Standard approach on quantitative techniques to be used to estimate food waste levels

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Colophon

Summary

The focus of FUSIONS is on promoting food waste prevention by optimising food use and waste prevention strategies. In order to reduce food waste it is necessary to quantify the waste and find the reasons why it occurs. The subject of this report is quantification of food waste all along the value chain from before the material is called food (primary production and processing) until final consumption (household and food service).

This report presents the work in FUSIONS Work Package (WP) 1 task 1.2 "Quantitative techniques and data integrity". The work is based on previous FUSIONS work on definitions and system boundaries (D1.1), Eurostat Review of Eurostat's reporting method and statistics (D 1.2), a literature review (D1.3) and the participants own experience and knowledge. This report forms an important part of the basis for the Quantification Manual (D1.5). The partners BOKU, DLO, IFR, INRA, MTT, OSTFOLD, SIK, and UNIBO have participated in the work, which was led by OSTFOLD and supervised by SIK.

Previous work in FUSIONS has shown that there are few studies on food waste and that the methodologies applied have not been harmonized between studies. Thus there is a great need for a harmonized methodology for monitoring of food waste. One important conclusion from this project is that there is not one single method that can be recommended for all applications. This report identifies a number of possible quantification methods that can be used, investigates their advantages and disadvantages, for what applications they should be used and present some guidelines on how to use them.

The report also gives some general guidelines on how to proceed when choosing methodology. E.g. first the goal and scope must be determined. If the goal is to reduce pressure on landfills the method(s) chosen will probably be different from a study where the goal is to identify and prioritize food waste reduction measures. Another important step is to determine what data already exists. In general, the following steps must be considered: Identification (is it food waste?), measurement, recording data, collecting data, calculation of waste.

The main methods studied are: Measurement, scanning, waste composition analysis, food waste diary, questionnaires, calculations based on existing statistics, interviews and surveys, and mass balances. Recommendations are given for each step in the value chain from primary production, processing & manufacturing, wholesale, retail and marketing, redistribution, food service and households (end users for food preparation and consumption). Some methods have mainly been used in one sector, e.g. scanning in retail, food waste composition analyses for households, direct measurements in production, whereas other are more commonly used in all areas, e.g. interviews and questionnaires.

There is little available data on food waste in EU-28 and it might take many years to rectify this situation. One concern is that this will be a barrier towards identifying and implementing measures to reduce food waste amounts. In this report a simplified framework for quantification of food waste is suggested that can be used to fill data gaps until detailed food waste data is available.

The report also gives advice on data quality, schemes to classify companies and food products, food waste prevention methodologies and waste treatment.

Contents

1   Introduction

The overall aim of FUSIONS is to *contribute* significantly to the harmonization of food waste monitoring; feasibility of social innovative measures for optimized food use in the food supply chain and the development of a Common Food Waste Policy for EU-28. Its focus is on promoting *food waste prevention* by optimising food use and waste prevention strategies.

The FUSIONS Project will deliver the definitional choices for food waste, suggest standard quantitative methodologies for measuring food waste, develop a food waste quantification manual and estimate EU-28 food waste levels based on these analyses:

- Report: "FUSIONS definitional framework for food waste" providing the main definitional choices for food and drink waste (D1.1).
- Report: "Report on review of (food) waste reporting methodology and practice" giving an overview of existing methods and practices for quantifying food waste (D1.3).
- Report: "Standard approach on quantitative techniques to be used to estimate food waste levels", in progress, presents a selection of methods suitable for monitoring the resource flows leaving the food supply chain (D1.4) (present report).
- Report: "Food waste quantification manual to monitor food waste amounts and progression" will recommend how to *practically measure* and quantify all resource flows in different steps of the food supply chain focusing on EU-28. It will provide a harmonized method for representative, effective and meaningful quantification of food waste (D1.7) (coming report).
- Report: "Estimates of European food waste levels and analysis of food waste drivers" which will present an estimate of food waste amounts produced in EU-28 by mapping existing datasets against this definitional framework (D1.8). It will also give input to the manual (D1.7) on quantification (coming report).
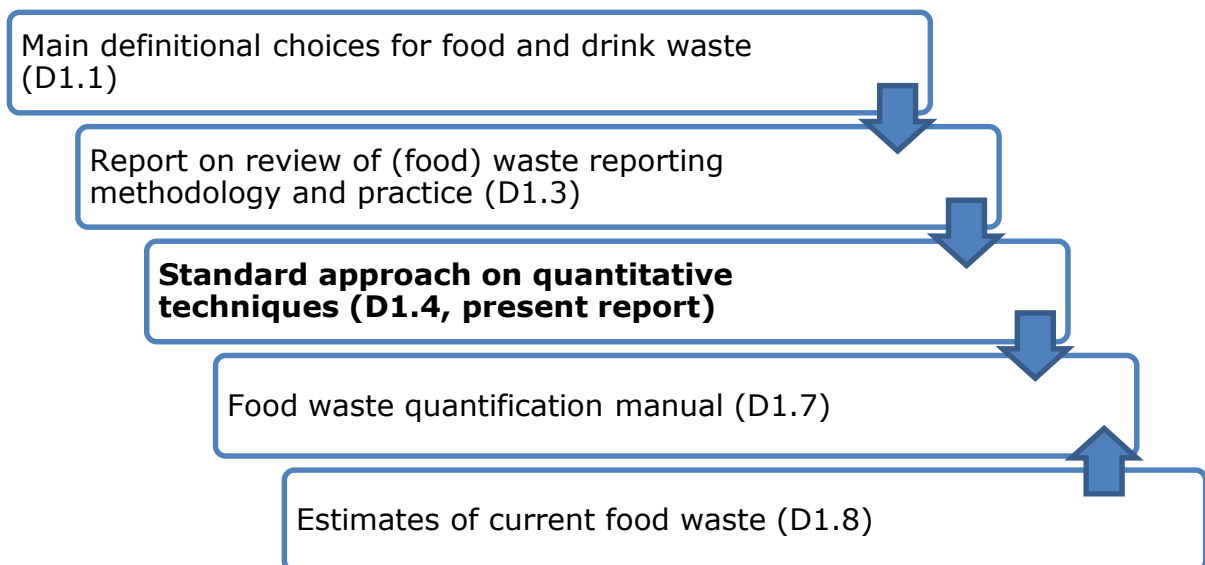
Figure 1.1 Related work on definition & quantification within FUSIONS

"The FUSIONS definitional framework for food waste presents" the *FUSIONS theoretical framework*, by which we can separate and quantify all resource flows leaving the food supply chain. It establishes the system boundaries and definition of food waste, and provides general guidance on boundary conditions relating to food, the food supply chain and the edibility of food, which will facilitate the collection of comparable data. Based on the FUSIONS theoretical framework a technical framework is given which presents the resource flows leaving the food supply chain which today are considered practically feasible to measure and monitor on an EU-28 level. The FUSIONS definition of food waste is:

Food waste is any food, and inedible parts of food, removed[1] from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea).

The technical framework will serve as the base for the Food waste quantification manual. The analysis of existing datasets will be conducted to establish how existing data maps onto the new framework, to bring transparency to existing data and allow accurate comparisons to be made. Clearly there will be gaps in the datasets, so the other activity will be to develop a Food Waste Quantification Manual which will recommend suitable methodologies for quantifying food waste. It will be focused on delivering guidance to Member States undertaking new work to quantify food waste so that over time, data gaps will be filled.

The work in this report is done in the frame of Work Package (WP) 1 task 1.2 "Quantitative techniques and data integrity". The aim of the task is to provide recommendations on standard approaches on techniques to be used to estimate the level of wasted food in EU-28. Another aim was to provide a general framework for monitoring food waste for the different steps in the food supply chain.

The outcomes are based on the criteria document (ref "FUSIONS definitional framework for food waste", Annex A) and an extensive literature review and the combined knowledge and experience of the FUSIONS Consortium.

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[1] *The term 'removed from' encompasses other terminology such as 'lost to' or 'diverted from'. It assumes that any food being produced for human consumption, but which leaves the food supply chain, is 'removed from' it regardless of the cause, point in the food supply chain or method by which it is removed.*

2 Goal and scope

The main aim of this report is to provide recommendations on standard approaches on quantitative techniques to be used in FUSIONS to estimate the level of wasted food across EU-28.

The sub goals are:
- Develop a set of standard methods to be used in a standard approach for estimating levels of "food waste" removed from the food supply chain in different steps of the food supply chain.
- Calculate indicators (e.g. tonnes of food waste per per person) for quantification of "food waste" removed from the food supply chain
- Develop methods for scaling up levels of "food waste" removed from the food supply chain sector-wise; through the supply chain and to national levels

The methods developed and described shall benefit from the knowledge from the earlier reports in FUSIONS: "D1.1 Main definitional choices for the food and drink waste produced within Europe" by applying to any of the fractions identified in the FUSIONS general technical framework, this report also includes a criteria document, describing a common view on application and criterias for the methodological framework; "D1.2 Review of Eurostats reporting method and statistics" and "D1.3 Report on review of (food) waste reporting methodology and practice".

3 Terminology

The fraction discussed in this report is in accordance with the FUSIONS definition:

"Any food and inedible parts of food removed from the food supply chain" (See D1.1).

This definition refers to both food waste and fractions not being valorized to other biomaterials or industrial uses or used as Feed (see D1.1). *The quantitative techniques developed are thus developed for estimating the levels of all edible and inedible parts of food leaving the food supply chain regardless of destination*. The starting point of the food supply chain is production right before harvest, which implies that pre-harvest activities are excluded from the scope.

The term "food waste" is used in the report and refers to materials that are not necessarily classified as food, nor as waste. This means that waste from plants and animals will fall under this definition even though they are at a stage before they are classified as food according to the EU. The term waste is used different from the legal EU definition of the term in that it also contains materials not ending up in waste management systems e.g. that are used as animal feed. The use of the term "food waste" follows the FUSIONS definition that has a wider scope than the term food waste usually has, as described above and in D1.1. To avoid any misunderstanding the term is put in inverted commas in the whole report: "food waste".

When referring to other studies the term food waste is written without inverted commas, and may have different meaning depending on the basis for the particular study.

The steps in the supply chain are mainly not exactly following the terminology used in definition in D1.1. A description for the steps are presented below (see also chapter 6):

- Primary production starts right before harvest and includes harvest, post-harvest activities and processing of farm staples
- Processing and manufacturing is processing of product, where the products are no longer intact (cut, mixed, heat treatment etc.) and includes packaging of processed products.
- Wholesale and logistics are activities at wholesale store and transport to retail, food service and redistribution
- Retail and marketing include all activities at retail or market distribution centres and outlets or sales booths.
- Redistribution has the starting point at the gate of the donor and the end point at act of handing over the food to end consumer.
- Food service includes food preparation and consumption out of home
- Households includes food preparation and consumption at home

4 Organisation and work method

4.1 Organisation

The work on this report is mainly based on three FUSIONS deliverables:
- D1.1: Main definitional choices for the food and drink waste produced within Europe
- D1.2: Review of Eurostat's reporting method and statistics
- D1.3: Report on review of (food) waste reporting methodology and practice

This report will form an important basis for the work on a manual for quantifying "food waste". This manual will be developed during 2014-2015. The aim of the manual is to give detailed guidance on how to go about quantifying "food waste". Figure 3.1 describes how this report fits in with some the FUSIONS reports mentioned above.

D 1.1. Definitions and system boundaries.

D 1.3 Summary of some existing published scientific studies.

D1.2 Review of Eurostats reporting method

Participants own experience and knowledge

This report. D 1.4. Methodology review.
Overview and classification of methods.

Some scientific studies not covered by the literature review, e.g. studies published after the review.

D 1.5. Quantification method manual.

Detailed guidance on method selection and application for selected

Stakeholder consultation and Expert consultation through FUSIONS external advisory board (EEAB)

Figure 4.1. Context of this report

4.2 Procedure

The content of this report has been written by the partners mentioned in table 4.1. The work was coordinated with the work done in T1.6 Food waste statistics by IVL. The report was edited by OSTFOLD and by the WP1 leader Karin Östergren from SIK.

The sections on the specific steps in food supply chain were written by different groups, which organised the work to find a best practice approach for each subsector, see table 3.1. As mentioned before, the recommended approaches are based on the participants own experience as well as a number of written sources. Of these sources, the review (D1.3) and the definitions (D1.1) were the most important.

Table 4.1 Partners participating in the working groups

Task	Participants (responsible partner underlined)
Primary production and processing of farm staples	<u>MTT</u>, OSTFOLD, UNIBO, INRA
Processing & manufacturing	<u>SIK</u>, UNIBO, IFR
Wholesale and logistics Retail and marketing Redistribution	<u>BOKU</u>, UNIBO, OSTFOLD
Food services Households	<u>DLO</u>, MTT, IVL, OSTFOLD

5 Overview of methods

The following methods have been identified in the review report on "food waste" methodology (Møller et al., 2013):

- Measurement (Weighing or volume)
- Scanning (Electronically recording)
- Waste composition analysis
- "Food waste" diary
- Questionnaires
- Calculations based on statistics (at national level or at other level e.g. country, municipality, company etc.)
- Interviews and surveys
- Mass balances

The choice of method depends on what is already known. If the amount has not been measured, then a measurement might be needed, or an estimate can be used. Scanning relies on recorded existing unit amount. The scanning counts the units and records the identity of each unit. Questionnaires, interviews and surveys are most relevant if amounts are known, but not recorded or if the recorded data are not readily available. Waste compositional analysis is a special case of measurement mostly applied to mixed flows, i.e. waste that contains both "food waste" and non-food materials. "Food waste" diary is a way of recording waste amounts when it occurs or shortly after. It is normally used for consumers but can be used at any point in the value chain, e.g. at the farm. When choosing and applying a quantification method the practitioner must first establish the scope of the study and what data is available. Before embarking on a quantification study, the practitioner should determine what is in and out of scope:

- Which steps of the value chain
- What types of businesses / households / organisations are in and out of scope
- What types of food are included
- What time period and geographical area are in and out of scope
- Which destinations are included

In addition, the research questions / objectives need setting, which are determined by what you want to use the information for: i.e. what decisions will be based on the information, what communications will be based on the information.

Then it must be evaluated what has been done previously, specifically what information is already available, where it is available and in what form.

When this information is in place there are some steps to be considered:
1. Establish whether the flow is "food waste"
2. Measure or estimate amounts, and if possible find other information necessary to fulfil the purpose of the study. i.e. the reasons for the waste
3. Record the information
4. Collect recorded or measured data
5. Make the quantification needed, e.g. the ratio of wasted material to overall amount entering the system

The situation might be very different from case to case. In some cases the "food waste" has a commercial value. Then the amounts are probably recorded somewhere. In some cases the wastage is not recorded, often not even measured.

Figure 5.1 below illustrates methods used to quantify wasted food *before* discarding or *after* discarding the waste.

Figure 5.1 Illustration of quantifying wasted food

Examples A and B show how different measuring methods can be used in different situations along the supply chain:

Example A	Carrot production on the field: The amount of wasted carrots on the field is already classified as "food waste" when the carrots are harvested, and to quantify this waste it will be measured after discarding, either by weighing or by measuring by volume.
Example B	"food waste" at household: When using a "food waste" diary, the "food waste" is quantified/ estimated before putting it into the bin. When using a waste composition analysis the amount of "food waste" is quantified after discarding, by collecting the containers, sorting the content and measuring the quantity of each fraction.

Recommendation will be developed in chapter 8 - 14 for each step in the supply chain. The recommendations are developed to be applicable for any of the fractions defined by the FUSIONS general technical frame work (See D1.1).

The different methods have their advantages and disadvantages. The choice of method must be made according to the goal and scope of the study and be adapted to the object under study.

Often a combination of methods should be used in order to reduce sampling error and/or because they complement each other. The following example illustrates this:

To map the amount of wasted food per person in a country, several waste composition analyses have been conducted through direct measurement of waste in local municipalities. The amount of wasted food per capita and the amount of total organic waste (of which food waste is one component) per capita have been measured. Then the percentage of wasted food of the total organic waste ("food waste" factor) can be estimated. From these figures, the average amount of wasted food per person can be

calculated. By combining those figures with national waste statistics and correcting for the different collection systems, estimates can be used to extrapolate the total amount of wasted food per person for the entire country. By assuming that those types of waste factors are representative also for other regions, amount of wasted food can be estimated based on amounts of total waste measured. The example shows that aggregated national waste statistics can be used in combination with direct measurements of waste to obtain robust results.

In addition to giving more exact numbers on quantity, the combination of methods gives other advantages. The waste compositional analyses could be designed so that it give information about how much bread, dairy products, meat, fruits, vegetables etc, is wasted. It can also give information about other things such as how much is or is not packaged and how much is cooked and how much unprepared. It can furthermore give indications on the reasons for the wastage. Moreover, the results can be further used by other tools such as interviews with the consumers responsible for the waste about their reasons for their actions or with kitchen diaries.

5.1   Applications for the methods

Studies on the amount of "food waste" can serve many purposes. Thus there are several different motives for carrying out quantification of "food waste".
Below are listed only a few of several purposes/motives:

- Increasing profitability for value chain actors
- Reducing environmental impacts
- Basis for planning and carrying out measures to reduce waste
- Benchmark and monitor trends over time of the amount of "food waste", to study effects of measures to prevent "food waste" or effects of changes in the society
- Increasing food supply
- Improving food security, e.g. a country`s degree of self-sufficiency.
- Reducing pressure on landfills
- Improving consumers economy
- Making comparisons between value chain actors, between products, between regions etc.

In some cases the reduction of "food waste" is the main purpose, and in such cases several of the benefits mentioned above will probably be achieved. In other cases the emphasis is one particular of the benefits stated above, e.g. reducing the need for new landfills.

It is important to keep in mind the primary motivation or purpose of the study when choosing and adapting the methodology for quantification. Different purposes require different data and different level of detail. If e.g. the data is to be used to plan measures for reducing amount of "food waste", then information about apparent causes and root causes is important to have. If the purpose is to reduce landfill amounts, waste composition data on landfilled waste fractions is the most important information.

One very important purpose of quantifying "food waste" is to use this information as a basis for planning and implementing measures to reduce the amounts. This topic is covered in the Appendix 3 on Prevention methodologies and waste treatment.

5.2 Indicators

Indicators is a way of expressing the amount of "food waste" in a way that aids understanding of the figures. It is also a tool that could be used in the quantification. A typical indicator would be amount of "food waste" per household per year in a country. By multiplying this number with the number of households the total household "food waste" is calculated.

Four main dimensions are important when comparing the indicators for "food waste":
- The time scale: to monitor trends over time for the same type of processes, sectors or food chains
- The chain scale: to compare how much "food waste" per produced amount is generated at each step in the chain
- The food product scale: to compare how much "food waste" in total and per produced amount is generated from different categories of food and food sectors
- The geographical scale: to compare how much "food waste" in total and per produced amount or per capita generated from different geographical areas (municipalities, regions, countries, etc.).

In table 4.1, the different scales are shown and linked to actual levels in the supply chain and to the different steps in the supply chain. The table also shows common indicators, by describing the nominator and denominator:

$$Indicator = Nominator/denominator$$

The denominator is the produced amount for all scales and all steps in the supply chain, except for waste from household, that have traditionally been presented per capita.

The produced amount is defined as the sold amount or otherwise handed over to destination, such as giving food to redistribution. This means that losses in storage should be included in the total "food waste", i.e. the nominator. In some cases it can be difficult to get good mass based data for what is "produced", i.e. from retail and food service. In those cases, one must transform data from economic units to mass units, by using transformation factors. Mass data is preferred over economic data for several reasons, e.g. because economic units are susceptible to inflation and differences between products (e.g. between 'value' and' premium' ranges). Volume measurements should be converted to mass for comparison purposes. Also in household transformation factors can be used to extrapolate specific measures for a region to a national number of "food waste" per capita.

Table 5.1 Examples of indicators for "food waste"

Step in the food supply chain	Nominator	Denominator
Primary production Processing & manufacturing Wholesale Retail and marketing Redistribution Food service	Amount of total "food waste" for each step Amount of "food waste" for product categories for each step	per produced or sold amount (tonnes)
Households	Amount of total "food waste" or per category of food	per capita

To make relevant and meaningful comparisons between sectors and geographic areas, it is important to use the same types of definitions, the same boundaries around the different steps in the food chain and the same methodologies for quantification of "food waste" with representative samples. When using the indicators in Table 5.1, it is possible to compare directly between countries <u>without</u> taking import and export into account. If total amounts of "food waste" were compared between sectors in different countries it is necessary to correct for import and export by using the total mass entering the system, i.e. produced amount minus export and plus import. Indicators for any fraction defined by the FUSIONS general technical framework (See D1.1) can be developed in the same way.

5.3   Quality attributes for the methods

When choosing a quantification method it is important to consider some quality attributes for the method. How can we judge what is a good method? There are several attributes to consider.

One important attribute is data quality. The quantification cannot be better than the underlying data allows. This very important aspect is covered in detail in Appendix 1.

Another important aspect is flexibility. The general approach to be developed should be able to use data from different sources, e.g. national and international statistics, and local studies.
Versatility is another important attribute. The method should be applicable to as many <u>levels of the food supply chain as possible</u>, e.g. regional such as the EU, national such as specific countries; a city or a single company or production line. It should also be applicable for as many <u>sectors in the food supply chain as possible</u>; e.g. the production (agricultural sector) or the household sector. The approach should also include the aspect of "food waste" prevention and describe if it is an integrated part or an additional approach.

Economy is another important consideration. The resources available for waste studies are often very limited. Thus, it is important to find ways of cutting costs. Using data sets, which are currently available, is one important strategy that has the additional benefit that it not only saves practitioners time, but also the value chain actors time. . When collecting primary data the data collection should not be an unaffordable bureaucratic burden for the food supply chain actors but should rather motivate to and contribute to the ongoing internal waste reduction work.

The methods shall provide consistent and reliable indicators for monitoring the generation and prevention of "food waste" for consecutive years to be able to compare "food waste" on a consistent basis between parts of the value chain, between different types of food and between nations as well as taking into account variation/differences in consumption, population and production.

There are a number of other success factors for waste studies. Experience have shown that terminology is important. It is important that the same terminology is used in all cases and that the involved actors understand the terminology. In this project several terms for "food waste" has been considered, e.g. secondary resources for the part of the value chain where the term food is not appropriate according to EU definitions. It was decided to use the term "food waste", see chapter3 on Terminology.

5.4 Classification

Another important aspect to be considered is the harmonization of results between countries, sectors and steps in the food supply chain and harmonization with other data.

Of major importance is the classification of the companies along the food supply chain according to the type of business activity they do. For this purpose, it is proposed that the NACE codes (NACE - Nomenclature statistique des activités économiques dans la Communauté européenne) should be used, see Appendix 3, section 1.

It is also important to use a harmonized classification of products. For this purpose, we propose the classification in Appendix 3, section 2.

6 Introduction to approaches to specific steps in the food supply chain

The reviewed scientific studies and the participants experience have revealed that different methods are relevant and applicable in different situations. Sometimes several methods should be used in combination to achieve the best possible result.

As mentioned in the overview (Chapter 5) a number of factors should be considered, before choosing a method. The planning should start with determining the goal and scope of the study. Then the available information on the object of the study should be reviewed and, if necessary, more information collected before an approach is chosen.

Based on the combined experience and knowledge available in the project it was decided to divide the detailed account of methods according to the different steps of the food supply chain. This division is not self-evident. E.g. a division based on type of food could also have been feasible.

The division into steps of the food supply chain is based on several reasons:

- The activities in the different steps are often very different from each other.
- The same steps for different products, often bears many similarities.
- This approach is actor-oriented, i.e. the division follows industry borders. Even though some companies are virtually integrated, the general rule is that separate companies do production, processing, transport, wholesale, retail, etc.
- The available information, e.g. statistical data, is often divided into similar categories.
- The steps are well known to actors in the food supply chain and the general public.
- Laws and regulations are often directed towards specific actors and follow the same borders that are used here.

