 | 0,02 | 3,00 | included | 332,32 | Two data sources covering more than one chain step were disaggregated to provide additional results. Transport: was taken from pork. Retail & distribution: |
| | n | 9 | 4 | 2 | 1 | 1 | | | | |
| Fish | Median value | 29,64 | 0,00 | 1,36 | 0,90 | 0,00 | 0,25 | | 32,25 | Four data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 5 | 5 | 5 | 5 | 5 | 2 | | 5 | |
| Chicken | Median value | 69,00 | 0,93 | 0,13 | 0,90 | 0,06 | 2,83 | | 72,78 | Retail & distribution: taken from fish |
| | n | 7 | 3 | 2 | | 2 | | | 7 | |

# 10.7 Eutrophication potential database on product level

**Figure 10.3: Median value of the eutrophication potential for each life cycle stage in g $PO_4$ eq /kg (n = number of literature sources related to the given median value)**

| Indicator product | Unit | Primary production | Food Processing | Transport (average) | Retailing & Distribution | Packaging | Food consumption | Waste Management | Total | Assumptions/Limitations |
|---|---|---|---|---|---|---|---|---|---|---|
| Apple | Median value | 0,24 | 0,00 | 0,12 | 0,00 | 0,01 | 0,02 | | 0,43 | Consumption was assumed to be stored in a refrigerator with similar emissions to milk |
| | n | 7 | 3 | 3 | 1 | 1 | | | 7 | |
| Tomato (GH vs. Field) | Median value Field | 0,47 | 0,00 | 0,12 | 0,00 | 0,14 | 0,02 | | 0,67 | Three data sources covering more than one chain step were disaggregated to provide additional results. Processing, Transport and Retail & Distribution were assumed to be the same as for apples. Consumption was assumed to be stored in a refrigerator with similar emissions to milk. |
| | n | 4 | 1 | 2 | | 1 | | | 4 | |
| | Median value Greenhouse | 0,63 | 0,00 | 0,12 | 0,00 | 0,14 | 0,02 | 0,004 | 0,90 | |
| | n | 5 | 2 | 2 | | | | | 5 | |
| Potato | Median value Fresh | 0,77 | 0,00 | 0,01 | 0,07 | 0,01 | 0,01 | | 0,86 | Five data sources covering more than one chain step were disaggregated to provide additional results. Packaging: assumed to be the same as apples. |
| | n | 10 | 5 | 5 | 2 | | | | 10 | |
| Bread | Median value | 2,07 | 0,09 | 0,03 | 0,00 | 0,07 | 0,00 | #BEZUG! | 2,57 | Three data sources covering more than one chain step were disaggregated to provide additional results. |
| | n | 7 | 7 | 7 | 5 | 5 | | | 7 | |
| Milk | Median value | 6,25 | 0,20 | 0,04 | 0,08 | 0,03 | 0,02 | 0,01 | 6,61 | |
| | n | 25 | 9 | 5 | 4 | 4 | 2 | | 25 | |
| Pork | Median value | 42,23 | 0,40 | 0,10 | 0,00 | 0,25 | 0,02 | included | 45,13 | Five data sources covering more than one chain step were disaggregated to provide additional results. Packaging: was taken from beef. Retail & |
| | n | 18 | 9 | 5 | 3 | 1 | 1 | | 18 | |
| Beef | Median value | 143,50 | 0,40 | 0,10 | 0,05 | 0,09 | 0,03 | included | 144,17 | Two data sources covering more than one chain step were disaggregated to provide additional results. Processing: was taken from pork. Transport: was |
| | n | 10 | 3 | 2 | 1 | 1 | | | 10 | |
| Fish | Median value | 2,68 | 2,68 | 0,14 | 0,05 | 0,20 | 0,00 | | 5,95 | Four data sources covering more than one chain step were disaggregated to provide additional results although in accordance with the eutrophication |
| | n | 4 | 4 | 4 | 2 | 2 | 1 | | 4 | |
| Chicken | Median value | 27,15 | 0,27 | 0,04 | 0,08 | 0,00 | 0,03 | | 27,52 | |
| | n | 8 | 4 | 2 | 1 | 3 | | | 8 | |

Criteria for and baseline assessment of environmental and socio-economic impacts

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