However, in this project the experience have been that it can be difficult to establish clear borders between the different steps of the food supply chain.

The specific approaches for quantifying "food waste" specific for each step in the supply chain are described in chapter 8-14. To get an overview of the whole food supply chain, the boundaries of each step are illustrated in *Figure 6.1*. As shown in the figure, the steps in the supply chain are based on activities. Some activities can be performed by different stakeholders i.e. washing and sorting of vegetables can be conducted by either primary producers or processing industry. The coupling of activities and stakeholders will vary among countries and products and it is not possible to find a strict boundary that will handle all situations. These problems mainly arise between production and processing, but also occur in transportation between the steps in the supply chains, because it varies who is responsible for the activity.

The primary production step is sometimes defined as activities that take place at farm site and that does not include processing or packing of processed product. In this case primary roduction is defined according to activity, hence parts of the production may occur off-farm. This also includes processing activities that do not destroy the integrity of the product, e.g. drying, washing and sorting. Processing is defined as processing of product, where the products are no longer intact (cut, mixed, heat treatment etc.) and includes also packaging of processed products. This means that washing, sorting, drying and packing is part of the primary production step (because the product remains intact) but if washing, sorting, packing takes place together with processing & manufacturing activities leading to a processed product then these activities are considered at the processing step.
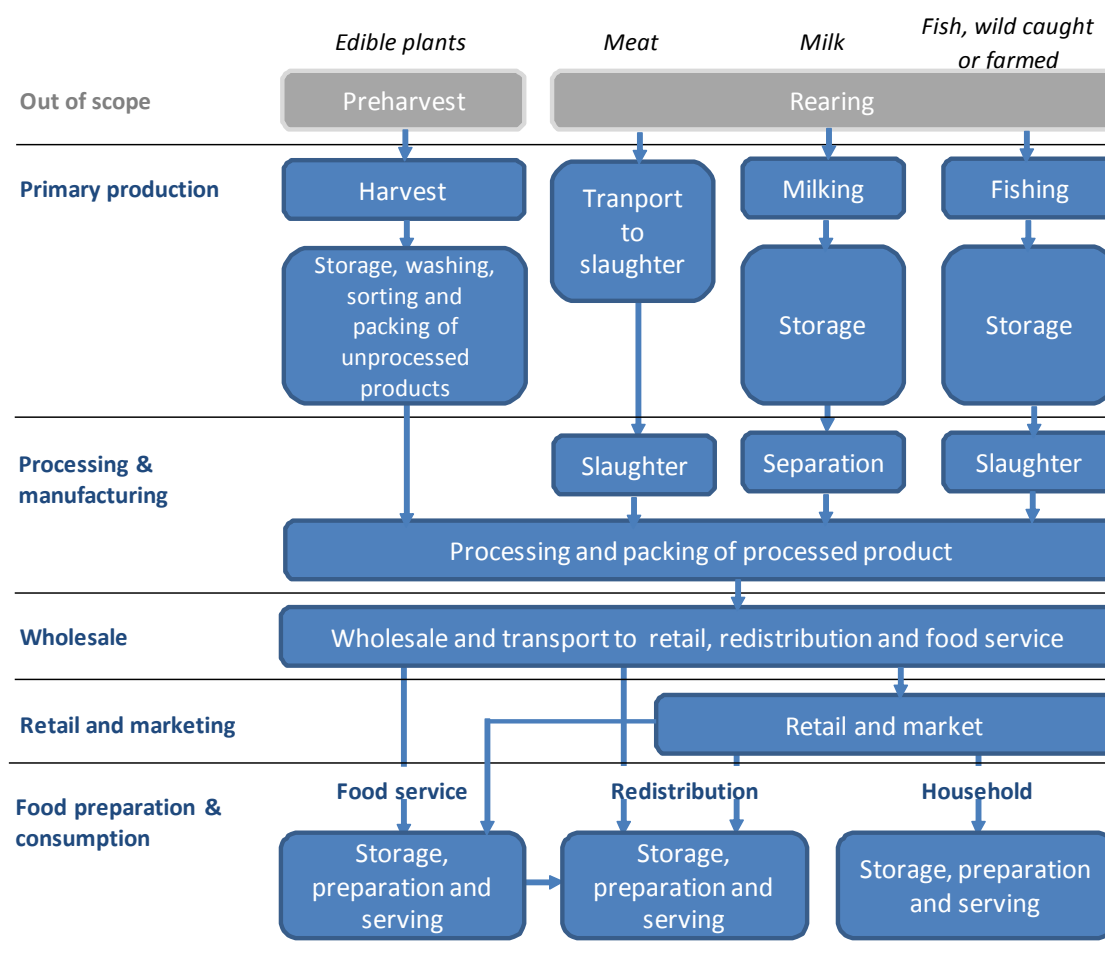
Figure 6.1 Supply step boundaries

Figure 6.1 is meant as an illustration of the division into life cycle steps used in this report. It is not intended to show all material flows between the actors. In many cases some steps are omitted, e.g. when products, sometimes even unprocessed, are sold on the farm or on markets. This is especially prevalent for fruits and vegetables. Another example is redistribution of food from a production or wholesale company to consumers via a charitable organisation.

7 Recommendations on overall level

The work in WP1 has identified the following needs for methods for quantifying "food waste":

- Need for harmonized methodologies in the EU as well as globally
- the need to use different methods for different types of problems and research questions (need flexibility within the main framework)
- Need to consider data both on the micro level and the macro level, e.g. data for one organisation as well as entire sectors or entire food chains
- Need to considerproduct-/process specific rules which specifies methods to be used within the main framework

The amounts of "food waste" in Europe every year is staggering. In order to influence policy it is important that reliable figures on an aggregated level are available to politicians and other decision makers.

Literature review and the author´s experience indicates that starting from the current "food waste" data situation, it will take several years until reliable and detailed "food waste" statistics on a national level will be available in all EU member states."The most important reasons for this is the large number of value chain actors especially in the start and end of the value chain (farmers and consumers), the large number of products and the limited data currently available.

The question is whether there is any way to make "food waste" data available to decision makers within the next few years in order to bridge data gaps. One possible way is to use a framework analogeous to the one used by IPCC for the National Greenhouse Gas inventories. The framework is general, but an example of how it can be applied is given below each step.

- **Tier 1   Simplest method.**
  European average waste compositional figures are applied to national household waste amounts
- **Tier 2   More specific method**
  National waste statistics and national composition analyses are available
- **Tier 3   Most detailed level**
  National waste statistics, several detailed waste composition analysis and supporting studies are avilable**.**

In the example used above the simplest method could be to use average data on waste composition for the whole of Europe. For example: One European study shows that 1 ton of household waste contains 1 kg beef. For the Tier 1 approach a country could use this and multiply with their own number for household waste to calculate household beef waste. This approach could be short-time implemented in those countries which have a current weak national "food waste" data base in order to bridge data gaps.

If specific numbers for the country on the amount of beef in household waste exists, the Tier 2 approach can be used. This approach could be immediately implemented in those member states which already have more detailed information on national "food waste"

composition in order to consider national conditions in a proper way. Meeting Tier 2 is a mid-term goal for member states which currently only meet tier 1.

In the Tier 3 approach national waste statistics and several detailed national waste composition analyses is combined with other studies to give a more detailed national result. The other studies might be e.g. diary study, interviews and questionnaires. This level is a long-term goal for the EU member states.

8 Description of approaches for primary production

8.1 Process description

System boundaries for the primary production step data are presented in *Table 8.1* and *Figure 8.1*. The table does not contain all products. The starting point for edible[2] plant-products intended for human consumption is a product ready for harvest, and thus pre-harvest activities are excluded from the scope. Accordingly, for animals the starting point is when the animal is ready for slaughter. Thus, the system border between meat and plant products is harmonized, following the analogy: *harvest=slaughter*. The general principle for the ending point for the production-step is when the product is ready to be processed or transported to wholesale/retail/end-user. For edible plant-products, processing is e.g. peeling and milling. However, processes where the product stays mostly intact, i.e. the product is harvested, dried, washed, sorted and/or packed (unprocessed), are part of the production step. For meat production the general principle for ending point is "transport to slaughterhouse" i.e. before slaughter, and for milk the general principle for the ending point is "transport to dairy" i.e. before pasteurization, homogenization and to processing into other products.

Table 8.1 System boundaries for the primary production-step data (not all products are mentioned)

Starting points "when the raw material enters the economic/technical system for food production or home grown consumption"	- When crops are mature for harvest - When fruit and berries are mature for harvest - The harvesting of wild crops, fruit and berries - When animals are ready for slaughter (live-weight) - When wild animals are caught or killed (live-weight) - The drawing of milk from animals - The catch of wild fish in the net on the hook - When fish from aqua-culture is mature in the pond
Ending points "when the raw-material/sub-product/product exit the economic/technical system for food production or home grown consumption"	- When crops, fruits and berries (including wild berries and mushroom) have been dried, washed, sorted and/or packed (unprocessed) - At "transport to slaughterhouse" i.e. before slaughter (including losses due to injuries, fractures etc during loading at farm and unloading at arrival at the slaughterhouse) - When milk enters processing at the dairy, i.e. before pasteurization, homogenization and processing other products, such as, cheese. - When fish has been killed and bled, and fins and intestines are removed and the fish is ready to be cut in parts, heat-treated, salted, dried or processed in some other way.

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[2] Excluding plant products produced for other purposes than for human consumption whether they are edible or not.
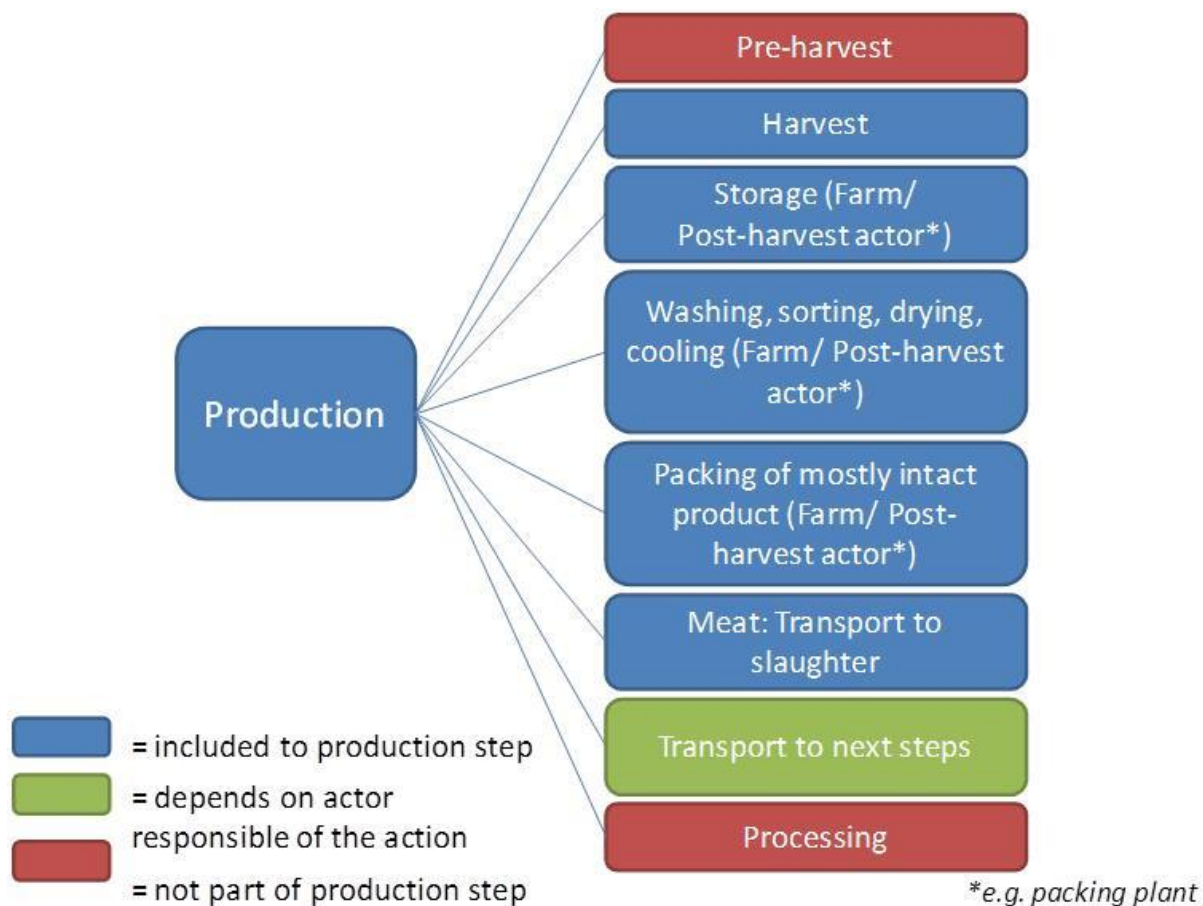
Figure 8.1 Process description for primary production

It is very important to note that different food chain actors (e.g. primary producers and industry) may perform activities that belong to the primary production step. For instance, packing of unprocessed products can be done by producers and by packing plants, but the process still belongs to the primary production step. Likewise, primary producers may also perform activities that belong to other steps. For instance, primary producer can process his own product. In other words, "production specific activities" and actors that are traditionally linked to production actors (farmers) are not always the same. Moreover, some activities are similar but, according to the used definition, they can also belong to different steps of the supply chain. For instance, packing of unprocessed product is production but packing of processed product is processing.

The required level of detail in data collection is highly dependent on the purpose and scope of the study.
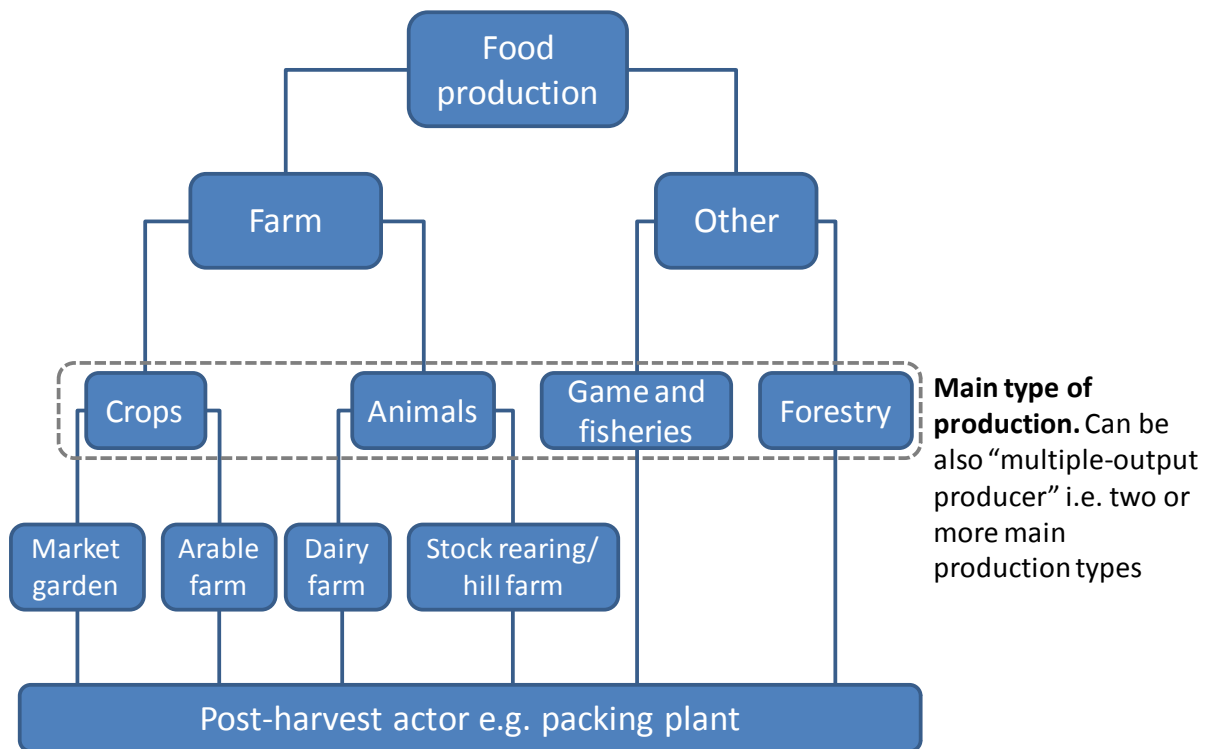
Figure 8.2 Level of detail

8.2 Indicators and data requirements

8.2.1 Recommended indicators

Indicators can be used to relate the results in different levels. Indicators can then be used to scale up the results and to give results for a specific product, for different sectors (e.g. horticulture and dairy products) and for geographical areas (e.g. entire countries or regions).

The most suitable indicator for "food waste" (or any fractions of it) in primary production is based on the quantity of production e.g. "food waste" per produced unit. In specific, total production volume gross yield is the most suitable denominator, but there is limited data on this figure, whereas, statistics on sold amounts per year are usually available. Therefore, *"food waste" or any fraction of it per sold unit* is the most practical indicator and suggested here. It should be noted that the sold amount excludes all product that is not sold for human consumption. In practice, in case like cereals or legumes, it is often not possible at production step to determine the final markets (human consumption, animal feed, biomaterial etc.) to which products are directed when sold by the farmer.

Moreover, besides the chosen indicator, additional indicators are meaningful to attain more information of processes (i.e. economic value, land use etc.) and of markets for a specific product.

Animal mortality during transport is indicated by both a ratio of the number of dead animals related to total number of transported animals and by the total number of dead animals (Petracchi et al., 2006, Malena et al., 2007). The number of dead animals during

transport (and on the farm) is systematically recorded in many countries by a mandatory national animal health service and included in national statistics on agriculture (see Malena 2007, for pigs and cattle). In Europe, national identification databases for farm animals exist and contain death records. In plant production, losses at harvest are indicated in percentage of harvested amount, losses at storage in percentage of amount to be stored (Peter et al., 2013). Additionally, in some cases the masses of lost produce are indicated. To aggregate data on the amount of wasted food data for harvest and post-harvest activities (storage, packing, etc.), a common denominator needs to be determined, for example the amount of harvest in plant production. In animal production for example, lost animals (number of animals, live-weight) at transport and discard of part of the animal (carcass weight) cannot simply be added either.

Production of exported and imported products should be taken into consideration. Export and import may be relevant when a post-harvest company or slaughterhouse further handles the product. At the primary production step, exports and imports of live animals for slaughtering can be an issue according to country-specific issues. It is best if data on domestic production and domestic waste are gathered separately from data on imports and exports. In this way, one can compare waste rates between imported and domestic products.

Additionally, there is a need to collect data and follow up data that supports waste prevention (see Appendix 2). To support these targets the minimum requirements for data collection for different product categories are presented in *Table 8.2*.

Table 8.2   Product group specific data need

Edible plant products	Amount of "food waste" in product (group) level The final fate of the waste Production volume Sold or donated amount Proportion of the product which is edible in the stage of disposal Production area: hectare, acre etc.: often readily available.
Animal products, fish (wild), aqua-culture	Production volume Sold or donated amount Total number of animals ready for slaughter Number of milking cows

It is recommended to collect data on root causes for waste. Root causes are the fundamental reasons behind waste. It can be that shops order too much product because they want a large display to show abundance, that they want to be sure they always have enough product, that the staff is not sufficiently trained or a number of other reasons.

8.2.2   Product specific rules

The same rules should in general apply for all products. However, some product specific issues need to be given a special attention. These considerations are given below.

Edible plant products
Edible plant products are mostly from open field production and these crops are more subject to weather conditions and diseases (fungi, insects, weed, etc.) than other production. Conditions may vary strongly from year to year and from area to area, and

even within the same area. Soil type and management techniques strongly affect the waste amounts. As a further complication, the number of producers is often large for these product categories. One consequence of this is that it can be more complicated to attain a representative sample at the primary production step. This makes it difficult for direct measurement of waste, such as gathering data directly from farmers, but also for estimates or extrapolations of waste from data. This means that:

- In order to achieve temporal representativeness rolling averages over several years should be considered
- Different technologies and practises should be analyzed separately, e.g. organic and conventional
- Different geographical areas and climate zones should be analyzed separately
- A minimum share of the total population must be analyzed
- Data should be gathered from several sources, e.g. questionnaires complemented with some interviews and expert opinion
- Special care must be taken when selecting samples for direct measurements, e.g. areas for pre-harvest waste
- These products are often stored for a long time, and waste rates increase with storage time. This should be considered when measuring waste rates
- The quantification of inedible parts may be more difficult for crops where these parts are left in the field (e.g. cauliflower) than products where these parts are harvested and thus enter the value chain.

Farmed fish

Farmed fish is in many ways parallel to meat value chains. The majority of the waste occurs during the lifetime of the fish. The life cycle stages included in the system boundaries considered in this report are the transport of (live) fish to slaughter, the slaughter and other processing without destroying the integrity of the fish (i.e. gutting) and transport to processing. The waste rates in these stages are often very small as these are industrial processes that are easier to control than the processes during the lifetime of the fish. The latter processes are a result of the interactions between biological and industrial processes.

Wild fish

The production phase for wild fish goes from the fish being brought aboard until it is bled and gutted. Wild fish are usually killed and gutted shortly after being caught. The harvesting phase i.e. the fishing activity can, however lead to high waste. The major reasons are the fishing technique and discards.

All fishing techniques have weaknesses that lead to loss of product or reduction of quality. Most fishing techniques catch large quantities of fish in one batch, e.g. a trawl haul. The fish is often pressed together while the trawl is in the sea, especially in the later steps of the haul when large quantities of fish are pressed into a small volume. This leads to some fish dying during the process. This dead fish is not used for human consumption, and thus is waste. Some fish is not bled properly after slaughter or has compressions damage, and is thus of inferior quality. This fish is often sold for human consumption but has reduced quality. The reduced quality usually means reduced price and reduced profits or even zero profits. This kind of economically less profitable food production is not counted as waste since it is used as human food.

After the fish has been caught, it is common practice in many countries to discard fish that is not commercially profitable or is not allowed to land because of government regulations. This includes some by-catch species and wrong type of (usually undersize) target species. It may be very difficult to find data for discards because this is a controversial issue and in some countries, discards are illegal. The situation will probably change in the coming years since discards are gradually being phased out in Europe.

A main reason for discard of milk is antibiotic treatment residues in milk due to mastitis of milking cows. This milk must not directly enter the human food supply chain. It can either be fed to calves (The restrictions are to be confirmed) or be poured down the drain. It is necessary to distinguish regular milk fed to calves (not considered "food waste" as necessary for the reproduction process of animal production systems) from discarded milk. Another important waste reason may be short shelf life due to strict regulations on expiry date.

Meat

Losses of animals can occur by trauma when loaded on trucks, driven to the slaughter facility and unloaded (preslaughter mortality). The number of animals that are "dead on arrival" (DOA) is registered by EU member states in a national database. For bovine animals specifically, but also for other farm animals, the requirements on cattle identification, registration and tracing are governed by several pieces of EU legislation and are very strict. The legislation allows having a thorough record of dead animals on the farm, during transport or at the slaughterhouse. Since legislation on the transport of animals has become more and more strict for animal welfare reasons, preslaughter mortality has decreased.

8.3 Quantification of the amount of wasted food

"Food waste" from primary production goes into many streams: animal feed, left to field, fermented to biogas, etc. A specific point for quantifying losses at production is the large number of producers and large variety of products, whereas for instance the number of processing companies is by far lower. Additionally, waste may vary a lot between farmers (e.g. practices, geographical area), within farms (e.g. between different fields due to different soil types) and between products. Seasonal variations in crop production (especially due to changing weather conditions) highlight the importance of collecting data from several years. Some products are stored for some time, and thus measurements will have to be made several times during the storage process. Overall, these different factors of variation in "food waste" levels need to be taken into account when quantification methodologies are designed.

It is very common that ready to be harvested farm commodities are left to field to enrich the soil, or that part of production, e.g. of cereals, are used as animal feed. Furthermore, farm products are often raw material (animals, grains, seeds etc.) that need to be converted to define the edible part relevant for "food waste" data.

8.3.1   Measuring (mass or volume)

There are two common ways to quantify "food waste" directly: mass or volume. It is also possible to count losses, such as the number of dead animals, and to convert them into lost mass. Only a few examples of on-site measurements to quantify "food waste" in production were found (e.g. Castro-Garcia et al. 2006), and therefore the conclusion is that measurements on "food waste" in production seem to have been rarely performed or to have not been recorded.

Although on-site measurements (e.g. field sampling) are rarely used to calculate "food waste", the method is a good way to attain accurate results. However, they are time -

and money consuming, and especially field sampling can only be used for short sampling periods and for selected areas with small sample sizes. Additionally, due to seasonal variation it is recommended that samples are taken from a several year period (see more 7.2). Overall, weighing is a fundamental method used in quantification of "food waste".

8.3.2   Scanning

At primary production step, scanning is usually not an option as products are still basic farm commodities not equipped with barcodes. Scanning is only an option when unprocessed packed products, equipped with barcodes, are lost or wasted at production step (or at transport from production to next step).

8.3.3   "Food waste" diary

"Food waste" monitoring by diary has not been common practice so far (no examples found), but could prove useful for farmers also to track related practices or incidents. It can be used for short sampling periods and for selected areas with small sample sizes, but also as part of common book keeping or mandatory data collection (performance monitoring or other type of mandatory monitoring i.e. use of pesticides, animal diseases and veterinary treatment, etc.).

8.4   Data collection and survey

Indirect data collection can be divided into data collection from existing written sources and from involved actors. Examples of data from existing written sources include statistical datasets. These data can be actual waste data and other data that can be used to calculate waste data (see 7.4.2). Examples of collection from involved actors include survey questionnaires and interviews.

8.4.1   Questionnaires and interviews

Questionnaires and interviews are widely used methods for collecting data. Both methods are also used in several studies to study the amount of "food waste" in primary production (Ahokas 2012; Beretta, 2012; Franke et al., 2013; NRDS, 2012; Davis et al., 2011; Terry et al., 2011). Both methods enable comprehensive data collection from producers: not only on amounts, but also on other relevant issues, such as handling of waste and possible root causes for waste are (see section 8.5). They also enable sharing of information with producers e.g. on waste prevention measures. Interviews and survey questionnaires are especially useful in filling data gaps.

Questionnaires sent by email enable the targeting of a large number of participants. However, it might still be difficult to get a high response rate. For instance, confidentiality issues may lower the response rate, and thus it might be appropriate that the first contact with producers is facilitated by a professional organization in the field of farming which provides a basis of confidence (farmers' unions, farm networks for data collection used for specific purposes, etc.). Interviews are more time consuming but they usually have higher success rates with responses.

Human factors, like understanding of used terms and questions, challenge the use of both methods. Sampling biases (like bias towards particularly interested and involved participants who diminish the average waste level) need to be considered as well as producers' possibility to estimate or measure waste amounts. Overall, the low response rate and sampling bias complicate the aim to get a representative sample when using interviews and questionnaires.

8.4.2   Calculation methods from statistical data

Statistical data can be used in different ways to calculate total waste of a product at the relevant level (national, regional, etc.). Multiplication of per unit waste with the total consumption is possible to obtain national data. Another example of the macro level approach is to calculate waste of a product based on the collected amount of waste generated in a country and data from waste composition analyses. Since this indicator by definition only shows the part sent to waste treatment, similar investigation must be done to find out how much is used for other purposes e.g. for animal feed and energy production.

Many statistics are based on sold amounts of a product. Net - and gross harvest can be estimated by multiplying harvested amount per hectare or animal and comparing it to statistical data on total number of animals or field surface.

Few examples of statistical data providers:
- The Farm Accountancy Data Network (FADN) could be used as a possible tool to gather "food waste" data on an EU-level from farmers although the information found in FADN is mainly economic data and very general. An extension to cover waste specific aspects would be necessary. It should be noted that Norway is not part of the FADN.
- In Eurostat waste statistics the required data are the same, but all countries are free to choose their own methods for collecting data, which so far makes it difficult to compare waste figures. However, harmonization work on methodologies is ongoing.
- Country specific farmers' unions' statistics, public farm statistics, and farm networks could be used. E.g. in some countries the statistical agency have a number of model farms or model fishing boats that they have an agreement with that they deliver data at regular intervals or that the agency receive the data the units send to the government anyway.
- National animal farm identification systems for death of farm animals.
- A mass balance approach may also use statistical data (see 7.4.3).

8.4.3   Mass-balances

Mass-balances are ways of calculating waste using other data, e.g. sold harvest, total harvest, waste treatment, users of discards (Gustavsson et al., 2011 & 2013) but require available statistics and/or expertise (Almeida 2011; Beretta 2012). Mass-balance is a method that in principle can be used for all levels, but is usually used for a larger unit (company or national level) or the whole supply chain. A very simple version of mass-balance is to collect or estimate total harvest data and compare that number to data on sold amount. Overall, in production mass-balances can be best used for situations where data seems clear, for example for losses at slaughterhouses (output of pork meat relative to input of live animals) (Franke et al., 2013).

Inversely, estimates on wasted food retrieved from mass-balances, for example from food balance sheets of governmental statistical agencies, may not be a reliable indicator. In food balance sheets, losses are one amongst other parameters when putting supply and demand in the equation.

Total domestic supply = total domestic demand, of which:

Total domestic demand = production + imports – exports + stock variation
Total domestic demand = Seeds + Losses + Feed + Industrial usage + Processing + human consumption (without industrial processing)

According to the methodology manuals provided with food balance sheets, losses is one parameter which is, at least partially, used for outbalancing other parameters (production, industrial processing etc.) which are based on primary data. It can be expected that the losses parameter in food balance sheets do not reflect loss amounts based on primary data, but is an adjustment variable.

Furthermore, in order to avoid double counting, what is reported as losses may not include amounts of for example vegetables discarded from the supply chain and fed to animals or returned/left in the field, as has been reported for for example cauliflower in France's food balance sheets (see http://www.agreste.agriculture.gouv.fr/IMG/pdf/SBIL_FLEG_1_Choux-fleursBrocolis.pdf).

Overall, mass-balances or food balance sheets produced by statistical departments are quite heterogeneous from one commodity to another and from one country to another. This heterogeneity makes the use of mass-balances difficult to calculate waste data currently difficult.

8.5 Methodological recommendations

8.5.1   Recommendations for quantification of wasted food

The recommended methods for quantifying "food waste" are on-site measurements (Castro-Garcia et al. 2006) and "food waste" monitoring by diary, whilst, no existing examples were found on the latter. However, the monitoring by diary method could be introduced as e.g. part of the farmers' mandatory data collection.

8.5.2   Recommendations for data collection and survey

The recommended methods for data collection are interviews and questionnaires (Ahokas 2012; Baretta 2012; Franke et al., 2013; NRDS 2012; Davis et al., 2011; Terry et al., 2011), statistical data, and mass-balances. The first two are applicable to calculate conversion factors, while, mass-balances (Gustavsson et al., 2011 & 2013; Almeida 2011; Beretta 2012, Franke et al., 2013) provide a holistic picture. Statistical data providers that provide data on the amount of wasted food amounts were not identified and thus mass-balances is currently a more applicable method.

8.5.3 Summary of presented and recommended approaches

The suggestions for approaches and used practices are based on the arguments presented in sections 8.3 and 8.4, and the aim, goals and restrictions presented in chapter 2. Additional details for good practices are provided in 8.2. In *Table 8.3* the approaches are evaluated by the suitability of the method, i.e. "readiness for use". All the reviewed approaches are still in early steps of development, and thus none of the approaches is received as directly applicable. The recommended approaches also apply to the quantification of "food waste".

Table 8.3 Summary of recommended approaches for quantification and data collection of the amount of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies* for improved insight	Internal prevention approaches**
On-site measurements		x	x
"food waste" diary		x	x
Interviews and questionnaires		x	x
Statistical data (Possible tools: Eurostat, FADN)	x		
Mass-balances	x		

* Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem

** Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally (good manufacturing practice for reducing wasted food)

This project has reviewed several studies, identified possible methodologies, evaluated the methodologies and based on this have put forward some recommendations on which methodology to use for the different purposes. Altogether, according to the literature review, very few studies have been made on losses and waste in production and there have been little or no efforts to standardize data collection and calculation methodologies (Smil, 2004). Therefore, the subject discussed here to give methodological suggestions to measure the amount of lost or wasted food in production should be received as the first approach for quantification of the amount of wasted food in production and which will require further development in future.

The used approaches in the primary production sector are data collection methods which include measurements, interviews, surveys questionnaires and assessing existing data e.g. from waste treatment plants, government statistics or farm accounts. The quantity of waste is calculated as an absolute number or a percentage of total amount of product through mass-balances and other simple mathematical procedure. The main complicating factors are the large number of producers and the often large variation in waste and yields from product to product, year to year, area to area, between technologies etc. In addition, the lack of studies, and therefore examples on good practices, are a definitive drawback. Additionally, it is not clear what "edible waste" in production is, which complicates the estimation. Furthermore, at the primary production step, the final use of a product is not always known since animal feed, pet food, bioenergy, biomaterial and industrial systems are closely interconnected. This means that "production intended for human consumption" is a theoretical concept facing challenges when applied in practice.

The methods used to calculate waste would be different depending on the level of progress of knowledge so there is need for a road map.

To estimate the levels today, when insufficient data is available, on-site measurements should be made to examine waste levels and the reasons behind the waste. Based on the results indicators can be made quantifying waste per unit-packaged product, per acre production area or based on other readily available data. In the future, when methods are mature and the data needed in the assessments are incorporated in national statistics or other readily available sources, waste can be monitored using both indicators and other methods and data, which confirm the results from the indicators. Additionally, different methods might be necessary to quantify waste in the different phases/activities within production.

Harvest waste is often not recorded, hence weighing should be used in the initial phase for plant products. This is a very resource intensive method so great care should be taken to find representative samples. For animal production, the harvest waste equals animal mortality incurred in the transport to the slaughterhouse. Animal mortality is often systematically recorded, and hence the data collection method depends on where the amount is recorded.

Waste during storage, washing, sorting and other initial processing can be quantified directly from gathered data or using mass-balances, but initially it is necessary to get an overview of which fractions (side flows, by-products) exist, how they are treated and the reasons and root causes for this waste. This overview can be achieved by contact with the involved actors through interviews and questionnaires.

9 Description of approaches for processing & manufacturing

9.1 Process description

The generic "Processing & manufacturing" step of the supply chain, considered in this section, starts when raw materials enter industrial food processing industries (food manufacture) and ends when the sold manufactured goods leave the food processing industries. Different processing industries (bakeries, dairies etc.) perform different types of activities when transforming raw materials into various food products, and in order to know which activities that occur within a specific food processing industry, *the specific process needs to be mapped*. A "process", in this context, refers to a series of activities which could include all, or a few, activities occurring in a food processing industry; reaching from incoming raw materials to finished product.

Figure 9.1 shows a generic process description for food manufactures indicating the types of activities, which often occur at a food manufacturer. Certain activities, such as sorting may occur several times in different steps of the process.
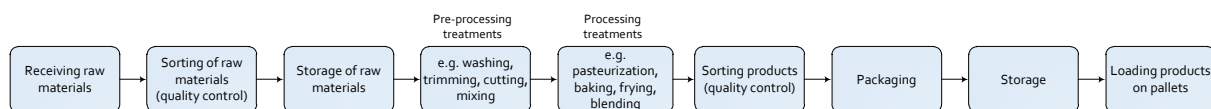
Figure 9.1 A generic process description for food manufacturers

When quantifying "food waste" in a food processing industry, it's important to map the process of interest at a level detailed enough to clarify *all activities* which may generate waste.
Figure 9.2 shows the process description for a bakery, with a deeper description of the activity "mixing of the dough", to illustrate that processes can be described with different levels of detail. If only considering the process of industrial bread baking as for the lower level of detail in
Figure 9.2 (visualised at the top), then it might be so that the amount of wasted food occurring during e.g. "separating the dough into pieces" or "shaping the dough pieces" (visualised in the bottom) is neglected.
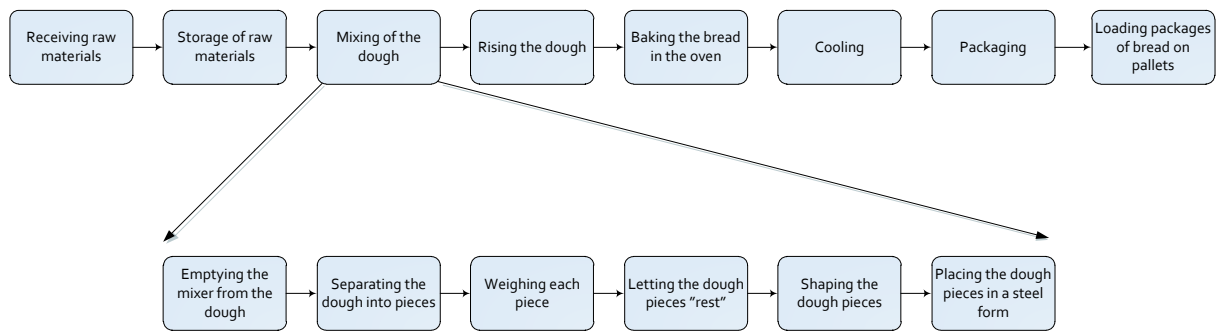
Figure 9.2 A process description for a specific bakery (as an example), with a deeper description for the activity "mixing of the dough"'

9.2   Indicators and data requirements

One indicator suitable for monitoring "food waste" in the food processing industry is:

Indicator = Total "food waste" (tonnes)/total manufactured food sold (tonnes)

This indicator mirrors resource efficiency, since it relates the amount of wasted food to the volumes produced (or more specifically, sold). Monitoring only the absolute volumes of the amount of wasted food may be misleading, since a company having a large share of waste on a small production volume may seem to have less waste than a company having a small share of waste on a large production volume.

On the other hand, since FUSIONS aims to increase resource efficiency by reducing the amount of wasted food it is also important to consider the food categories/food supply chain sectors/geographical regions, which generate the largest volumes of the amount of wasted food. The largest amount of the amount of wasted food will in many cases generate the largest environmental impact and monetary losses, even though the percentage of the amount of wasted food might be low.

The data need for the suggested "micro level approach" for quantifying the amount of wasted food requires:

1. Total "food waste" (tonne), primary data collected by weighing the amount of wasted food in the processes where it occurs
2. Total manufactured food sold (tonne), data collected from food manufacturers

The data need for the suggested "macro level approach" for data collection and survey requires both:

1. Total manufactured food sold (tonne), available from national/government statistics
2. Waste percentages (%), derived from detailed and representative "micro level" case studies.

9.3 Quantification of the amount of wasted food

For quantifying the amount of wasted food, weighing as an on-site measurement is recommended.

The pros and cons, of the presented micro level method for quantifying the amount of wasted food, in the context of the aim and goal of FUSIONS are discussed based on a *subjective evaluation* of the criteria: *data match; representativeness (time and sample size); accuracy; potential to quantify the amount of wasted food by product group and for edible and inedible parts separately*. The method is evaluated based on its *potential* to fulfil the FUSIONS aims and goals, if applied in an optimal way:

- The data collected matches the chosen indicator, since primary data on the amount of wasted food is collected and food manufacturing companies have data on the total manufactured goods sold
- The representativeness (time and sample size) is high since primary data is collected and in so the representativeness is 100 %. The data collected is however only representative for the time during which it was actually collected and for the company in which it was collected
- The accuracy of data depends on the persons(s) collecting the data, and can vary depending of the skill of this person(s)
- The method allows for quantifying the amount of wasted food by product category
- The method allows for quantifying the amount of wasted food separated in edible and inedible parts

9.4 Data collection and survey

This section deals with so-called 'macro level' approaches e.g. the use of statistics, interviews, surveys, mass balances and questionnaires.

Four main methodological approaches were identified as being of relevance to the quantification of the amount of wasted foods (and by-products) arising from the processing & manufacturing step of the food supply chain. Each study has however used a differing methodology with both merits and deficiencies depending on the purpose of the quantification being undertaken.

The pros and cons of the presented estimates or extrapolations of waste from data for quantifying the amount of wasted food, in the context of the aim and goal of FUSIONS are discussed based on *subjective evaluation* of the criteria: *data match; representativeness (time and sample size); accuracy; potential to quantify the amount of wasted food by product group and for edible and inedible parts separately*. The approaches are evaluated in each section, based on their *potential* to fulfil the FUSIONS aims and goals, if applied in an optimal way.

9.4.1 European production statistics

AWARENET (2004) uses European production quantities according to NACE codes along with a waste & by-product percentage (=transformation factor) applied to each of 19 production processes (the transformation factors applied are presented in AWARENET, 2004) to calculate a total figure for wastes and by-products generated within Europe. The

19 selected production processes give wide coverage over five key food sectors (fish, meat, dairy, wine and vegetables). However, they do not cover all production wastes from the food processing industry.

No attempt was made to calculate the edible/inedible wastes and by-products separately although it was recognised that "a great part of this volume" is valorised in some way (e.g. spread on land, animal feed, composting, etc.) but no further details are given. It is also appropriate to note that in many cases, the transformation factor is a range but a single value was used to calculate the waste quantity.

Pros and cons of the method:
- The data collected is considered to match the chosen indicator quite well since data is collected on production quantities according to NACE codes (similar to "total manufactured food sold") and since the amount of wasted food is calculated using a combined factor for the amount of wasted foods & by-products.
- Regarding representativeness, key sectors considered do not cover all production wastes from the food processing industry.
- Regarding accuracy, it is not possible to determine the amount ofby-products included in the waste figures, and these can be defined differently than the FUSIONS definition of the amount of wasted food.
- The method does allow for quantifying the amount of wasted food for a number of key food sectors (fish, meat, dairy, wine and vegetables)
- The method does not allow for quantifying the amount of wasted food separated in edible and inedible parts

9.4.2   EUROSTAT waste statistics

BIOIS (2010) uses EUROSTAT data from 2006 on manufacturing and household wastes although there is no standard method for data collection amongst member states. The chosen data set was EWC_09_NOT_093 Animal and vegetal waste excluding slurry and manure with the NACE branch DA being used for the manufacturing sector and branch HH for the household sector. The manufacturing sector figures quoted may also include some green waste and wastes originating from the tobacco industry. The definitions used for wastes and by-products may lead to discrepancies in the data and it is not possible to determine how much by-product is included in these figures. However, the data set is complete for most member states and represents the best data available for the food-manufacturing sector across the EU.

Data gaps were filled using assumptions as well as supplementary evidence from national studies to provide detail for wholesale/retail and catering/food service, which is aggregated under Other Sectors.

There would appear to be wide variation in the reported quantities of waste between member states that may be partially explained, for instance, by the concentration of food manufacturing in countries such as the Netherlands but may also reflect issues around data quality and definitions of waste. The limitations of this estimate are fully acknowledged in the report and probably reflect both data availability and the particular estimate required.

Pros and cons of the method:
- The data collected does not quite match the chosen indicator since no data is collected on "total manufactured food sold".

- Regarding representativeness, the statistics is considered complete for most member states and represents the best data available for the food-manufacturing sector across the EU.
- Regarding accuracy, the data collected is not complete, since the "food waste" statistics reported for the manufacturing sector may also include some green waste and wastes originating from the tobacco industry. In addition, it's not possible to determine the amount of by-product included in the figures, and these can be defined differently than the FUSIONS definition of "food waste". There would appear to be wide variation in the reported quantities of waste between member states.
- The method does not allow for quantifying the amount of wasted food by product category, only total the amount of wasted food is quantified.
- The method does not allow for quantifying the amount of wasted food for edible and inedible parts separately.

9.4.3   Mass-balance approach

FAO (2011) quantified food losses and waste on a global scale using FAOSTAT's Food Balance Sheets, presenting mass-balanced volumes of supply element (production, imports, stock variations, exports) and utilization elements (feed, seed, processing, waste, food) for different countries/regions of the world. The study also used (for certain crops) allocation factors to determine the part of the produce oriented to human consumption (and not for animal feed) and conversion factors to determine the edible mass.

The production volumes for all commodities (except for oil crops and pulses) were collected from the FAO Statistical Yearbook whilst the production volumes for oil crops and pulses were collected from FAO's Food Balance Sheets. Data was analysed along the food supply chain from agriculture to consumption for seven regions of the world grouped by income for each of seven food groups (cereals, roots & tubers, oilseeds & pulses, fruits & vegetables, meat, fish & seafood, and dairy products).

Pros and cons of the method:
- The data collected does not match the chosen indicator, since there are no specific data for "total manufactured food sold" available in the Food Balance Sheets.
- The representativeness (time and sample size) is difficult to determine
- The accuracy of data is also difficult to determine
- The method allows for quantifying the amount of wasted food by product category, since Food Balance sheets are available for different commodity groups
- The method does not allow for quantifying the amount of wasted food considering edible and inedible parts separately, but conversion factors can be used

9.4.4   Combining data sources

C-Tech Innovation (2004) calculates the mass-balance for the UK Food & Drink Processing Industry using a range of statistics including production data from UK government departments and data from a waste survey of 20,000 businesses undertaken by the Environment Agency. In some cases, statistics relating to England and Wales or Great Britain were scaled in proportion to the number of food processing employees to provide figures for the UK as a whole.

The study considers the resource and waste flows from the nine sub-sectors of the food and drink processing industry identified by the Standard Industry Classification 1992, SIC(92) system (

Table 9.1). Sub-sector 15.7 relates to the manufacture of prepared animal feeds enabling co-products used in the feed industry to be excluded from the calculation of the amount of wasted food.

Table 9.1 Industry sector classifications used in the C-Tech study

SIC code	Industry activity
15.1	Production, processing and preserving of meat and meat products
15.2	Production, processing and preserving of fish and fish products
15.3	Production, processing and preserving of fruit and vegetables
15.4	Manufacture of vegetable and animal oils and fats
15.5	Manufacture of dairy products
15.6	Manufacture of grain mill products, starches and starch products
15.7	Manufacture of prepared animal feeds
15.8	Manufacture of other food products
15.9	Manufacture of beverages

After allowance for the flows of products and co-products from one sub-sector to another, the sub-sector mass-balances are consolidated into an overall mass-balance for the UK food and drink processing industry.

Pros and cons of the method:
- Data is collected which can be used to match the chosen indicator quite well. The study uses PRODCOM data that publish "total manufactured food sold" and the data on waste was collected from a National (England and Wales) waste survey that included 20,000 businesses, including food and drink manufactures.
- The representativeness (time and sample size) is difficult to determine
- The accuracy of data is also difficult to determine
- The method allows for quantifying the amount of wasted food by product category, one mass flow for each sector of the food and drink industry was produced
- The method does not allow for quantifying the amount of wasted food for edible and inedible parts separately

The examination of the four key methods identified above for the quantification of food manufacturing wastes clearly shows that each have their advantages and disadvantages. Overall, when selecting an appropriate methodology, there is a need to ensure that the selected data set is both complete and matches the required indicator/definition. There may be particular industries/activities where the exact definition of the amount of wasted food is critical to good quality data collection e.g. fish processing carried out at sea, milling with high proportion of by-products rather than "waste". In addition, when using production data, there is a need to ensure import/export is considered and accounted for in international studies.

9.5   Methodological recommendations

9.5.1   Recommendations for quantification of the amount of wasted food

For quantifying the amount of wasted food (the micro level approach), weighing in combination with Lean Six Sigma is recommended. The method is foremost suitable for monitoring the amount of wasted food within single food processing industries and for supporting working company-internally with "food waste" prevention /improved resource effcienty in the production system. The method can be applied in all types of food processing industries.

Gunnerfalk (2006) and Svenberg (2007) followed the Six Sigma approach including the DMAIC methodology (Define, Measure, Analyze, Improve and Control) to measure food waste and for mapping the causes of food waste in a single production line in a food processing industry. The Six Sigma methodology has been applied in other industries for cutting different kinds of wastes and their associated costs, and projects have showed it to be successful also for preventing food waste (Gunnerfalk, 2006, Svenberg 2007, and Lindbom 2013).

The recommended company-level approach for quantification of "food waste" can be concluded by:
1. Mapping the process
2. Weighing "food waste" in the process where it occurs (=collecting primary data)
3. Perform measurements frequently enough

Map the process: Before starting the measurements it is important to map the process (the series of activities in which the "food waste" occurs or may occur) in order to understand the process and what activities the process is made up of. A process, in the context of a food processing industry, may e.g. the whole production line from the mixing of raw materials to the end product; part of a production line or single activities such as filling up containers or packaging. Understanding the process is necessary for understanding where waste can occur (see also
Figure 9.2).

Weighing the amount of wasted food: The Six Sigma methodology emphasizes the importance of making decisions based on facts (Gunnerfalk, 2006). Therefore, it is preferable to quantify the amount of wasted food by measuring the the amount of wasted food where it occurs, in other words by collecting primary data. The amount of wasted food varies a lot between food processing companies; within companies (e.g. between different production lines) and between products, so the measurements need to be specific to give a true picture of the the amount of wasted food amounts occurring in a certain food processing industry.

Perform measurements frequently enough: It is also important to measure the amount of wasted food frequently enough to illustrate the variations in the amount of wasted food levels over time. When following up mean values for weeks/months or even years, the variations in waste levels are not visible and the causes behind the waste are more difficult to identify. Measuring the amount of wasted food should preferably not be a single (isolated) project; the work should rather be an on-going, regular, part of the daily work.

Conversion factors: could be used for quantifying edible and inedible parts separately, different conversion factors for different product groups.

The volumes of wasted food should preferably also be *related to the different causes of waste*, to enable to see what causes the largest volumes of wasted food. This is further described in Appendix 2.

9.5.2 Recommendations for data collection and survey

For the macro-level approach, a method using PRODCOM data is suggested. It is similar to the method using European production statistics, but slightly modified. The method is foremost suitable for producing "food waste" statistics for the food processing industry; on a sectorial, national or European level.It is suggested to quantify "food waste" using:
1. Total sold manufactured food (tonnes), given in the EU PRODCOM system (Eurostat, 2010)
2. Waste percentages (%), derived from detailed and representative "micro level" case studies

The EU PRODCOM system (Eurostat, 2010) classifies products according to an eight-digit code: the first four digits are the classification of the producing enterprise given by the Statistical Classification of Economic Activities in the European Community (NACE) (Eurostat, 2008). Most product codes correspond to one or more Combined Nomenclature (CN) codes, which is the system used for customs and taxation.

The EU PRODCOM database includes data on (Eurostat, 2010):
- The physical volume of production sold during the survey period (used for the recommended macro level approach)
- The value of production sold during the survey period
- For some products, the volume of total production during the survey period

Table 9.2 shows the various food product categories classified by the NACE Rev.2 3-digit code (it can be seen that this is similar to the SIC system used in the C-Tech (2004) study above).

Table 9.2 Food product categories by NACE code (Rev. 2).

NACE code (3 digits)	Description
10.1	Processing and preserving of meat and production of meat products
10.2	Processing and preserving of fish, crustaceans and molluscs
10.3	Processing and preserving of fruit and vegetables
10.4	Manufacture of vegetable and animal oils and fats
10.5	Manufacture of dairy products
10.6	Manufacture of grain mill products, starches and starch products
10.7	Manufacture of bakery and farinaceous products
10.8	Manufacture of other food products
10.9	Manufacture of prepared animal feeds
11.0	Manufacture of beverages

It is suggested to use the more specific 4 digit code if possible – however, if resources do not allow, the 3 digit code could suffice although there will be undoubtedly greater variation in the quantities of wastes arising from the processes listed under the more generic 3 digit code.

Product group specific "food waste" percentages (developed and improved over time with detailed and representative case studies) would be applied to the volumes of

manufactured food to quantify the the amount of wasted food having occurred to produce the volumes of sold manufactured food. The waste percentages would be determined by mapping and evaluating food production systems in collaboration with industry professionals (preferably using the suggested micro level methodological approach for quantifying the amount of wasted food). Ideally, the waste percentages should define edible and inedible wastes and co-products separately.

The following equation quantifies the amount of wasted food (tonne):

$$Food\ waste\ (tonne) = \frac{Total\ sold\ manufactured\ goods\ (tonne)}{100\ \% - Waste\ percentage\ (\%)}$$

Allowance for the flows of products and co-products from one food product group to another should be made to ensure the avoidance of double counting before consolidating the sub-sector mass-balances into an overall mass-balance for the EU food and drink processing industry. This is the same approach as undertaken in the C-Tech (2004) UK study.

9.5.3   Summary of presented and recommended approaches

Table 9.3 presents a summary of the presented and recommended approaches for quantifying the amount of wasted food (or any fraction of "food waste"), from a micro level and top down approach. The recommended approaches also apply to the quantification of "food waste".

Table 9.3 Summary of presented and recommended approaches for quantification and data collection of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies for improved insight*	Internal prevention approaches**
Weighing in combination with Lean six Sigma (Gunnerfalk, 2006 & Svenberg, 2007)			X
European production statistics (AWARENET, 2004)	X		
EUROSTAT waste statistics (BIOIS, 2010)	X		
Mass-balance approach (FAO, 2011)	X		
Combining data sources (C-Tech Innovation, 2004)	X		
PRODCOM data (developed)	X		

*   Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem

**   Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally (good manufacturing practice for reducing wasted food)

Weighing in combination with Lean Six Sigma is mostly relevant for stakeholders to work internally with mapping their waste and working with waste prevention within their own business. However, results can be linked to the recommended macro level approach for quantifying "food waste" statistics on a European level.

Using PRODCOM data includes the results from detailed micro level studies (as suggested) together with available European statistics.

10 Description of approaches for wholesale

10.1 Process description

The present chapter deals with "wholesale" which is defined with the starting point at the gate of processing & manufacturing and the end point at the gate into the end user (e.g. retail, food service or household). The whole process in the present food supply chain level consists of the transport process from processing to wholesale, the commissioning process, the storage of products and the distribution to client (see
Figure 10.1). It has to be mentioned that in practise the transport processes may be conducted by different stakeholders. One situation is that a separate haulier delivers the order from processing to wholesale and from wholesale to the client (e.g. retail, food service). In this case, information on "food waste" could be found at the logistic company. Another option is that producers/processors have their own truck fleet for delivery directly to their clients. In this case, the process remains the same but information on "food waste" is found at producers/processors or from the logistic companies. This consideration is also relevant if the wholesaler´s client (e.g. retailer) has their own truck fleet. Then, information on "food waste" generated during transport process can be found at retail level or logistic companies. Independent of the stakeholder, the transport process has to be considered within the methodology.

A similar situation can also be found at the next step, which is commissioning. The commissioning step could lead to a refusal of products which in some cases are wasted on site or which are transported back to origin. In both cases a registration of the returned products at the wholesale is not common as the financial burden has to be paid by the supplier (this means producer/processor). Therefore, information on amount and further fate of the refused products can be found at producer/processor level. It is important in such situations to distinguish between the economic transactions and how the physical waste flow is organized, to avoid both double-counting and zero waste registration.
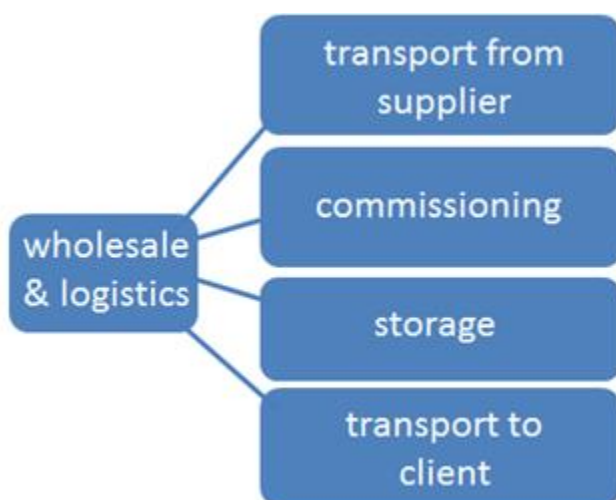
Figure 10.1: Process description for wholesale

Addressing level of detail there is the no specific suggestion to distinguish between different types of wholesalers.

10.2   Indicators and data requirements

Indicators should match the requirements as described in chapter 5. In order to compare "food waste" along the food supply chain absolute values are needed using the same units. According to the FUSIONS point of view, a mass based approach is recommended also for this issue. This means that available "food waste" information, e.g. economic value or volume based onformation, should be converted into mass through conversion factors (e.g. economic value per kg product).

In order to provide comparable "food waste" indicators the following data are needed for wholesale and logistic processes:
– total "food waste" generated per year
– rejected amounts during commission activities per year
– conversion factor to calculate mass out of economic value (coming from packaging, product description, estimation) on the level of products or product categories as far as possible
– food amounts donated to redistribution per year
– conversion factor for calculating inedible parts
– turnover in economic value
– total input of food products in mass

The information on donated food is important to distinguish between economic loss and real "food waste". As for the wholesaler the donated products are not sold, they are accounted as economic loss and are registered within the stock-keeping tools and/or book keeping tools. From a waste management point of view, food donated for human consumption is not waste but waste prevention and therefore has to be subtracted from the wasted amounts (see also chapter 10.3).

The total "food waste" per year forms the basis, which further can be converted into related indicators. The following indicators should be used for wholesale and logistics:
– total "food waste" generated per year
– "food waste" quota using turnover (in economic value) as denominator
– total "food waste" in mass per year to total input of food products in mass per year (kg "food waste" per kg input)

The indicator "total "food waste" per total input" could not only be used for comparison between companies but also other stakeholders along the food supply chain.

A split of "food waste" data into product categories is preferable as relevant information for designing appropriate prevention measures, disposal options and environmental impact. A standardized classification scheme should be used. Further information on classification of product groups is provided in Appendix 3.2.

Further information with respect to representativeness, uncertainty etc. are summarised in Appendix 1 on data quality.

10.3   Quantification of the amount of wasted food

Literature research conducted within FUSIONS indicated that there is a lack of public available "food waste" data from wholesale (Møller et al., 2013). Especially the transport steps within this part of the food supply chain are rarely mentioned and considered in literature. The review of relevant European literature indicated that on the one hand useful data for characterization and quantification of "food waste" at wholesale are not available from literature or statistics and on the other hand, direct measurements have also major disadvantages. Therefore, one has to use information from key personnel to receive additional information (e.g. share of "food waste" within organic waste, share of donated food) as basis for rough estimations of "food waste" from wholesale. Data might also be available from the logistic companies which operate on behalf of the warehouses, and where most large companies have access to data on damaged food and goods from their own activities.

10.3.1   Interviews

Interviews with key personnel from wholesale sector was used e.g. by Kranert et al. (2012), Stenmarck et al. (2011), WRAP (2011) and Beretta (2012). In most cases, it is not clear if information given by interviewees represent estimates made by the respondent based on experience, or if exact figures from company´s database were communicated. The literature review indicated that information from interviews with key personell couldn't be used for estimates on "food waste" quantity as all reports used other approaches in addition.

Pros and cons of the method:
The interviews based on company´s level could be seen as useful input in order to clarify general conditions, how assumptions could be chosen, which detailed data could be provided by the company as basis for further calculations etc. A pro of expert interviews is that they may estimate quantities or shares of "food waste" at their company at higher quality level than others. The disadvantage of interviews is that often the outputs represent estimates or qualitative information on "food waste" rather than measured quantitative figures on "food waste". Therefore, calculation of statistical characteristics of provided data is not possible. In addition, in-depth interviews are time consuming and expensive and therefore, often the results do not represent the sector in a proper way which has a negative impact on extrapolation on a region or nation.

10.3.2   Scanning

Hanssen and Schakenda (2010; 2011) used scanning method in order to determine food waste from 13 Norwegian wholesale and distribution centres split into 9 different product categories, giving very precise data about food waste. A number of different causes for food waste were used by registration, making it possible to choose between waste originating at the warehouse and waste that did not belong to their own operations.

Other approaches at level of wholesale such as waste sorting analysis are not mentioned within the reviewed literature.

Pros and cons of the method:
The scanning method represents an accurate approach to register "food waste" on a detailed level. Relating the wasted products directly with the product database of the

company, allows a deeper insight and many analyses. Nevertheless, the literature review indicated that either this method is not used to a larger extent for quantification of "food waste" or the conducted studies are not published due to confidentiality issues.

Another disadvantage of the reviewed approaches was that there was no detailed information on which processes have been included in the food supply chain step "wholesale". Therefore, it was not clear which processes could be covered by the used approaches. For example, it is assumed that the scanning method at the wholesale and distribution centres could only include products that are already owned by the companies and therefore products wasted during external transports and commissioning processes are not included and would have to be tracked by using other approaches.

10.4 Data collection and survey

10.4.1 Statistics from authorities or waste management companies

Literature research on wholesale and logistics showed that there are no or only poor "food waste" data available via statistics from (inter)national authorities or larger units of wholesale and logistics as well as scientific literature. Kranert et al. (2012) describe that available waste management data from wholesale umbrella organisations do not cover the whole sector and furthermore are related to organic waste in general. In most cases, the assortment of wholesalers of perishable goods include besides food also plants and flowers. Beretta (2012) indicate that only information on the handled number of pallets was available which had to be transformed into mass by estimate the average mass per pallet. Statistics from authorities related to wholesale are rare as in most cases more aggregated information is available only (BIOIS, 2010).

Pros and cons of the method:
The advantage of using (inter)national statistics or statistics from larger units of the wholesale sector is that the variation of "food waste" from single stakeholder may be balanced to a certain extent. On the other hand, at present there are a lot of uncertainties with respect to covered market share and waste streams, waste data related stakeholders respectively processes, composition of recorded (organic) waste and applied approaches used to establish the statistics.

10.5 Methodological recommendations

10.5.1 Recommendation for quantification of wasted food

The following methodology that is suggested as standard approach for wholesale is based on existing data found at the wholesale with integration of further details to keep the additional effort as low as possible while generating useful data. Besides the suggested two methodologies, also others are possible (e.g. diaries) but seem not to have the required effectiveness with respect to the requirements mentioned in Appendix 1.

In general, two approaches could be implemented to set up a "food waste" data basis for wholesale:
- based on existing company data or
- based on on-site measurements, if company data are not available or confidential.

In general, most of the organic waste which is generated at wholesale is assumed to belong to edible "food waste". Most of the products are already packed and mostly in case of fresh fruits and fresh vegetables it might occur that inedible parts such as leaves have to be removed during/after storing, fall out of the boxes or have to be removed during display.

Methodology based on company´s data base

Existing company data coming from electronic stock-keeping tools and/or book keeping systems can be used as baseline information and adjusted with new information for quantification of "food waste". Depending on the responsibilities for the transport from supplier to wholesale, data on "food waste" between gate of supplier and gate of wholesale have to be collected. If quantification of "food waste" of the wholesale is to be recorded honestly, those quantities that are sent back to suppliers (edible products not commissioned by wholesale as not meeting required standards) should also be considered. As in most cases there is no tracking of those amounts at the wholesaler (as not entering the wholesaler´s gate from a book-keeping perspective), the implementation of a "food waste" diary at wholesale or recordings of supplier should be taken into consideration.

Basic information from wholesaler´s electronic book keeping system which holds information about general product details, sales of the product and non-sold products (information that come from scanning of non-sold products at time of removal) is normally available at least in economic terms (level of detail varying but mostly available on single product level). This information source often also includes breakage as well which belongs also to "food waste" according to the FUSIONS definition. Economic information should be converted to mass based amounts by using information from logistics (needed for truck load calculation), packaging (information printed on product´s packaging and included partly in products specification) or estimation of product experts in case of unpacked products or if no other information is available (e.g. 1 piece of mango equals to 350 g on average). This leads to information of non-sold products in mass units.

It has to be considered that "food waste" as defined by FUSIONS includes only mass based waste and not economic based amounts. Therefore, there is a difference between non-sold products in general or products sold to reduced prices that mean an economic loss for a company, and those non-sold products that are donated to redistribution sector. If there is a cooperation with food banks or other organisations which redistribute (parts) of the non-sold food products for human consumption, these amounts should be subtracted from the overall "food waste" data. The same is the case when products are used in own canteens or given/sold to employees to reduced prices. Some companies already record these amounts in their electronic systems, others should implement a scanning and recording approach or conduct a "food waste" diary for extrapolation for one year.

In order to split the total "food waste" into edible and inedible amounts, conversion factors have to be introduced to subtract the inedible parts (if applicable, e.g. with fresh produce). To provide comparable data, the time span considered for the calculation of total "food waste" should be one calendar year. Figure 12.2 shows a scheme how to calculate the "food waste" quantity based on existing data adapted with further

information. On the left side of the scheme the related process steps are indicated (logistics, commissioning, storage, logistics) which were also displayed in *Figure 10.1*. In order to achieve a total sum of "food waste" at wholesale, the calculated "food waste" split into edible and inedible parts of each single process step has to be summarised. One should keep in mind that all information should be provided for certain product categories mentioned in Appendix 3.2.
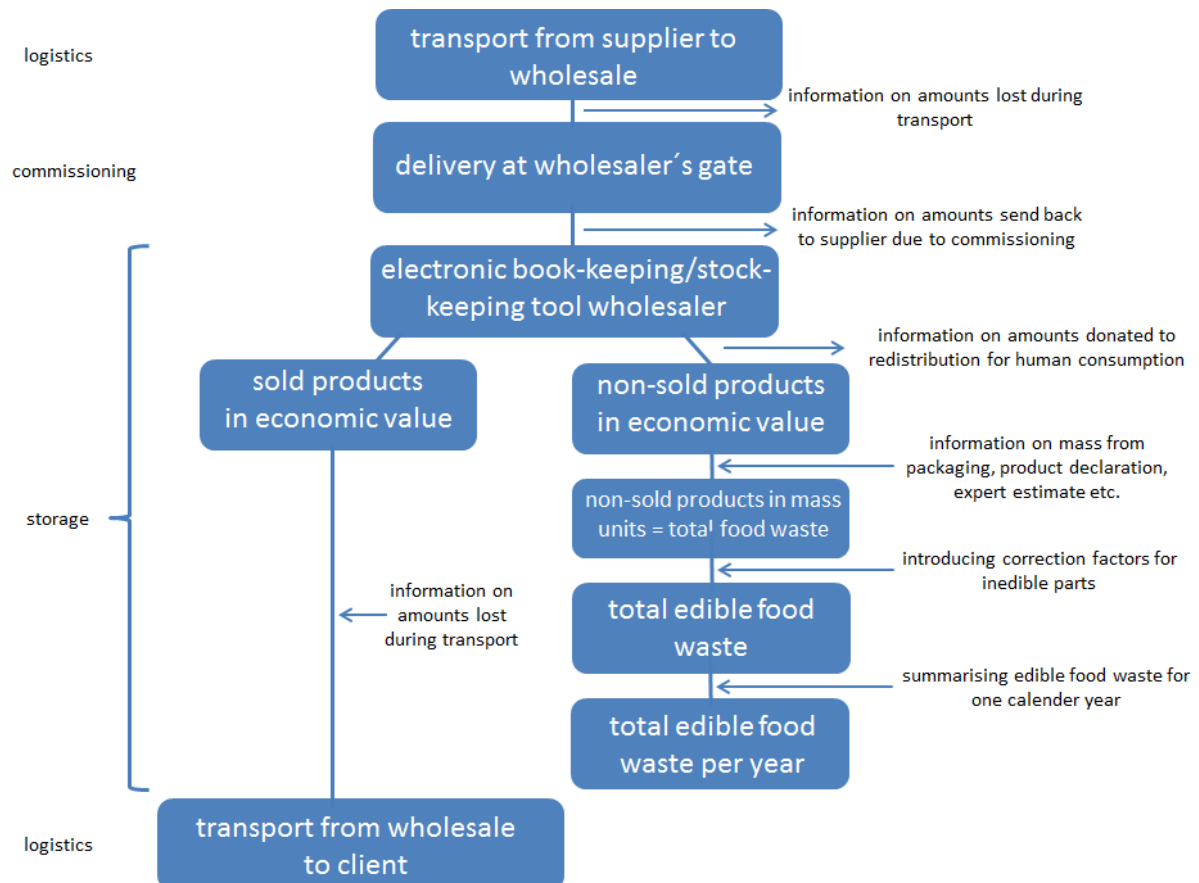
Figure 10.2: Scheme of quantifying "food waste" at wholesale based on existing company data adapted with further information

In order to provide "food waste" indicators, the total edible "food waste" generated per year should be converted. In case of wholesale an edible "food waste" quota using turnover (in economic value) could be used. With this indicator a comparison with other wholesalers nationally and internationally would be possible.

Another option is to relate total edible "food waste" in mass per year to total input of food products in mass per year (kg edible "food waste" per kg input). This approach would allow also a comparison with other stakeholders (not only wholesalers or other companies) with respect to "effectiveness" of input utilisation.

The pros of the described approach are that a large amount of existing continuous data (amount and composition) are available if the data base is an electronic system which is used for other purposes (e.g. recording for tax purposes, book keeping, controlling) and that there is no extrapolation from small-scale on-site measures necessary which are often not representative. In addition, the data are available on article basis and later a grouping with respect to certain product categories could be conducted easily, if required. Cons are that there is a conversion from economic data to mass based data necessary, one has to consider manually the subtraction of packaging mass and mass of inedible

parts (if not available, the conversion factor of inedible parts could also be considered on a national basis, if composition data are available) and correction for products that are not sold to full price but not wasted either (donations, sold to employees, used in canteens etc.). Also for the information on returned amount during commissioning process as well as transport processes, a separate recording has to be implemented at wholesalers respectively double-counting with recordings at supplier level should be avoided.

Methodology based on on-site measurements

If a wholesale company does not have an electronic system where the necessary information is stored, they could use the registration of their waste from the wholesaler´s waste management company and conduct waste sorting analyses to determine composition and calculate amounts or eventually use waste factors available in literature. *Figure 10.3* shows a scheme of quantifying "food waste" at wholesale based on existing waste management data and additional waste composition analyses. The available waste management data, which usually is available in mass or volume of waste is obtained from the external waste management company that is in charge of disposal of the wholesaler´s waste. If the waste management data are already available mass-based, they can be used directly. If waste management data are only available in volume (not available bin volume but real waste volume), a conversion factor (bulk density) has to be determined to calculate mass from volume recordings together with the composition analyses.
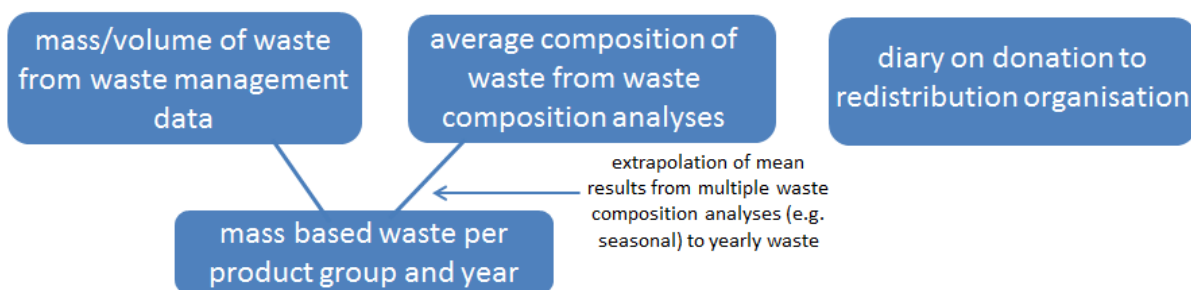
Figure 10.3: Scheme of quantifying "food waste" at wholesale based on existing waste management data and further on-site measurements

In addition, the composition of the generated waste is measured by separate waste composition analyses, which have to be planned according to the information given in Appendix 1. Of course, conversion factors to consider packaging mass, inedible parts etc. have to be applied also within the present methodology similar to the approach described in for companies' data base. In contrast to the methodology described for on-site measurements, the product categories have to be determined according to Appendix 3.2 before conducting the sorting analysis as a detailed analysis per single article is not feasible and there is less option for a changed classification at a later point of time.

There is also a difference to the previous described method with respect to food products which are donated to redistribution organisations. In order to register those donation activities, which can be accounted as "food waste" prevention measure, a separate diary should be implemented on regular basis in order to also track potential internal optimisation options on the one hand and to prove the level of existing prevention on the other hand.

Along the approach of the previous described methodology, the process steps of logistics have to be recorded separately.

Pros are that a data basis related to "food waste" could be provided but cons are that the approach is very time consuming, needs proper planning in order to consider all data requirements and therefore is expensive. This should be considered particularly with relation to a long-term approach (to provide regular data for a longer period).

Another downside with using data from waste management companies is that it probably will not reflect all "food waste" generated; parts of the "food waste" may be sent to biogas plants and farms (used as animal feed) and this waste will not be included in the data from waste management companies.

10.5.2   Recommendations for data collection and survey

The best approach for the forthcoming decades seems to implement a national system where branch related data are already provided by the branch itself, as this should ensure data consistency in a proper way. In case, that single data from wholesale companies are collected, there should be a standard approach suggestion for companies provided from authority or authorised research organisations (see section 10.5.1). If this system can be implemented, an extrapolation should include a weighing method according to the market share of the respective company.

The pros of this approach are that a branch estimation is also possible in case not all companies declare their "food waste". If it is not possible to implement the described standard approach on company level, e.g. as there is no consideration of inedible parts, this issues could also be added on a national assumption, if appropriate information is available. The cons of the suggested approach are that the extrapolation is very rough if the characteristics of outlets, characteristics of assortment etc. cannot be considered. Also, if only aggregated values are available for specific companies, the calculation of statistical factors such as margin of deviation is not possible. This means that it is not possible to estimate the error of the total result. Furthermore, the consideration of inedible parts without knowledge on representative composition of "food waste" from wholesale and logistics is not meaningful (single measurements seem to be not representative).

10.5.3   Summary of presented and recommended approaches

The following section summarises the previous described approaches for wholesale, discusses the pros and cons and also evaluate the matureness of the method. The results are summarised in *Table 10.1*.

Interviews of key personnel (e.g. Kranert et al., 2012) could be used for collection of additional information valuable for further calculations of data achieved by application of other approaches. Literature review showed that in most cases interviews were combined with other approaches for quantification of "food waste". The results from interviews could give a deeper insight on conditions of "food waste" generation, barriers and incentives for prevention and therefore could be valuable for deeper studies and stakeholder "self assessment". In combination with company´s recording, they could help to achieve the suggested indicators even if not all relevant information is available as the experts could give an estimate. The accurateness of estimation on product level seems to be lower than total "food waste". In contrast, it is assumed that key personnel

could have a good quality estimation of the share of edible and inedible parts of their company´s "food waste". With respect to representativeness related to time, it is expected that interviewed experts could give a good estimation on changes or trends over a certain time period. Nevertheless, conducting in-depth interviews is time consuming and therefore it is assumed that the covered number of stakeholders is in most cases not representative for the branch (except if market concentration is high). The uncertainty of the achieved results from interviews of key personnel was already mentioned above and depends on the specific issue. The method is already applied in a large scale and could be used to get an overview on total "food waste" as well as to differ between edible and inedible parts.

The scanning method as used e.g. by Hanssen and Schakenda (2010, 2011) results in very detailed information on article level and is therefore suitable for both deeper studies as well as stakeholder "self assessment". Relating the wasted products directly with the product database of the company, allows a deeper insight into "food waste" and many analyses. In case it is possible to convert the economic data to mass data, the requirements of the suggested indicators can be achieved. As the method is based on article level, also a detailed assessment of product categories (level of aggregation can be changed after data collection easily) and a calculation of edible and inedible fractions are possible. Nevertheless, the literature review indicates that either this method is not used to a larger extent for quantification of "food waste" so far or the conducted studies are not published due to confidential issues. This means that at present the method is only used in small-scale projects and cannot fulfil representativeness with respect to time period or sample size. If conducted on regular basis, this method is very promising to provide detailed data on "food waste". The uncertainty of the scanning method is preliminary restricted on the sample size and the quality of the underlying product database. It is assumed that not only packed products can be scanned using the bar code displayed on the packaging but also unpacked products could be registered by using a separate bar code for identification (e.g. used for ordering system). As it is assumed that bar code and scanning system is already established at wholesale companies, the method is directly applicable for both total "food waste" and differentiation of fractions.

The method to use (inter)national statistics and/or aggregated statistics from umbrella branch organisations as e.g. conducted by BIOIS (2010), Kranert et al. (2012) or Beretta (2012) could be used in general for rough estimations on member state level or EU-28 level. The advantage is that the effort for the user is limited and a general overview on the situation can be achieved. As important information such as composition of the waste related to food and non-food components and in most cases also the coverage of the market share is missing, the method does not even fulfil the basic requirements of the indicator "total "food waste" per year". Due to this lack, also other related indicators suggested for wholesale cannot be calculated. With respect to the level of detail, meaning composition of the waste stream related to edible and inedible fraction or specific product categories there is also no information available. Usually, the time span of data recording of (inter)national statistics and aggregated statistics from umbrella branch organisations is one year and could be available on a long-term period. The sample size (coverage of branch) is often uncertain, especially for (inter)national statistics as due to the aggregated level, specific stakeholders of the food supply chain (or processes) cannot be tracked separately. In total, many uncertainties occur with this method. With respect to the suitability of the method, it needs to be developed further to track edible and inedible fraction as in most cases the share of other organic (non-food) waste cannot be determined.

The method of using information already available at company level (stock-keeping/book keeping tools, see section 0) is a modification of the above mentioned scanning method.

Here, the recording of the unsold products is conducted on a regular basis and automatically processed within the stock-keeping/book keeping tool. This leads to a very detailed information basis on "food waste" primary related to economic values. In case the conversion into mass data is possible, the method fits perfectly for the required indicators. If implemented on a branch scale, the method provides data for all levels – EU-28, member state as well as in-depthstudies and stakeholder "self assessment". The data can be assessed related to product categories, edible and inedible fraction can be calculated, it can be used for a long-term recording for the whole company or branch. Of course some uncertainties may occur due to conversion of economic value in mass data, problems with booking inconsistency etc. but by far those errors are much smaller than those resulting from other quantification methods. On the one hand, the technology of electronic stock-keeping/book-keeping tools is well established and allows a detailed differentiation of tracked "food waste" types and is directly applicable. On the other hand, due to confidentiality issues it will take a lot of effort in future in order to implement this method on a large scale.

In case where stock-keeping/book keeping tools are not available due to small company size or confidentiality, on-site measurements (with or without scanning) described for on-site measurements can be conducted. With proper planning, they can provide deep insights into "food waste" characteristics, which make them suitable for in-depth studies as well as stakeholder "self assessment". They may fulfil the requirements of suggested indicators for retail and markets also on detailed level of product categories and edible/inedible fractions. The main problem approaching with the method is representativeness in time and for the company or branch, which includes the uncertainty that if extrapolated, the data do not represent the average. This disadvantage could be decreasing with an increasing number of available literature data as increasing knowledge on influencing factors could enhance proper planning. The method is already widely used, and is directly applicable.

Data from direct measurement of waste could be used to better estimate conversion factors to be used for calculation of detailed data from national statistics in future. The recommended approaches also apply to the quantification of "food waste".

Table 10.1 Summary of presented and recommended approaches for quantification and data collection of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies for improved insight*	Internal prevention approaches**
Interviews of key personnel (Kranert et al., 2012)		x	x
Scanning (Hanssen and Schakenda, 2010, 2011)		x	x
(Inter)national statistics, aggregated statistics from umbrella branch organisations (Monier et al., 2010; Kranert et al., 2012; Beretta, 2012)	x		
Stock-keeping tools	x	x	x
On-site measurements		x	x

*   Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem

**   Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally (good manufacturing practice for reducing wasted food)

11 Description of approaches for retail and markets

11.1 Process description

The present chapter deals with "retail and markets" which is differentiated into three different types of stakeholders:
- large in-store retailers
- small in-store retailers
- retail via market stalls

The large in store retailer has the starting point at the input of products at the gate of the retail centre of distribution and the end point at act of purchase to end consumer. The process steps for large in store retailers is slightly different to small in-store retailers as well as retail via market stalls as for the small retailers and the market retail the absence of a distribution centre is assumed.

It is assumed that in the case of large in store retailers the producer, the wholesaler or a separate haulier delivers the order to the large retailer´s distribution centre. The processes where "food waste" may occur at large in store retail starts therefore with the arrival of (food) products at the large retailer´s distribution centre. It includes the commissioning, the storage at the large retailer´s distribution centre, the handling and transport processes to the large retailer´s outlets, the (short-time) storage at the outlets and the display at the shelf. The relevant processes for large in store retail ends with the act of purchase to end consumer. The commissioning step could lead to a refusal of products which in some cases are wasted on site or which are transported back to origin. In both cases a registration of the returned products at the large retailer is not common as the financial burden has to be paid by the supplier (this means producer/processor). Therefore, information on amount and further fate of the refused products can be found at producer/processor level.

In case of small scale retailers (e.g. freelance retailer with one outlet) as well as in case of retail via market stalls the food waste related processes start with the act of purchase at the wholesaler and includes the transport, the (short-time) storage, the display at the market and ends also with the act of purchase by the final consumer. It is assumed that due to the small scale of the business there is no distribution centre.

The activities which should be considered for quantifying "food waste" from retail and markets are displayed in *Figure 11.1*.
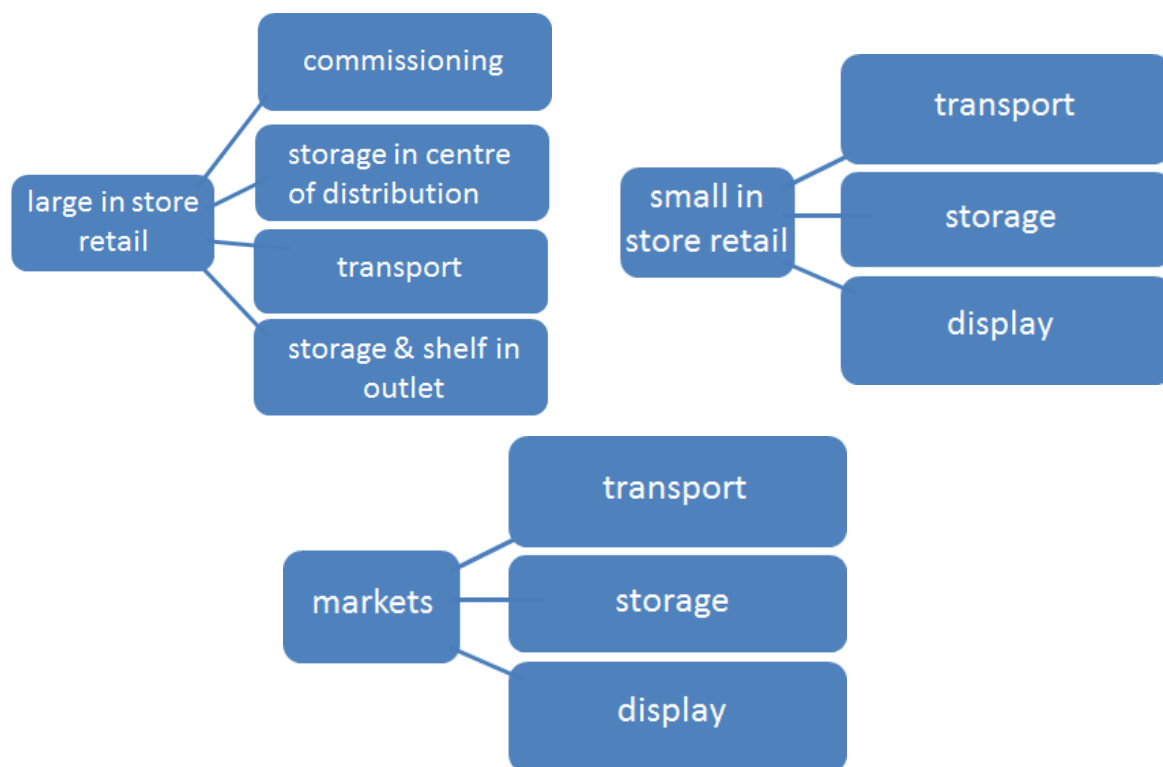
Figure 11.1: Process description for large and small in store retail (top) and markets (bottom)

According to the Statistical Classification of Economic Activities in the European Community, Rev. 2 (2008) retail activities are listed within group 47 and includes food retailing within subgroups

  - 47.1 Retail sale in non-specialised stores,
  - 47.2 Retail sale of food, beverages and tobacco in specialised stores,
  - 47.8 Retail sale via stalls and markets and presumably
  - 47.9 Retail trade not in stores, stalls or markets.

To clarify the level of detail, which should be considered within the level of "retail and markets", one should have a look to options for classification of retail activities. The structure of the classification uses in a first level of distinction the indicator if retail takes place "in store" or "not in store", in a second level if "specialised" or "non-specialised" and in a third level if "food predominating" or "other". This classification scheme (see *Figure 11.2*) could be valuable for an extrapolation of micro level based information towards NACE classification scheme but seems to be not the best option with respect to basic development of a quantification methodology.
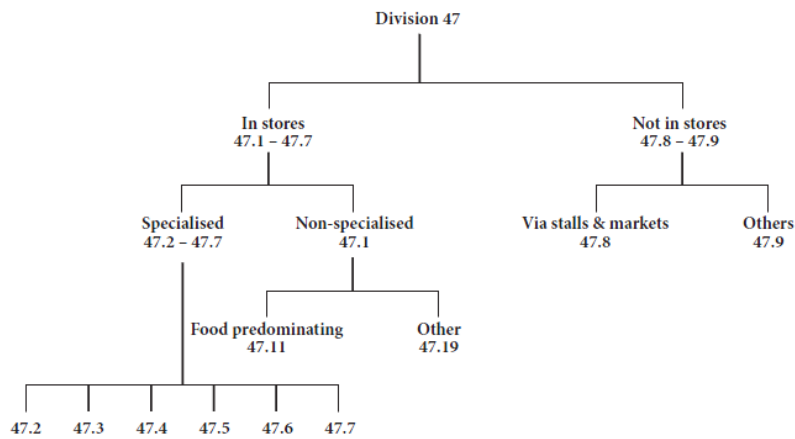
Figure 11.2: Retail classification structure according to Statistical Classification of Economic Activities in the European Community, Rev. 2 (2008)

Therefore, another classification should be used which is related to "food waste" issues. Unfortunately, no established classification of retail stores could be found in literature as many different schemes are used depending on the scope of classification. One popular indicator for a classification is sales area which is e.g. used by researchers (cf. Guy, 1998), by market research companies (cf. ACNielsen, 2013) and whose wording is also applied by professional journals (cf. Cash, s.a.; Handelszeitung, 2013). The problem is that different class sizes are used for the classification and in addition size-independent terms are used. *Figure 11.3* compares the retail classification mentioned by Guy (1998) with that used by ACNielsen (2013) for Austria. In addition to sales area, ACNielsen defines "discounter" separately without relation to size but with respect to assortment[3]. In many cases the business model at retailers also includes food service activities, e.g. cafés or restaurants, which have to be considered separately (see chapter 13).

Assuming that there is – beside other influencing factors - a relation between the sales area and the "food waste" (decreasing food waste quota with increasing sales area, cf. Schneider et al., 2013), an agreed classification of retail outlets could help with extrapolation of micro level results to overall sector.

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[3] Unfortunately, there is no clear definition of the term "discounter", e.g. by number of offered articles, way to display products etc.
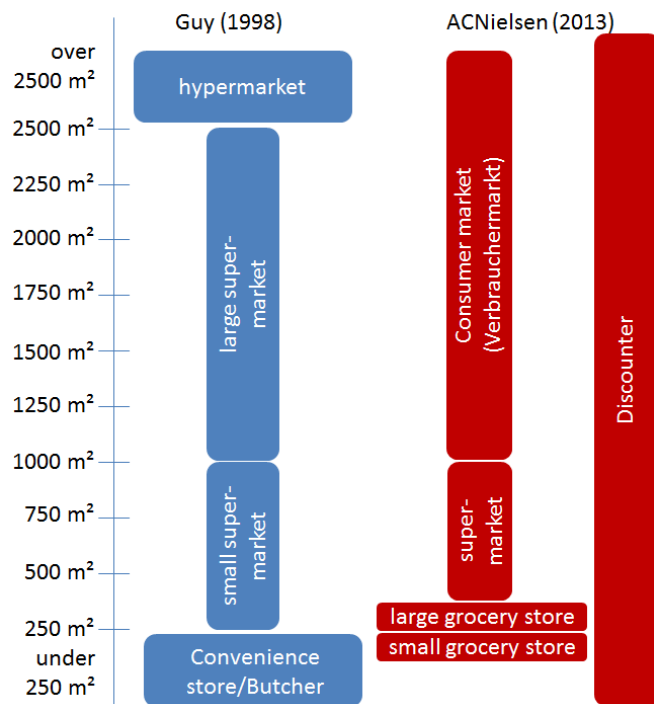
Figure 11.3: Comparison of different retail classification systems based on sales area

Addressing retail via market stalls there is the no suggestion to distinguish between different types of markets.

11.2   Indicators and data requirements

In order to compare "food waste" along the food supply chain absolute values are needed using the same units. According to the FUSIONS point of view, a mass based approach is recommended also for this issue. This means that available "food waste" information should be converted into mass.

In order to provide comparable "food waste" indicators the following data are needed:
  – total "food waste" generated per year
  – rejected amounts during commission activities per year
  – conversion factor to calculate mass out of economic value (coming from packaging, product description, estimation)
  – food amounts donated to redistribution per year
  – conversion factor for calculating non-edible parts from the entire product, e.g. the share of the banana that is peel
  – turnover in economic value mass

The information on donated food is important to distinguish between economic loss and real "food waste". As for the retail the donated products are not sold, they are accounted as economic loss and are registered within the stock-keeping tools and/or book keeping tools. From a waste management point of view, food donated for human consumption is not waste but waste prevention and therefore has to be subtracted from the wasted amounts (see also chapter 11.3).

The total "food waste" per year forms the basis, which further can be converted into related indicators. The following indicators should be used for retail and markets:
- total "food waste" generated per year
- "food waste" quota using turnover as denominator
- total "food waste" in mass per year to total input of (food) products in mass per year (kg "food waste" per kg input)

The indicator "total food waste per total input" could not only be used for comparison between companies but also other stakeholders along the food supply chain.

A split of "food waste" data into product categories is preferable as relevant information for designing appropriate prevention measures, disposal options and environmental impact. Further information on recommended product category classification is provided in Appendix 3.2.

Further information with respect to representativeness, uncertainty etc. are summarised in Appendix 1 on data quality.

11.3 Quantification of wasted food

Literature research conducted within FUSIONS indicated that there is a lack of public available "food waste" data from retail and markets (see report D1.3). Especially the market activities are rarely mentioned in literature.

11.3.1 Interviews

The literature review indicated that interviews among key persons in the retail sector or in specific retail shops accounts for an important qualitative approach, giving indications about how much "food waste" is generated in retail companies. The interviewed experts give their estimates on "food waste" as percentage intervals in relation to turnover of product categories (e.g. Mena et al., 2011; WRAP, 2011c; WRAP, 2011d). In most reports, it is not described in detail how the interviews have been carried out and how the retail representatives have prepared themselves for the interviews or questionnaires to estimate food loss from the outlets.

Pros and cons of the method:
The interviews based on company´s level could be seen as useful input in order to clarify general conditions, how assumptions could be chosen, which detailed data could be provided by the company as basis for further calculations etc. An advantage of expert interviews is that they may estimate quantities or shares of "food waste" at their company at higher quality level than others. The disadvantage of interviews is that often the outputs represent estimates or qualitative information on food rather than measured quantitative figures on "food waste".. Therefore, calculation of statistical characteristics of provided data is not possible. In addition, in-depth interviews are time consuming and expensive and therefore, often the results do not represent the sector in a proper way which has a negative impact on extrapolation on a region or nation.

11.3.2   Scanning

In order to conduct a quantitative measurement of food waste, most of the reviewed literature quantified the food waste in a smaller number of retail shops (Hanssen & Olsen 2008; Hanssen & Schakenda 2010 and 2011; Jensen et al., 2011; Buzby et al. 2011; Beretta, 2012) and in some cases also characterized the data with respect to specific product categories (Hanssen & Olsen 2008; Hanssen & Schakenda, 2010 and 2011; Buzby et al., 2011; Venkat et al., 2012). In most reviewed reports, the detailed data collection method is not described in detail. Hanssen & Schakenda (2010) as well as Eriksson et al. (2012) scanning method where each food item was scanned by the outlets and the data on food waste were compared with turnover data for each product group. Using established modern stocking and logistic systems, such data are available from a number of retail companies, both from each shop and more aggregated data. As mentioned by Stenmarck et al. (2011) the access to the described data is often difficult due to strict confidentiality issues.

Pros and cons of the method:
In contrast to interviews, the scanning method represents an accurate approach to register "food waste" on a detailed level. Relating the wasted products directly with the product database of the company, allows a deeper insight and many analyses. Nevertheless, the literature review indicate that up to date this method is not used for whole retail companies as quantification method for "food waste" or the conducted studies are not published due to confidentiality issues.

The reviewed approaches had no detailed information on which processes have been included into the food supply chain step "retail". Therefore, it was not clear which processes could be covered by the used approaches. For example, it is assumed that the scanning method at the retail could only include products, which are already owned by the companies, and therefore products wasted during external transports and commissioning processes are not included and would have to be tracked by using other approaches. Furthermore, investigation methods for retail via market stalls is not represented in reviewed literature.

11.4   Data collection and survey

Literature research on retail and markets showed that there are no or only poor "food waste" data available via statistics from (inter)national authorities or retail umbrella organisations as well as scientific literature. Therefore, authors from literature use up-scaling factors such as economic turnover (e.g. Hanssen and Schakenda, 2011) or indicators based on amount of waste per employee (Jensen et al., 2011) calculated at detailed micro level investigations.

Pros and cons:
The usage of (inter)national statistics or statistics from retail umbrella organisations is not very common and in most cases data from small-scale investigations were used for an extrapolation. This approach includes the risk of uncertainty as a small-scale sample size runs the risk not to represent the typical variation of the main unit. There are several influencing factors that have an impact on "food waste" of a retail outlet and the measurement of "food waste" quantity, which is restricted to a specific time of the year, or selected outlets may not represent the average value.

11.5　Methodological recommendations

11.5.1　Recommendation for quantification of wasted food

The following methodology, which is suggested as the standard approach for retail, is based on existing data found at the retail and markets with integration of further details to keep the additional effort as low as possible while generating useful data. Besides the suggested two methodologies, also others are possible (e.g. diaries) but seem not to have the required effectiveness with respect to the requirements mentioned in Appendix 1.

In general, two approaches could be implemented to set up a "food waste" data basis for retail and markets:
- – based on existing company data or
- – based on on-site measurements, if company data are not available or confidential.

In general, most of the organic waste, which is generated at retail and markets, is assumed to belong to edible "food waste". Most of the products are already packed and mostly in case of fresh fruits and fresh vegetables it might occur that inedible parts such as leaves have to be removed during/after storing, fall out of the boxes or have to be removed during display.

Methodology based on existing retail company´s data base
It is assumed that accurate data are only available at larger retail companies and therefore small-scale retailers and market retailers are more likely to apply the methodology described for companies' own data base. Existing company data coming from electronic stock-keeping tools and/or book keeping systems can be used as basis information and adjusted with new information for quantification of "food waste". In case the data from the centre of distribution activities are separated from the activities located at the outlets of a retailer, the information of the "food waste" at centre of distribution has to be treated separately according to the approach described at chapter 10 (wholesale) as the centre of distribution of a retailer is quiet similar. Similar approach as in wholesale is also applicable for the logistic process between distribution centre and retailer´s outlets.

If quantification of "food waste" from the retail sector is to be recorded honestly, quantities which are sent back to suppliers (edible products not commissioned by retail as not meeting required standards) should also be considered. As in most cases there is no tracking of those amounts at the retailer (as not entering the retailer´s gate from a book-keeping perspective), the implementation of a diary at the retailer or recordings of supplier should be taken into consideration. Alternatively, the products rejected by retail shoud be recorded by the wholesaler, producer or whoever takes care of the rejected food, since they know better the ultimate fate of the rejected food.

Basic information from retailer´s electronic book keeping system which holds information about general product details, sales of the product and non-sold products (information that come from scanning of non-sold products at time of removal) is normally available at least in economic terms (level of detail varying but mostly available on single product level). This information source often also includes breakage as well which belongs also to "food waste" according to the FUSIONS definition. In contrast to wholesalers, at retail outlets also other influences on the amount of non-sold food products have to be considered as e.g. stolen products. As it is not known what happened to those food

products, it is assumed that it does not belong to "food waste" and therefore should not be considered in detail.

Economic information should be converted to mass based amounts by using information from logistics (needed for truck load calculation), packaging (information printed on product´s packaging or included partly in products specification) or estimation of product experts in case of unpacked products or if no other information is available (e.g. 1 piece of mango equals to 350 g on average). This leads to information of non-sold products in mass units.

It has to be considered that "food waste" as defined by FUSIONS includes only mass based waste and not economic based amounts. Therefore, there is a difference between non-sold products in general which mean an economic loss for a company and those non-sold products, which are donated to redistribution sector. If there is a cooperation with food banks or other organisations which redistribute (parts) of the non-sold food products for human consumption, these amounts should be subtracted from the overall "food waste" data. Some companies already record these amounts in their electronic systems, others should implement a scanning and recording approach or conduct a diary for extrapolation for one year.

In order to split the total "food waste" into edible and inedible amounts, conversion factors have to be introduced to subtract the inedible parts (if applicable, e.g. with fresh produce). To provide comparable data, the time span considered for the calculation of total "food waste" should be one calendar year. *Figure 11.4* shows a scheme how to calculate the "food waste" quantity based on existing data adapted with further information. On the left side of the scheme the related process steps are indicated (commissioning, storage at distribution centre (large retailer), transport to outlets, storage at outlet and display) which were also displayed in Figure 11.1. One should keep in mind that all information should be provided for certain product categories mentioned in Appendix 3.2.
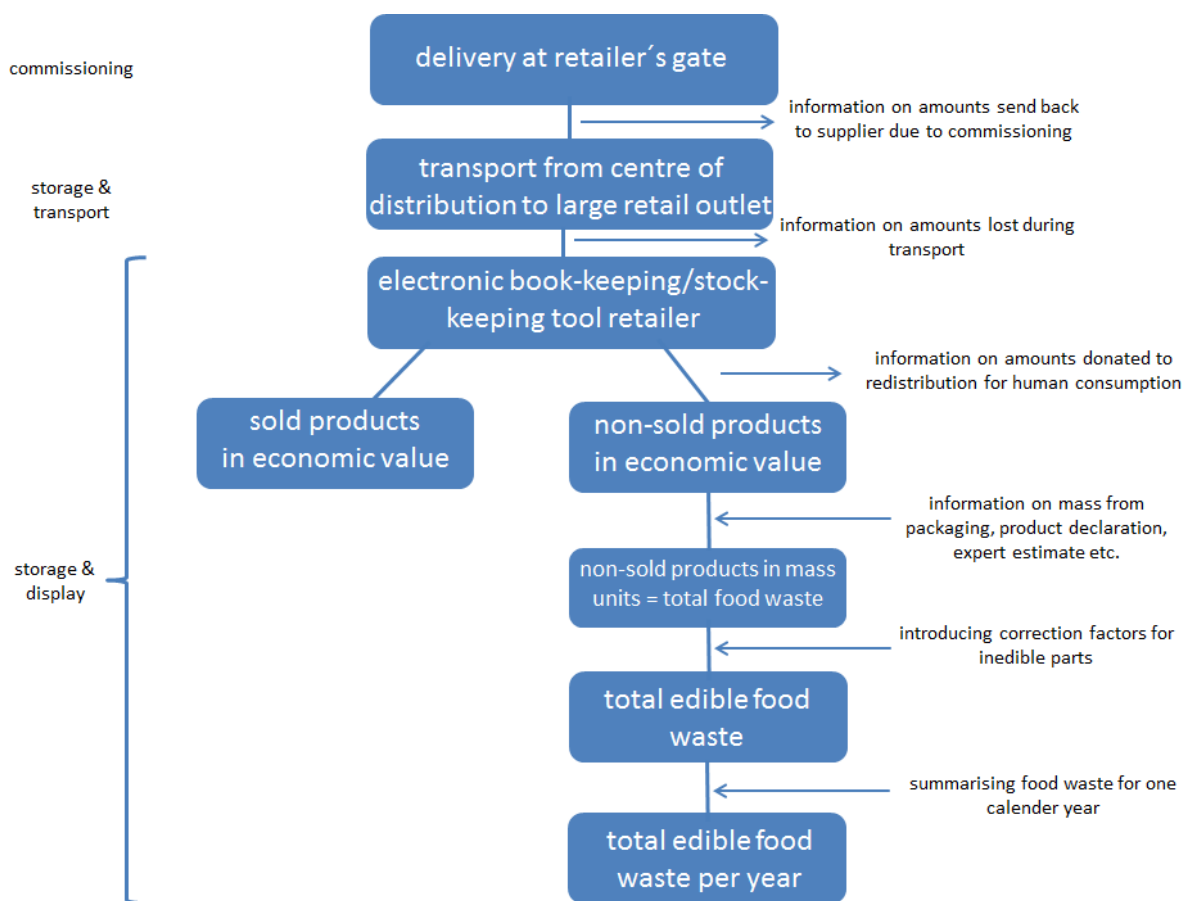
Figure 11.4: Scheme of quantifying "food waste" at retail based on existing company data adapted with further information

In order to provide "food waste" indicators, the total edible "food waste" generated per year should be converted. In case of retail an edible "food waste" quota using turnover (in economic value) as denominator should be used. Consequentially, a comparison with other retailers is possible. Another option is to relate total edible "food waste" in mass per year to total input of food products in mass per year (kg edible "food waste" per kg input). This approach would allow also a comparison with other stakeholders (not only wholesalers or other companies) with respect to the "effectiveness" of input utilisation.

The pros of the described approach are that a large number of existing continuous data (amount and composition) are available if the data base is an electronic system which is used for other purposes (e.g. recording for tax purposes, book keeping, controlling) and that there is no extrapolation from small-scale on-site measures necessary which are often not representative. In addition, the data are available on article basis and later a grouping with respect to certain product categories could be conducted easily, if required. Cons are that there is a conversion from economic data to mass based data necessary, one has to consider manually the subtraction of packaging mass and mass of inedible parts (if not available, the conversion factor of inedible parts could also be considered on a national basis, if composition data are available). In addition, for the information on returned amount during commissioning process, a separate recording has to be implemented at wholesalers or delivering producers/processors respectively double counting with recordings at supplier level should be avoided.

Methodology based on on-site measurements (small retailers and markets)

If a small retail or market company does not have an electronic system where the mentioned information is stored, they could use the registration of their waste from the retailer´s waste management company and conduct waste sorting analyses to determine composition and calculate amounts. *Figure 11.5* shows a scheme of quantifying "food waste" at retail based on existing waste management data and additional waste composition analyses. The available waste management data, which usually are available in mass or volume of waste is obtained from the external waste management company that is in charge of disposal of the retailer´s waste. If the waste management data are already available mass-based, they can be used directly. If waste management data are only available in volume (not available bin volume but real waste volume), a conversion factor (bulk density) has to be determined to calculate mass from of volume recordings together with the composition analyses.
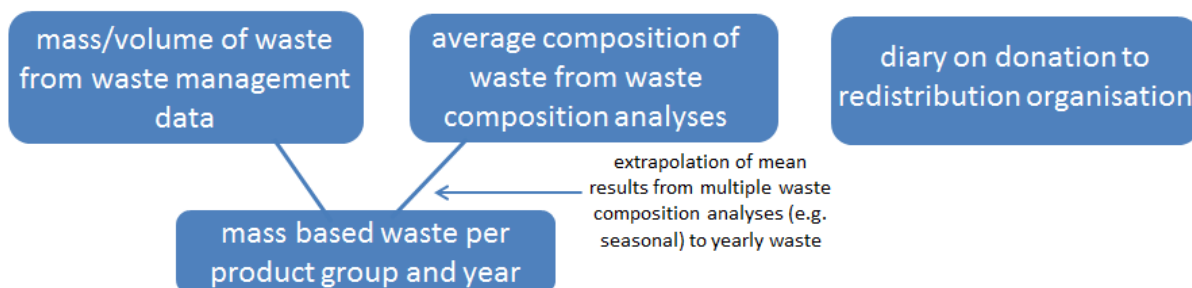
Figure 11.5: Scheme of quantifying "food waste" at retail or markets based on existing waste management data and further on-site measurements

In addition, the composition of the generated waste is measured by separate waste composition analyses, which have to be planned according to the information given in Appendix 1. Of course, conversion factors to consider packaging mass, inedible parts etc. have to be applied also within the present methodology similar to the approach described for companies' own data base which uses existing data. In contrast to the methodology described for companies' own data base, the product categories have to be determined according to Appendix 3.2 before conducting the sorting analysis as a detailed analysis per single product is not feasible and there is less option for a changed classification at a later point of time.

There is also a difference to the previous described method with respect to food products, which are donated to redistribution organisations. In order to register those donation activities, which can be accounted as "food waste" prevention measure, a separate diary should be implemented on regular basis in order to track potential internal optimisation options on the one hand and to prove the level of existing prevention on the other hand.

Pros are that a data basis related to "food waste" could be provided but cons are that the approach is very time consuming, needs proper planning in order to consider all data requirements and therefore is expensive. This should be considered particularly with relation to a long-term approach (to provide regular data for a longer time period). Especially, when considering the large number of small retailers (e.g. freelance retail) and retailers based on markets, the effort in comparison to the overall impact of those companies should be taken into account.

In case of markets, which have an overall organisation of infrastructure, it is assumed that the small retailers located at this kind of market could also be handled as a whole facility and not as individual companies. This means that the approach described above

should not be conducted by each individual market retailer but by responsible market authority who also has the access to the necessary waste management data. Therefore, the approach from the present chapter could be applied from authority´s point of view. In order to get information on the input of the market, a survey could be conducted to support the indicator "food waste in kg per kg input".

11.5.2   Recommendations for data collection and survey

The best approach for the next decades seems to implement a national system where branch related data are already provided by the branch itself as this should ensure data consistency in a proper way. In case, that single data from retail and market companies are collected, there should be a standard approach suggestion for at least the largest retail companies provided from authority or authorised research organisations (see methodology for companies' own data base in Chapter 11.5.1). If this system can be implemented, an extrapolation should include a weighing method according to the market share of the respective company (basis turnover).

The pros of this approach are that a branch estimation is also possible in case not all companies declare their "food waste". If it is not possible to implement the described standard approach on company level, e.g. as there is no consideration of inedible parts, this issues could also be added on a national assumption, if appropriate information is available. The cons of the suggested approach are that the extrapolation is very rough if the characteristics of outlets, characteristics of assortment etc. cannot be considered. Also, if only aggregated values are available for specific companies, the calculation of statistical factors such as margin of deviation is not possible. This means that it is not possible to estimate the error of the total result. Furthermore, the consideration of inedible parts without knowledge on representative composition of "food waste" from retail and markets is not meaningful (single measurements seem to be not representative).

In case of markets, which could be handled as a whole infrastructure, the approach described for in-site measuring could be conducted by the market authority.

11.5.3   Summary of presented and recommended approaches

The following section summarises the previous described approaches for retail and markets, discusses the pros and cons and also evaluate the matureness of the method. The results are summarised in *Table 11.1*.

Interviews with key personnel (e.g. Mena et al., 2011; Beretta 2012) could be used for collection of additional information valuable for further calculations of data achieved by application of other approaches. The results from interviews could give a deeper insight on conditions of "food waste" generation, barriers and incentives for prevention and therefore could be valuable for deeper studies and stakeholder "self assessment". In combination with company´s recording, they could help to achieve the suggested indicators even if not all relevant information is available as the experts could give an estimate. The accurateness of estimation on product level seems to be lower than with total "food waste". In contrast, it is assumed that key personnel could have a good quality estimation of the share of edible and inedible parts of their company´s "food waste". With respect to representativeness related to time, it is expected that interviewed experts could give a good estimation on changes or trends over a certain time period. Nevertheless, conducting in-depth interviews is time consuming and

therefore it is assumed that the covered number of stakeholders is in most cases not representative for the branch (except if market concentration is high). The uncertainty of the achieved results from interviews of key personnel was already mentioned above and depends on the specific issue. The method is already applied in a large scale and could be used to get an overview on total "food waste" as well as to differ between edible and inedible parts.

The scanning method as used e.g. by Hanssen and Schakenda (2010; 2011) and Eriksson et al. (2012) results in very detailed information on article level and is therefore suitable for both deeper studies as well as stakeholder "self assessment". Relating the wasted products directly with the product database of the company, allows a deeper insight into food waste and many analyses. In case it is possible to convert the economic data to mass data, the requirements of the suggested indicators can be achieved. As the method is based on article level, also a detailed assessment of product categories (level of aggregation can be changed after data collection easily) and a calculation of edible and inedible fractions are possible. Nevertheless, the literature review indicates that either this method is not used to a larger extent for quantification of "food waste" so far or the conducted studies are not published due to confidentiality issues. This means that at present the method is only used in small-scale projects and cannot fulfil representativeness with respect to time period or sample size. If conducted on regular basis, this method is very promising to provide detailed data on "food waste". The uncertainty of the scanning method is preliminary restricted on the sample size and the quality of the underlying product database. It is assumed that not only packed products can be scanned using the bar code displayed on the packaging but also unpacked products could be registered by using a separate bar code for identification (e.g. used for ordering system). As it is assumed that bar code and scanning system is already established at wholesale companies, the method is directly applicable for both total "food waste" and differentiation of fractions.

The method of using information already available at company´s level (stock-keeping/book keeping tools, see Chapter 11.5.1 Companies' own data base) is a modification of the above mentioned scanning method. Here, the recording of the non-sold products is conducted on a regular basis and automatically processed within the stock-keeping/book keeping tool. This leads to a very detailed information basis on "food waste" primary related to economic values. In case the conversion into mass data is possible, the method fits perfectly for the required indicators. If implemented on a branch scale, the method provides data for all levels – EU-28, member state as well as deep studies and stakeholder "self assessment". The data can be assessed related to product categories, edible and inedible fraction can be calculated, it can be used for a long-term recording for the whole company or branch. Of course, some uncertainties may occur due to conversion of economic value in mass data, problems with booking inconsistency etc. but those errors are much smaller than those resulting from other quantification methods. On the one hand, the technology of electronic stock-keeping/book-keeping tools is well established and allows a detailed differentiation of tracked "food waste" types and is directly applicable. On the other hand, due to confidentiality issues it will take a lot of effort in future in order to implement this method on a large scale.

In case the stock-keeping/book keeping tools are not available due to small company size or confidentiality, on-site measurements (with or without scanning) described in Chapter 11.5.2 for in-site measurement may be conducted. Presumed proper planning, they can provide in-depth insides to "food waste" characteristics, which make them suitable for deep studies as well as stakeholder "self assessment". They may fulfil the requirements of suggested indicators for retail and markets also on detailed level of

product categories and edible/inedible fractions. The main problem approaching with the method is representativeness in time and for the company or branch, which includes the uncertainty that if extrapolated, the data do not represent the average. This disadvantage could be decreasing with increasing number of available literature data as increasing knowledge on influencing factors could enhance proper planning. The method is already widely used and is directly applicable.

Data from direct measurement of waste could be used to better estimate conversion factors to be used for calculation of detailed data from national statistics in future. The recommended approaches also apply to the quantification of "food waste".

Table 11.1 Summary of presented and recommended approaches for quantification and data collection of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies for improved insight*	Internal prevention approaches**
Interviews of key personnel (Mena et al., 2011; WRAP, 2011a)		x	x
Scanning method (Hanssen and Schakenda, 2010; 2011; Eriksson et al., 2012)		x	x
Stock-keeping/book keeping tools	x	x	x
On-site measurements		x	x

*   Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem

**   Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally (good manufacturing practice for reducing wasted food)

12 Description of approaches for redistribution

12.1 Process description

The present chapter deals with "redistribution" which has the starting point at the gate of the donor and the end point at act of handing over the food to the final consumer. The process steps for redistribution vary according to the type and target group of the organisation. In Figure 12.1 it is assumed that the redistribution organisation collects the donated food products at the gate of the donor, sorts and stores the products and distributes them to other organisations, which hand over the food to their clients or directly use them for preparing meals. In case the redistribution organisation that collects the products from the donor and directly distribute them to clients, the intermediate steps are omitted.
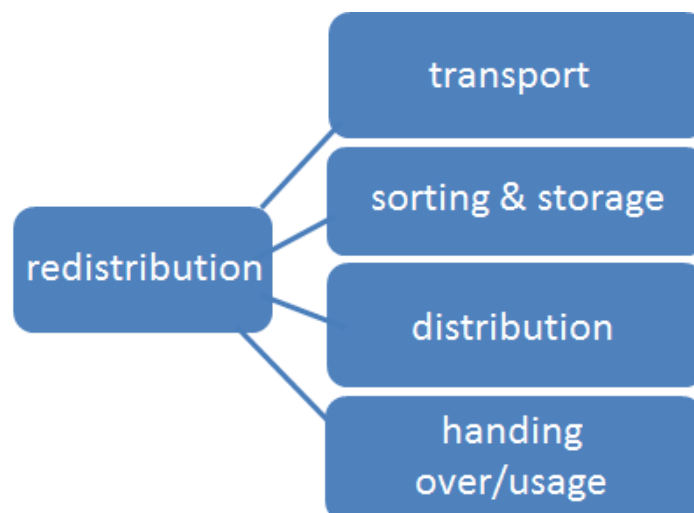
Figure 12.1: Process description for redistribution activities

The level of detail should be adapted according to the type of redistribution organisation based on the covered activities (see *Figure 12.1*). In general, the redistribution sector is similar to other stakeholders along the food supply chain and could be classified according to those levels. A redistribution organisation which solely focusses on collection, storing and delivery to other redistribution organisations could be compared to "wholesale" and accordingly also the approach described in Chapters 11.5.1 or 11.5.2 should be applied. A redistribution organisation which is delivered with donated products by other stakeholders and offers a shop for deprived people could be compared to "retail and market" and therefore the quantification approaches according to chapter 11.5 could be applied. A redistribution organisation which is delivered with donated products and use them for preparing meals for clients could be compared with "food service". Of course, different mixes of types of redistribution organisations are also possible (as in other levels of the food supply chain, too). One special case is gleaning, which is the activity of collecting product left in the field.

Figure 12.2: Level of detail for different types of redistribution organisations

12.2 Indicators and data requirements

In order to compare "food waste" along the food supply chain absolute values are needed using the same units. According to the FUSIONS point of view, a mass based approach is recommended also for this issue. In the case of redistribution, the most common records held by organisations include mass and not economic value as the products are assumed to have no further economic value and the organisations do not know the economic value.

In order to provide comparable "food waste" indicators the following data are needed:
- total "food waste" generated per year
- wasted amounts during sorting activities per year
- conversion factor to calculate mass out of economic value (coming from packaging, product description, estimation), if applicable
- food amounts shared with other redistribution organisations per year
- conversion factor for calculating inedible parts
- turnover in economic value, if applicable
- total input of food products in mass

The total "food waste" per year forms the basis, which further can be converted into related indicators. The following indicators should be used for redistribution:
- total "food waste" generated per year
- if applicable, "food waste" quota using turnover (in economic value) as denominator
- total "food waste" in mass per year to total input of (food) products in mass per year (kg "food waste" per kg input)

The indicator "total food waste per total input" could not only be used for comparison between different redistribution organisations but also other stakeholders including households.

A split of "food waste" data in product categories is preferable as the most relevant information for designing appropriate prevention measures, disposal options and environmental impact. Further information on that issue is provided in Appendix 3.2.

Further information with respect to representativeness, uncertainty etc. are summarised in Appendix 1 on data quality.

12.3   Quantification of wasted food

In general, the same approaches as described in the chapters 10.3, 11.3 and 11.3 could be applied for redistribution organisation adapted to the fact that in most cases no or only a marginal economic value or turnover is applicable. Experiences show that the redistribution organisations often do not have an appropriate electronic information system providing all required data mentioned above. Hence, they could keep "food waste" diary (on input, redistribution and own waste) and extrapolate to the overall activities for one year. The pros of this approach are that data from redistribution sector are available. But the cons include that those quantifying activities are time consuming if results should be representative and that the redistribution organisations themselves often have not the capacity to raise the necessary work load.

12.4   Data collection and survey

For the redistribution sector, interviews at the redistribution organisation could be used together with waste composition analyses to estimate "food waste". Extrapolation coud then be performed to cover all products in the sector. However, thedata quality requirements given in Appendix 1 must be considered when doing such an extrapolation. The pros of this approach are that a data basis could be developed over years. Cons that should be kept in mind is the representativeness of survey in relation to costs and how to difficulty of extrapolating from direct measurement of waste due to the huge variation of redistribution activities.

12.5   Methodological recommendations

As the recommended methodologies from other chapters of the present report can be applied to the redistribution sector, there are no further recommendations. The large redistribution organisations (eg food banks) have information on mass volumes broken down by sectors (eg processing, retail, food service) and product categories. This information can be used as a cross-reference when collecting data from these sectors about redistribution output volumes.

13 Description of approaches for food service

13.1 Process description

Within the food service sector, where there is a large variety of outlet types, some subsectors have similar characteristics that will be used to cluster the approach of quantification. The food service sector consists of the following subsectors:

- Restaurants
- Hotels
- Workplace canteens
- Café, bars, petrol stations
- Education
- Health care, home for elderly people.
- Leisure & entertainment
- Other, e.g. home food service for elderly people, festivals, large sports events and other public events.

The processes for food service activities are in general very similar and are represented in *Figure 13.1*. The figure distinguishes between storage, preparation and serving. Display waste is the food that is prepared for consumption but never bought or given to a consumer or a patient.
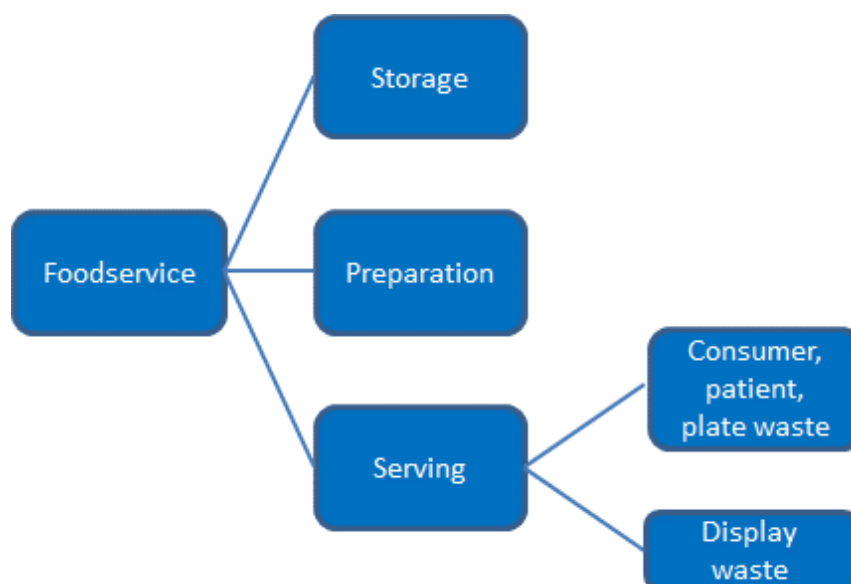
Figure 13.1: Process description for food service

13.2 Indicators and data requirements

Indicators should match the requirements as described in chapter 5.2. Comparison should be possible on a scale of time, area and step in food supply chain and food product categories. Therefore these elements should be part of the indicators defined. For food service the following indicators are proposed:

a) Amount of total "food waste" in food service *storage* per produced amount food in food services per country
b) Amount of total "food waste" in food service *preparation* per produced amount food in food services per country
c) Amount of total "food waste" in food service for *serving (plate leftover and display waste)* per produced amount food in food services per country

The produced amount is defined as the produced amount that are sold or otherwise handed over to destination, such as giving food to redistribution.

Note that these indicators are still on the level of total food. To match the requirement comparison between product categories more detail is needed, but for reasons of readability the indicators are not presented on this level of detail (the product categories are described in Appendix 3.2).

Data requirements: For the micro level approach measurements at food service locations are needed. The measurements should include the following data:

- Amount of "food waste" per product category (split in storage, preparation and plate leftovers) per outlet subsector
- Amount of food *produced* per product category per outlet sub sector
- Number of food service outlets per sub sector in the country (for upscaling)

13.3 Quantification of wasted food

Based on the previous subgroups the goal is to find suitable micro level methodology to quantify the data as needed and described above. These methodologies can be found in the overview reports. In most studies attention is paid to "food waste" in volume and value, rather than indicators, hence additional approaches need to be created for that purpose.

13.3.1 Weighing/"food waste" diary

The weighing and "food waste" diary methods are presented together, since in many cases the kitchen personnel performed the weighing by using a "food waste" diary or equivalent questionnaire.

In the UK several in-depth studies of the food service sector have been conducted (WRAP, 2013b-e). It is easier to achieve a reduction in waste, if the number and preferences of consumers are known. Therefore, the tendency is that there is more wastage in restaurants/hotels than in education/healthcare. In addition, restaurant/hotels usually make food from scratch using raw ingredients, which results in more waste (peeling and off-cuts). Several actions to reduce "food waste" are identified, e.g. menu planning, forecasting, procurement, delivery size and frequency.

Health care:
This subsector used weighing in several approaches (Barton et al., 2000; Sonnino & McWilliam, 2011; Supkova, 2011). No food waste is registered for storage and preparation. For display waste and consumer (patient) plate waste the following data are collected: food provision, food waste per patient, number of unused trays and number of patients (Barton et al., 2000). All studies have weighed on total food waste and only one study has split on products (Sonnino & McWilliam, 2011).

Workplace canteens:
A Dutch study (Soethoudt, 2012a) measured displayed (unsold) food on product level in 200 catering locations. No attention was paid to storage, preparation or consumer waste, since earlier research showed that these waste volumes were relatively small compared to the display waste. A Finnish FOODSPILL study weighed all avoidable food waste for one week study period in five work place canteens, waste was sorted for kitchen waste, serving waste (overproduction) and plate waste. This study showed the most important waste category was overproduction (Silvennoinen et al 2012).

Restaurants:
All reviewed studies have weighed on total food waste and no studies split on edible and inedible fractions or food categories. In one study, the food waste is measured for one day (SRA 2010) and in another for two days (Engström & Carlsson-Kanyama, 2004), except storage loss which was registered for two weeks. In the Finnish study (Silvennoinen et al., 2012) the kitchen staff and researchers were weighing all avoidable food waste for one day in 17 cafes and restaurants, the food waste was sorted in kitchen, serving and plate waste.

Education:
Different combination of weighing in combination with other method has been used to estimate the volume of the food waste in school canteens, including storage, kitchen, serving line and plate leftovers (Naturvårdsverket, 2009; WRAP, 2011b; Silvennoinen et al., 2012; Engström & Carlsson-Kanyama, 2004; Karlsson 2002; Buzby & Guthrie, 2002). The most used methods are monitoring the waste by weighing and asking information from restaurants personnel, management or customers (students or pupils). This was done by interviews, workshops or surveys.

When focus is on nutrition and health, study approaches can vary and very exact amounts, food types and qualities are needed. Especially in schools nutrition is very important as customers are children having their requirements for daily intake.

Pros and cons of the method:
In this section, the methodologies are evaluated as is (i.e. in the way they are applied in the study) and at the end the potential of the methodology is described and compared to other approaches. The difference is that in the literature studies can be carried out with low sample size or one day measurements and hence data have a high level of uncertainty, whereas the method itself can be very useful if these parameters of the methodology are adjusted.

Most of the reviewed studies in this section used data that match the indicators a-c in section 13.2 very well. However, not all studies have sufficient data quality regarding representativeness in sample size and time. As described above the data representativeness is a minor problem and in most cases the method can be recommended and adjusted to fulfil the needs.

13.3.2   Waste composition analysis

Waste composition is applicable in food service to measure the amount of "food waste". The method is usually used in households, but is suitable in all steps in the supply chain where "food waste" is collected and the number of wastage points is large (i.e. individual food service outlets and households). Therefore one of the important issues is to find the right sample size and representative samples. Another element to be considered when conducting a waste composition analysis is the waste collection systems used e.g. mixed waste collection, bio waste collection, energy waste collection.

A composition analysis of mixed waste from 138 businesses across the UK was conducted together with site audits (WRAP, 2011a). Before the analysis was initiated, information from literature was gathered for input in development of a sampling strategy. One study was published by WRAP in which larger samples were taken & previous fieldwork reassessed (WRAP 2013).

13.3.3   Interviews

This method was used in workplace canteens (Supkova, 2011) based on an online questionnaire that was answered anonymously by 60 experts. Only plate waste was evaluated, and the study did not consider edible/inedible fractions.

13.3.4   Digital photography

In a study from the USA (Martin et al, 2007) pictures were taken of plate leftovers and dietitians estimated the weight. The study measures only plate waste, and it was separated into edible/inedible fractions.

13.4   Data collection and survey

13.4.1   Statistics from authorities

In (Soethoudt, 2012b), all waste statistics available in the Netherlands were used to track down the food waste volume. Based on statistics from companies that compost, digest or incinerate waste, the Dutch government gained insight into the organic share in these flows. Moreover, using a coding system the type of supplier of the waste is classified in subsectors that can be linked to food service entities. In addition, animal feed (wet and dry) organisations provide statistics on their sourcing material. Together with studies that investigate in more detail the consumer "food waste" (composition analysis at garbage collecting companies), a good picture of "food waste" in the Netherlands, based on macro level reasoning, is presented.

Pros and cons of the method:
The Dutch study (Soethoudt, 2012b) was a very detailed analysis where statistical data from open sources in combination with direct measurements on the share of organic materials within certain waste flows gave as a result quantification of the volume of food waste. In various cases it is not clear what is the actual source/stakeholder generating the waste. A disadvantage is the dependency on annual statistics, which is already a

problem in the Netherlands. In other cases, there may be other weaknesses. E.g., a Nordic study (Marthinsen et al., 2012) contained no specific description of how the survey was carried out. This is not a general weakness with the method, just a weakness with this particular study. Many different sources were used, and the sources available varied from country to country.

13.4.2   Data from waste management companies

In a Swedish study, (Jensen et al., 2011) data on weight per employee was based on data from municipal waste companies recorded for one year. The number of employees was found in national statistics for different sectors. To calculate national amount of food waste from restaurants, the indicator was multiplied by the number of employees. In a Nordic study (Marthinsen et al., 2012) statistics of waste, number of food service companies, number of employees, turnover and number of meals served were used. To calculate total food waste key figures of amount on food waste per meal were used. The report also contains other key figures. Also used was a survey, asking for where food waste was generated; food prepared but not sold and plate waste (from the guests).

Pros and cons of the method:
The method (Jensen et al., 2011) requires a separate weighing of food waste from municipal waste companies, and data have to be available on company level for a representative number of companies. If that is available, it seems to be manageable and cost effective compared to other approaches available.

13.5   Methodological recommendations

13.5.1   Recommendations for quantification of wasted food

The weighing method, "food waste" diary and waste composition analysis all match the "food waste" indicators. The weighing and "food waste" diary methods are presented as one method, since in many cases the weighing was performed by the kitchen personnel by using a "food waste" diary or equivalent questionnaire.

In addition, waste composition analysis is a very good and proven method that produces reliable data. This method can be more costly than weighing/diary, because it must be performed by waste sorting companies, while weighing can be performed by the company's own kitchen staff. On the other hand, this point can provide better and more uniform analysis and it also avoids that firms are imposed for large workloads by weighing.

Both approaches are directly applicable, but further criteria are needed regarding samples per outlet type and samples in time, i.e. the length of the weighing period needed to have a representative amount. The studies presented used a time period from one day to two weeks, and further examination is needed to find the necessary number of days for measuring. However, studies have shown that there is more variation between outlets, than in different time periods for the same outlet. It is therefore important to use the proposed division into subsectors when organising the data

collection. National corporate statistics can be used to get an overview of the number of companies in each subsector as a basis for up-scaling to national figures.

13.5.2 Recommendations for data collection and survey

Statistics from authorities based on corporate statistics can be used to get an overview of the number of companies in each subsectors as a basis for upscaling to national figures. As mentioned above, it is important to use the proposed division into subsectors when organising the data collection.

Another method is using data from municipal waste companies for annual "food waste" data per food service company and upscaling by using the number of employees. This method requires good data on firm level in all countries, which is at present this not available for use in such studies. It may still be a future possibility, but this method requires many resources to develop. The method does not provide the possibility of division into edible/inedible fractions.

13.5.3 Summary of presented and recommended approaches

Table 13.1 shows the recommended approaches for quantification of wasted food and they also apply to the quantification of "food waste".

Table 13.1 Summary of recommended approaches for quantification and data collection of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies for improved insight*	Internal prevention approaches**
Weighing/"food waste" diary		X	X
Waste composition analysis		X	
Interviews		X	
Statistics combined with weighing/"food waste" diary	X		
Statistics combined with waste composition analysis	X		
Data from munipal waste companies	X	X	

*   Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem

**   Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally ("good manufacturing practice for reducing wasted food)

14 Description of approaches for households

14.1 Process description

The processes where "food waste" might occur are described/visualised for households in figure 14.1:
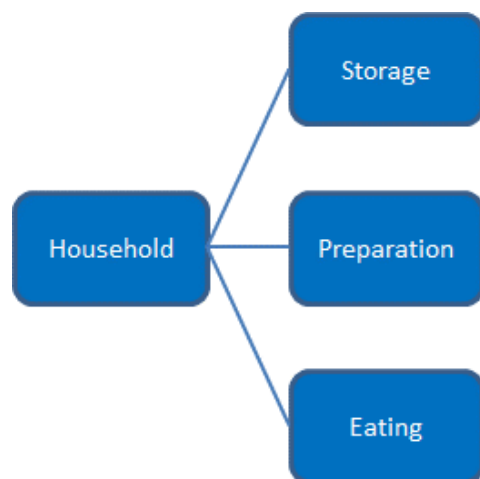
Figure 14.1: Process description for households

The process description for households is quite similar to food service. Typical examples of "food waste" at home can be linked easily to these processes. Expiry date during storage, cutting parts of vegetables during preparation and leftovers from eating are examples of "food waste" generated from the three steps.

14.2 Indicators and data requirements

Indicators should match the requirements as described in chapter 5.2. Comparison should be possible on a scale of time, area, step in food supply chain and food product categories. Therefore these elements should be part of the indicators defined.
For households the following indicators are proposed:

a) Amount of *total* "food waste" in household per capita
b) Amount of *edible* food waste in household per capita
c) Amount of *total* "food waste" in household per purchased amount of food in household per country

The produced amount of food is defined as the bought or acquired amount, such as bought in retail or given from redistribution, growing of own vegetables etc. Note that

indicator a) is proposed in chapter 5,2, and is in fact the most common indicator for households.

Note that these indicators are still on the level of total food. To match the requirement comparison between product categories more details are needed, but for reasons of readability, the indicators are not presented on this level of detail. (The product categories are described in Appendix 3).

In order to get the indicator a) data on amount of "food waste" and number of inhabitants is needed. To calculate indicator c), the amount of bought food for households is needed. It will require a major effort to calculate the amount of food in households and to do this the receipts for food purchases must be used (see further description in section 14.3.2).

14.3 Quantification of wasted food

Based on the previous subgroups the goal is to find suitable methodologies to quantify the data need as described above. These methodologies can be found in the overview reports D1.3 Report on review of (food) waste reporting methodology and practice.

14.3.1 Waste composition analysis

Waste composition analysis is used in several studies (WRAP, 2011; WRAP 2013a; Jensen et al., 2011; Katajajuuri et al., 2012) where the components of the different fractions of the food waste are weighed and analysed with regards to food categories or edible/inedible fractions etc. A sample is separated by hand in to different fractions. The method is described in for example (Lebersorger & Schneider, 2011).

Waste composition analysis can be used for measuring "food waste" for short or longer times and for different levels of detail. Often the waste composition analyses are used in combination with total mixed waste amounts to find the proportional amount for "food waste" to achieve the proportional composition of the waste stream.

If "food waste" types or the share between edible of edible and inedible "food waste" is required, waste composition analysis is necessary. For liquid "food waste" the only way is to have households to weigh and to note down the amounts for a certain time (see further below).

Pros and cons of the method:
Waste composition analysis can be done in a statistic way (e.g. by robust sampling made possible by selecting households appropriately) getting a good grip of the composition of waste. The share of "food waste" in mixed municipal waste will vary depending on the level of source sorting, the type of housing and also between developed and developing countries. However, it can still give accurate data if a large sample is investigated.

For waste composition analysis, there are things that differ more or less. For example many studies show that the share of food waste in mixed municipal waste is more or less the same in many countries (WRAP, 2011e, Jensen et al, 2011). But the same studies also show that the share of edible/ inedible sometimes differs (WRAP, 2011e), Jensen et al, 2011).

14.3.2 "Food waste" diary

Food waste diary (WRAP, 2009; Katajajuuri et al., 2012) can compile both qualitative and/or quantitative data from households and enable researchers to determine quantities, disposal routes (what is poured into the kitchen sink, home composted or fed to animals etc.) and reasons for disposal. In order to find out about liquid "food waste" that is normally thrown in the drain the only way is to engage households in weighing and keeping note (diary) of the amounts thrown away. This can be done for a limited amount of time (normally 4-7 days) and will give a waste factor for a household. Depending on the level of detail wanted the household can of course write down reasons and at what step the "food waste" thrown away. In studies carried out for example (WRAP, 2009) the households noted amounts and reasons for liquid food waste.

When performing a study using a "food waste" diary, the analysis can also be extended to map the amount of food produced, i.e. bought amount (see section 14.2). It is easier to organize when it anyway has been established contacts with households. This approach has been used in Finland (Katajajuuri et al., 2012).

The method will give the total amount of "food waste" from a specific number of households and can then be used to calculate the total amount of "food waste" in a country/region etc if assumed that the amounts/ household is the same.

Very often a "food waste diary" is used in conjunction with a food waste compositional analyses, These analyses complements each other well.

Pros and cons of the method:
The benefit of "food waste" diary is that it is carried out close to the waste source. This is the most accurate method to find liquid waste (it has been used in UK and is now tested in Sweden). The drawback is that the households know they are being monitored and they might change the behaviour and reduce their "food waste" or refrain from weighing all "food waste". Another drawback is underreporting by the consumers.

14.4 Data collection and survey

14.4.1 Statistics from authorities or waste management companies

In UK (WRAP, 2009 and 2011) and Sweden (Jensen et al., 2011) almost the same approach of using statistics from waste management companies is applied. The main idea is that "food waste" is occurring in different waste streams from the household – most common the mixed waste and source sorted organic waste. The proportion of "food waste" in both those two waste streams is normally known from waste composition analysis and a waste factor for each steam can be calculated. The amount of waste in each waste stream can be gathered differently either from the waste collector or from the treatment plant. By assuming that the waste factors are representative also for other regions, the total amount of "food waste" can be estimated based on amounts of total waste measured. If the share of edible/ in-edible "food waste" is known this is used as a waste factor in the same way.

Pros and cons of the method:

The benefit of this method is that it is robust, because the amount of waste is known and controlled by the waste management company. If weight based waste fees are used the data is very exact.

Indicators can be calculated by dividing fraction of "food waste" obtained by waste composition analysis by the total weight of a certain waste fraction ,as described in chapter 14.3.1 The indicators can be used to calculate "food waste" amounts in cass where only the amount of mixed waste is known. This is a fairly accurate method. An important assumption is that all households sampled have, **on average**, the same behaviour as those not sampled, which is most likely close to reality.

The drawback is that all sorts of "food waste" are measured and it is hard or even impossible to separate edible/inedible "food waste". To be able to get more detailed data waste composition analysis would be necessary.

14.4.2   Questionnaire and interview

A survey uses interviews of a randomly selected sample of respondents to map the attitudes or behavior of a population. A survey can be used to obtain an estimate of how often households throw away food, which food product categories becomes most often food waste and the major causes of food waste (Hanssen & Schakenda, 2010/2011).

A survey will most likely underestimate the amount of food waste, but can be used to see trends by repeating the same survey for more than one year. The underestimation might decrease over time as information campaigns and other awareness raising efforts take effect in the general population.

14.5   Methodological recommendations

For households the following methodologies are recommended (depending on the level of detail needed).

14.5.1   Recommendations for quantification of wasted food

Waste compostion analysis is recommended as a very good and proven method that produces reliable data. It can be relatively costly, but if establishing an appropriate level for implementation and updating it will be less resource demanding.

A "food waste" diary is a very useful supplement to waste compositin analyses because it captures information not possible to obtain through such analyses, e.g. liquid waste or waste given to pets or composted at home . A "food waste" diary, can also be extended to map the amount of food produced, i.e. bought amount when contact is established with households. That will be a good help if aiming for indicator c ("food waste" per produced amount of food in household). There are other ways of getting information on amount food bought per household e.g. as national statistics on food purchases.

Both waste composition analysis and diary will also give some input in why the food is thrown away.

14.5.2   Recommendations for data collection and survey

Using statistical data is recommended in combination with waste composition analysis for calculating "food waste" indicator (e.g. total "food waste" per amount of residual waste). Waste factors are calculated by using waste data from statistics/waste management companies combined with information from waste composition analysis on "food waste" amount in mixed waste. The method will give a robust answer on the total amounts of "food waste" from households in a country.

In order to get an indicator on the edible amount of "food waste" (indicator b) or data on different food categories it is necessary to have detailed data from waste composition analysis on the share of edible/ in-edible "food waste".

In order to get the indicator c, including the bought (produced) amount of food in the denominator, the results from waste composition analysis needs to be combined with data on food bought in the country. The latter can either be found in national statistics or by using a "food waste" diary (see section 14.5.1).

14.5.3   Summary of presented and recommended approaches

Table 14.1 shows the recommended approaches for quantification of wasted food and which also apply to the quantification of "food waste".

Table 14.1 Summary of recommended approaches for quantification and data collection of wasted food

Suitability to use in:	EU- 28 statistics	Basic studies for improved insight*	Internal prevention approaches**
Waste composition analysis		x	
"food waste" diary		x	
Statistics combined with waste composition analysis	x	x	

*   Basic studies for improved insight, as providing background information to calculate conversion factors and gaining a deeper knowledge of a specific problem. Such studies also give important insight into liquid loss going to the sewers, waste fed to pets or treated in home composting.

**   Internal prevention approaches: approaches aimed for the stakeholders to map the waste and work for waste prevention internally ("good manufacturing practice for reducing wasted food)

15 Recommendations and conclusion

Chapter 8-14 provide a detailed presentation of available and recommended approaches for each step in the supply chain. This chapter gives an overview for all the steps in the supply chain.

An overall quantification method consists of several parts. If no measurements have been made. the quantity (mass, volume) must be measured or assessed, the results must then be registered, registered data must be collected and finally quantification must be made based on collected data. In some cases one or several steps may be omitted, depending on the circumstances in the studied system. Estimates or extrapolations of waste from data is how national statistics can be used in combination with indicators from the direct measurement of waste to adjust the number and get data that are more specific.

Table 15.1 Recommended approaches

	Quantification and registration	Data collection and up-scaling for EU-28
Primary production	On-site measurements of mass or volume "food waste" diary Interviews and questionnaires	Statistical data (Possible tools: Eurostat, FADN) Mass-balances Interviews and questionnaires
Processing & manufacturing	On-site measurements of mass or volume	PRODCOM data (developed) European production statistics Eurostat waste statistics Mass-balances Combining data source
Wholesale	Scanning/Stock-keeping tools On-site measurements of mass Interviews of key personnel	(Inter)national statistics, aggregated statistics from umbrella branch organisations
Retail and market, redistribution	Scanning/Stock-keeping tools On-site measurements of mass Interviews of key personnel	Aggregated data from stock-keeping tools used in national statistics
Food service	Waste composition analysis On-site measurements of mass/"food waste" diary Interviews	Statistics combined with weighing/"food waste" diary Statistics combined with waste composition analysis Data from municipal waste companies
Household	Waste composition analysis "food waste" diary	Statistics combined with waste composition analysis

The recommended methods for quantifying "food waste" in primary *production* are on-site measurements and "food waste" monitoring by diary. For data collection it is recommended to use interviews/questionnaires, statistical data and mass-balances. The first two are applicable to calculate conversion factors while mass-balances can provide the total figures. Not one specific approach is recommended, but a combination of approaches will probably give a more complete picture, provide better background information and help to "calibrate" methods. Using a combination of different methods gives the possibility to validate and add additional information from other sources to see if the assumptions or calculations are correct.

In the *primary production* step, there have been little or no efforts to standardize data collection and calculation methodologies. The methods used to calculate waste will be different depending on the level of progress of knowledge, so there is need for a roadmap. To estimate the levels today, when insufficient data is available, on-site measurements should be made to examine waste levels and the reasons behind the waste. The results can be used to calculate indicators for amount of "food waste" in each sub-sector. In the future, when these approaches have been established and the data are incorporated in national statistics, the on-site measurement can be done at regular intervals to update the key factors.

The recommended approach for quantifying "food waste" in *processing & manufacturing* is weighing in combination with Lean Six Sigma (Gunnerfalk 2006; Svenberg 2007). The method is foremost suitable for monitoring "food waste" within single food processing industries and for supporting working company-internally with "food waste" prevention in the production system. The method can be applied in all types of food processing industries. For the macro level approach, a method using PRODCOM data is suggested. The method is suitable for producing "food waste" statistics for the food processing industry on a sectorial, national or European level.

In *wholesale*, scanning or the equivalent stock-keeping tools is recommended. The scanning method results in very detailed information on article level and is therefore suitable for both deeper studies as well as stakeholder "self assessment". If conducted on regular basis, this method is very promising to provide detailed data on "food waste". The method of using stock-keeping/book keeping tools uses information already available at company level. The approach is a modification of the above mentioned scanning method. Other available approaches are on-site measurements and interviews of key personnel. These approaches could be used for collection of additional information valuable for further calculations of data achieved by application of other approaches. The method to use (inter)national statistics and/or aggregated statistics from umbrella branch organisations could be used in general for rough estimations. if already available for some countries, it could be used for other countries who have no such information.

All approaches applicable for wholesale and logistic may also be used for *retail, marketing and redistribution*, except for the aggregated statistics from umbrella branch organisations. Instead of this, the aggregated data from stock-keeping tools can be used in national statistics.

In *food service*, the waste composition analysis, weighing/"food waste" diary approaches all match the "food waste" indicators. Waste composition analysis is a very good and proven method that produces reliable data. This method can be more costly than weighing/diary, but can provide better and uniform data. Both approaches are directly applicable, but further criteria are needed regarding samples per outlet type and samples in time, i.e. the length of the weighing period needed to reach a representative result.

Statistics from authorities can be used to get an overview of the number of companies in each subsector as a basis for upscaling to national figures. Another method is using data from municipal waste companies for annual "food waste" data per food service company and up-scaling by using the number of employees. This method requires good data on firm level in all countries, and at present, this is not made available for use in such studies.

In the *household* step, waste composition analysis is recommended as a very good and proven method that produces reliable data. It can be relatively costly, but if establishing an appropriate level for implementation and updating it will be less resource demanding. Statistical data in combination with waste composition analysis is recommended for calculating national figures. Waste factors is calculated by using waste data from statistics/waste management companies combined with information from waste composition analysis on "food waste" amount in mixed waste. The method will give a robust answer on the total amounts of "food waste" from households in a country.

Some approaches are recommended in several steps in the food supply chain. For quantifying data, on-site measurement by mass or volume is applicable for all steps in the food supply chain, except for household. The same applies to the "food waste" prevention method based on weighing in combination with Lean Six Sigma. However, these approaches are not recommended through the whole food supply chain, since other methods are considered more useful or more tested.

In general, the quantification of "food waste" is an area that has not matured, neither in research nor in practical application. When the area has reached a more mature stage, it is recommended that estimates or extrapolations of waste from data can be supported by harmonized micro level data. In the meantime, it is important to develop the recommended approaches for better knowledge and insight in mapping of the quantity of "food waste" and regularly evaluate and adjust to get the best possible data.

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1 Appendix - Data quality

This appendix highlights the most important issues that should be considered and more information can be found in specific references.

1.1 Definition of quality

Both single measures and specific policies regarding "food waste" prevention must be based on sound and accurate analyses. The analyses themselves require data and information to be as sound and accurate as needed for the purpose. At the same time it is not recommended to wait for many years until detailed data is available until taking actions. A balance must be found between the need for detailed data and the urgency of the problem. This means that particular attention should be paid on the quality issues during and after a quantification process of "food waste". If possible, tools to evaluate the quality level of the quantification process and data collection should be developed.

However, "food waste" is on such a scale that we cannot wait for more accurate statistics in many instances, as the benefits of action may be self-evident.
The concept of quality is not easy to define. Many interpretations are possible. Often in the technical and industrial areas, the ISO (*International Organization for Standardization*) definition is the most utilized. ISO defines quality as the "degree to which inherent characteristics fulfills requirement".

This definition takes care of the needs of each stakeholder involved in the different steps of producing a product. However, it has also received much criticism especially for the limitations that it imposes talking about *inherent* (which interpreted as *permanent*) characteristics and requirements. Critics pointed out that quality may also depend on temporary attributes and can exist also without any requirements.

Considering the goal of the deliverable and the quantitative and statistical dimension of this topic, a more appropriate definition is provided by Eurostat: "the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs" (Eurostat 2002, Eurostat, 2003a). It was included in the *European Statistics Code of Practice* - promulgated in 2005 and revised in 2011 – and then in the legal framework of the EU regulation n. 223/2009 of the European Parliament and of the Council on the production of European statistics.
In this section the concept is applied both to process and product (data) level.

1.2 Quality of data measuring in micro level methods

The methods identified as specific micro level methods aremeasurements (mass or volume), scanning (electronically recording), composition waste analysis and"food waste" diary. Some methods can be used both in micro level and macro level methods, e.g.

surveys, questionnaires, interviews and mass balances. If they are applied at a "micro scale" they are "micro level" methods.

These methods are not equally applicable to all segments of the food supply chain, because each of them has specific properties. However, each of them requires attention to achieve a good quality level.

Measurements: The direct measurements, mass or volume, allow the collection of primary data. Therefore, with a good procedure setting, there is the possibility to obtain relevant and consistent information. However, it is necessary to find representative samples and plan measurements at an appropriate level of detail, at an appropriate time of the year. Furthermore, to reach an acceptable level of data accuracy (the closeness of measure to the true values) high precision of the instruments and knowledge on how to use these instruments are required. One complicating factor is the difficulty of finding representativity given an often high number of units involved (companies, people, etc) and the high variability by season, geographical area, day of the week, consumer preferences, etc.   Direct measurements allows the estimation of uncertainty, however a problem of using external data for "food waste" quantity is that the confidence levels are often not known.

Scanning: The quality of the scanning method depends on the type of conversion needed to trace back the information, because these data are often based on economic data. Therefore, it could be necessary to start from the economic value to reach the amount of "food waste" in mass.

Waste composition analysis: This is another method that requires additional information to calculate the amount of wasted food. As in the previous cases, sample size and representativeness are key elements for a good quality level. Crosschecks with literature information and with other measurements can validate data.

"Food waste" diary: A method to quantify amount of wasted food that require particular attention and education by the person who has to measure and note the amount detected. Uncertainties, underreporting, seasonal variations and sampling are factors affecting the quality level. Furthermore, the completion of a diary can however introduce a bias in the behaviour of the participants.

Questionnaires:

The quality of data from questionnaires depends to a large degree on how the questions are expressed. The

Interviews:

Interviews are similar in many ways to questionnaires, but allows for more details to be added and more quality control performed. The resource use is high, which severely limits the number of study objects.

1.3 Quality of data collection in macro level methods

Macro level methods may also be called "top-down" levels. The rationale behind these methods is to use data from a few sources of data on an aggregated level (e.g. data on waste amounts from waste handling companies) rather than data from the "micro level", e.g. individual producers.

These methods refer to statistics, interviews, surveys, mass balances and questionnaires. They can be used as both macro level and micro level methods. When used to collect existing data at the macro level, they are macro level methods.

In order to maximize data quality and reduce the costs data collection techniques should be selected considering the objectives of the collection and the characteristics of the target population, the entire set of units for which the survey data is to be used to make inferences. The selection should take into account many factors. For example, when collecting data on sensitive topics a self-administered mode (without the presence of any interviewer) should be preferred. Also telephone interviews, in which the interviewer is present but may feel less intrusive for the interviewee, may be used, if convenient.

The best technologies available should be utilized. If possible, computer-assisted techniques should be preferred, as they ensure: efficiency, rapid checks with opportunity to verify responses during the interview, overall cost reduction and reduced use of paper. Finally, mixed methods should be preferred when they help in meeting multiple needs.

1.3.1   Surveys, interviews and questionnaires

The first issue to achieve a high level of quality in a process to collect data and information is the clarity of the basic items such as objectives, information needs to be met, content, concepts, periodicity, quality targets etc. These basic items should be clearly specified during the planning phase of a survey.

Response burden
An enterprise could receive only one or several questionnaires for different surveys in a year. However, from its perspective these requests sometimes appear as nuisances that can cause cost increasing without receiving any benefits. This can negatively impact on how or if it responds (Jones 2012).

As a consequence, a key aspect that requires attention and influences the quality of the collection process is the *response burden*, which is often defined as the effort required to answer a questionnaire. In a more general way, it could be considered as all circumstances and factors negatively affecting the quality and cost of collecting data directly from respondents (Haraldsen et al 2013).

It is usually quantified in terms of how long the survey takes to fill out. An excessive duration of the interview (or of the length of the questionnaire) could discourage respondents to answer or   alternatively could push them to give precipitate and incomplete responses. Thus, the minimization of this factor is a priority effort to achieve a satisfying quality level of data and information. For this purpose, an evaluation system is a good custom. Furthermore, not only the number of questions, but especially their level of complexity contributes to determine the response burden. The complexity depends on how difficult it is to provide the information, and how sensitive the respondent is about providing the information.

In light of these elements, it is possible distinguish between perceived response burden and actual response burden (Hedlin et al 2005). The first one is the subjective burden that differs from an individual to another one involved in completing the survey. It is difficult to be measured because it is affected by factors connected to the respondent's attitude to the survey, such as the *interest in the topic*, the *competence* and the *availability*. The second one (actual) can be measured considering the time required to fill in the questionnaire. This means the time needed to perform any necessary activity such as investigations, calculations, compiling etc. Moreover, the actual response burden is affected by a combination of factors, such as: the *survey organization* (usually, surveys conducted by government, agencies of official statistic bureaus inspire greater confidence than others); the *publicity*, (social attitudes to surveys promote a motivation to respond); the *implementation strategy* (which refers to the clarity of the questionnaire and the costs of return of information); the *questionnaire length* (which is usually correlated with the level of non-response); the *question comprehension* (difficult or easy

questions); the *mode of data collection* (e.g. online questionnaire, e-mail, or automated phone, paper forms etc.) (Willenborg et al 2014).

From an economic perspective, the response burden is a time (resource) consuming factor. Thus, it is usually measured in terms of cost, giving an economic value to the time taken to perform the aforementioned tasks. However, the time required – measured in minutes or hours – allows comparisons among enterprises, surveys, etc. over time and among different countries.

In order to lessen the negative effect of the response burden, some techniques as for example the support provided by interviewers to the interviewee in filling in the form or the availability of a free call number can be adopted. These techniques are often effective and used also to encourage people to take part to the survey, decreasing the number of non-responses (Istat 2012).

Sample design
To survey the totality of a group – generally named population – to be studied is extremely costly, for this reason a sample (a subset of the population) is used to represent and draw inferences about that group. Sampling is the selection of a subset of individuals/ units within a statistical population. A sample design is the framework that serves as the basis for the selection of a survey sample.

Sample selection should be carried out according to probabilistic criteria in order to guarantee an adequate accuracy of the estimates for the main variables / indicators of amount of wasted food and in order to draw correct inferences. Statistical inference makes use of information from a sample to draw conclusions (inferences) about the population from which the sample was taken. Every probability sampling design is characterized by two common elements:each unit of the population has a chance to be included in the sample; a random selection is required. Various types of sampling designs exist. The model at the base of them is the *Simple Random Sampling* (SRS) which is a method not very different from winning a lottery. A single number is assigned to each unit/element in the sampling frame. Then, a random selection allows to choose elements to put into the sample.

Other methods introduce changes while maintaining the basic characteristics of the SRS. The *Systematic Sampling* arranges all elements in the population in order and after the first random selection, other elements are selected (systematically) applying an interval calculated as the ratio between population size and sample size. *Stratified Sampling* is method useful when population includes a number of distinct categories. In this case, the frame can be organized by these categories, each of them represents a sub-population (stratum), out of which elements can be randomly selected. The advantage is the guaranteed representativeness in some important characteristics when groups are very different in size. *Cluster sampling* is a technique where the entire population is divided into groups (or clusters), and a random sample of these clusters is selected. It is used when it is not possible to obtain an exhaustive list of the elements of a population or when these elements are so widely scattered that surveying them would be too expensive. Cluster is desirable from an economic point of view because it saves money, but lowering the quality of data. Finally, the choice of sample design depends on many (economic, environmental, technical ...) factors that should be carefully evaluated. Obviously, the sample design and the sample size should be adequate with respect to population size and survey objectives. If a substantial reduction of the sample size is expected due to a high number of ineligible units or unit non-response, it may be useful to increase the number of the selected sample units (Istat 2012).
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The use of non-probabilistic methods for sample selection should be justified. This could be the case when a large number of e.g. farmers/ food industries are not willing to collaborate in the survey and the investigator has to choose the units of the population not agreeing to the probabilistic rules but according to the availability. However, inferences on the target population based on a non-probability sample increase the risk that estimates could be biased. In these cases, it is necessary to illustrate the assumptions justifying the sample representativeness and to calculate the related sampling errors.

The first step in establishing a statistically representative sample is to investigate which factors are crucial. The following are relevant criteria for production:
- Amount of producers in sample in relation to total amount of producers [also the representativeness can be calculated by any quantifying indicator (i.e. product sold) of the sample and compare it to total amount of product sold].
- Geographic area: e.g. climate conditions like temperature and rainfall
- Farm size
- Farmer practices (e.g. crop rotation, used cultivars etc.)
- Regional characteristics
- Farming type (e.g. organic /conventional/integrated production (IP) farming etc.)
- Technology, equipment, infrastructure (for example type of harvesting machine etc.)
- The yields can vary dramatically from year to year, especially with plant production. The temporal representativeness can be ensured by collecting a minimum of 3 years. In cases where there has been an extreme year, e.g. when harvests have been very low, a longer sampling period might be needed.

Questionnaire

The questionnaire is one instrument used to ask and gather information from respondents. Then, its conception is a key issue.

In the design phase, questionnaires have to be framed so that they:
- Effectively collect the information of interest;
- Contain only the necessary questions, avoiding to increase the response burden;
- Facilitate the fluency of understanding;
- Concern to standard definitions and concepts, explained for example in the opening pages;
- Can facilitate the data processing.

In addition, also the way how to manage the questions (or the questionnaire administrative mode) can have effects on the data quality (Bowling 2005). The most commonly used modes of administration are:
- Face-to-face administration, where an interviewer presents the items orally;
- Paper administration, where the items are presented on paper;

Computerized administration, where the items are presented on the computer.

If paper questionnaires are chosen, the graphical layout should express positive perceptions and help the user orienting among the different sections. If electronic questionnaires are adopted, they should be developed exploiting the technological potential for routing management and on-line quality control, without unduly burdening the interview (Istat 2012).

In order to ensure adequate response rates and a high quality level of the information collected, participation of respondents should be encouraged, and measures on the collection phase should be produced and evaluated.

Confidentiality

Confidentiality concerns the treatment of information that an individual has disclosed in a relationship of trust. Participants in data collection initiatives- to quantify amount of wasted food or any other type of topic - expect that identifying information will not be

divulged to others without their permission. Researchers and collectors have to inform participants about the degree of confidentiality that can be maintained.

The easiest way to protect confidentiality is to collect anonymous data, to avoid that data collection participants could be identified. Collectors can implement practices that increase the level of confidentiality. Examples for this are to use codes instead of recording identifying information and keeping a separate document with this information locked in a separate location; encryption of identifiable data; removing name, addresses etc. from the survey tool (questionnaire); closing answers in a sealed envelope or using the method of randomized responses (if these strategies can be used according to the objectives of the survey); limiting access to identifiable information.

1.3.2 Statistics and mass-balances

In some cases, direct amount of wasted food and/or indirect statistics published by authorities, administrations or statistical offices, could be used.

In order to achieve a good level of quality, it would be useful to understand the context in which available data on wasted food are generated and managed, for example the inherent legislation - especially if comparisons among different Countries are required - the goals with producing the data and the current usage of the data. Obviously, the evaluation of the quality of these statistics should be performed before starting their use. This evaluation can be made taking into account, for instance, coverage, content, concepts and definitions used, frequency and timeliness of records, stability over time. However, all phases of acquisition and processing of statistics should be documented (Istat 2012).

In order to improve the quality of both the collection process and the data, good relationships with the agencies providing "food waste" statistics should be established by formal agreements. Key elements such as procedures and timing for data transmission, required quality level etc. should be included in these agreements (Istat 2012).

1.4 Quality of the data

In the previous sections good practices to achieve a satisfying level of quality in methods to quantify (or estimate) the amount of wasted food have been disclosed. However, planning for high quality in how to collect data does not remove the requirement of giving attention to the quality of the statistics produced or data found. This section lists the criteria used to measure the data quality.

According to the definition given by Eurostat, the quality of data can be measured with respect to the following criteria (Eurostat, 2003a; 2003b):

Relevance refers to the degree to which statistics meet current and potential needs of the users.

The accuracy refers to the closeness of estimates to the unknown true values.The level of accuracy is related to the amount of errors that may occur in the production process of survey estimates; the greater the number of errors, the lower the accuracy.

Timeliness refers to the period between the availability of the information and the event or phenomenon it describes.

Punctuality refers to the delay between the date of the release of the data and the target date (the date by which the data should have been delivered).

<u>Accessibility and clarity</u> refer to the conditions and modalities by which users can obtain, use and interpret data.

<u>Comparability</u> refers to the measurement of the impact of differences in applied statistical concepts, measurement tools and procedures where statistics are compared between geographical areas, sectorial domains or over time.

<u>Coherence</u> refers to the adequacy of the data to be reliably combined in different ways and for various uses. The coherence depends on the statistical processes by which data were generated. If in a data collection harmonised methods - methods that refer to the same concepts such as classifications, definitions, target populations etc. - were used, outputs are coherent and they can be combined. For example, when statistics are coherent a researcher can add the amount of wasted food of Italian farms to waste of Greek, Spanish…farms, to obtain the agricultural waste at the production stage in Mediterranean Europe. However, if these national statistics are not coherent, the results cannot be of a good quality level.

Measuring the quality of data according to the above mentioned components is not so easy because it is only possible to obtain direct measures (i.e. numeric values)for a limited number of components (typically timeliness, accuracy and comparability). For the other components, subjective opinions may be given.

1.5 Identifying, monitoring and correction of errors and outliers

Usually, a statistic is affected by error when its value does not correspond to the true value. Obviously, the presence of errors can lead to distortions in the estimation phase and in the data analysis.

The errors in a dataset (data matrix) could occur due to any of the phases of acquisition and adjustment of information such as collection, revision, recording etc. For this reason, the data check should be as close as possible to the information collection stage, in order to make it easier to identify and correct conflicting or abnormal situations.

There are many classifications of errors. It is useful to know the most common ones in order to reach a good level of data quality.

1.5.1 Types of errors

Many types of errors can occur during a quantification and estimation process of the amount of wasted food. Consequently, different negative effects on estimates and analyses are possible. Among the existing error classifications, a very common distinction is between systematic and random (or stochastic) errors:

- *Systematic errors* are constant in a series of repetitions of the same direct measurement method (i.e. weighing) or in a data collection using the same model (questionnaire). They are caused by structural defects of the measuring instruments or by the imperfection of the model statistical structure. An example of systematic error is a scale that, if loaded with a standard mass, provides readings that are systematically lower than the true mass.
- *Random (or stochastic) errors* are those errors caused by random factors not directly identifiable. An example of random error is putting the same mass on a

scale several times and obtaining a result that vary from one measurement to the next. The differences between these readings and the actual mass correspond to the random error of the scale measurements.

A further and key distinction is made between sampling and non-sampling errors:

- The *sampling errors* occur because not the whole population (for example all farms), but only a part of it (the sample) is considered in the survey. These errors depend on the probability, the sample design, the sampling technique etc.
- The *non-sampling errors* are caused by all possible inaccuracies committed during a "food waste" estimation process. They can be due to, for example, the interviewee who does not answer or provides incorrect information, the interviewer who could influence the interviewee, the technique such as face-to-face, postal, telephone interview, the characteristics of the questionnaire such as length, complexity, biased questions etc.

Non-sampling errors consist of coverage errors, partial and unit non-response errors, as well as measurement errors:

- *Coverage errors* are typical of the sampling frame - lists with the units constituting the population - used to design and select the sample. They can be:
    1. Under coverage errors, units belonging to the target population but not listed in the sampling frame;
    2. Over coverage errors, units included in the sampling frame which do not belong to the target population;
    3. Duplications, units listed several times in the sampling frame.

- *Non-response errors* result from a failure to collect complete information on all units in the selected sample. These errors affect survey results in two ways. First, the decrease in sample size (then the reduction of information collected), second the increase of variability associated to final bias. They can be distinguished in:
    1. Partial non-response that occurs when a statistical unit, for example a farm included in the sample, gives an incomplete answer to a question or decides to answer to a part (subset) of the questionnaire;
    2. Unit non-response that occurs when no data are collected for the surveyed unit, because the unit does not answer to any question of the questionnaire.

- *Measurement errors* may occur during data collection and/or subsequent treatment phases as revision, registration etc., but also in a direct measurement of the amount of wasted food at a stage of the food supply chain. As in the previous cases, the available value does not correspond to the true value of the amount of wasted food.

The mentioned errors can cause at least three types of problems that threaten the data quality: values out of the domains, outlier and incompatibility of responses (in a statistical model as a questionnaire).

Considering that a domain is a set of permissible values, a value out of domain does not belong to a set of allowable values. For example, if the whole production of each farm included in a sample do not exceed 1000 tonnes per year, the domain - for the amounts of wasted food - could be conceptually limited between 0 and 1000 ton (obviously, the minimum and maximum extremes are very unlikely in reality). If the "food waste" of a unit results in 1500 ton per year, this value is clearly outside the domain, then it is not allowable.

An outlier is an anomalous value of a statistical unit that shows characteristics significantly different from those of other units. This means that a data set may have one or more items with unusually large or unusually small values, called outliers. They often arise from some errors in data collection or data recording procedures. Statistical techniques able to identify outliers exist, but they are not sufficient to decide, simply based on the numbers, that a value is false. In other terms, an outlier is an extreme point, but not necessarily wrong. Finally, incompatibilities exist if the values of one or more variables contradict the logical and / or mathematical rules.

An outlier is different from a value out of domain in that the latter is an impossible value whereas the former is a value that is possible but probably a result of an error.

1.5.2 Strategy to identify and correct errors

To determine the impact of errors on data is not simple, because often information external to the quantifying process (other data to do comparisons) is needed, but may not even be available. For this reason, bias prevention is recommended, but when it is not enough methods to reduce errors have to be adopted.
The overall procedure for error detection and treatment should be based on a transparent, reproducible and documented system. Moreover, this procedure should be organised in phases according to the different error types and to the proper methods for correcting them.
Here, the discussion of these issues cannot be exhaustive but it will try to outline in a concise manner the key points.

The identification of the errors in a data set is based on different types of controls:

- Consistency checks. They refer to incompatibility rules, as a set of non-conflicting constraints that must be simultaneously satisfied by each statistical unit so that the corresponding information can be considered correct. These rules are both formal/logical and mathematical;
- Validity checks. They verify that the values of a given variable are internal to a range that is according to the definition of the variable.
- Statistical checks. They are used to isolate variables with values that differ significantly from other variables in the rest of the sample or from previous surveys. With high probability, these values are incorrect; more tests are needed to establish it.

Since *sampling errors* tend to decrease by increasing sample size, methods to reduce them are increasing the sample size and ensuring that the sample adequately represents the entire population.

From a practical standpoint, *systematic errors* are usually much more serious nuisance factors than random errors - because their magnitude cannot be reduced by simple repetition of the measurement procedure several times. By contrast, the effect of the *random errors* may be reduced by repetition of the experiment or observation and averaging the outcomes.

Over coverage and *multiple listings* will result in an increase of sampling error and cost but no significant biases and this can be handled by statistical method.
Under coverage cannot be detected in the measurement process and is the most serious type of coverage error. It will always result in biases, large or small, which are difficult to detect and evaluate. There are methods to detect under coverage and assess its effects.

Non-response errors are determined by collecting any or all of the following: unit response rate, weighted unit response rate, item coverage rate, distribution of reason for non-response, comparison of data across contacts etc.

The localization of outliers is done by the determination of acceptance intervals. If a statistical unit is outside of this interval, it is considered abnormal, checked and, if necessary, to be fixed.
After identifying the outliers, there are two possible alternatives: exclude them from the subsequent processing and the final estimates; or checking whether outliers identified are due to wrong situations or whether it corresponds to the actual situations.

Furthermore, seasonal adjustment procedures should be aimed at removing the seasonal component of time series (if data on the amount of wasted food are collected every year and even in the same period). The approach used to seasonal adjustment of data should be based on sound and generally accepted methodologies.

With regard to the data validation, some actions are required:
- Prior to the dissemination, results should be evaluated together with subject experts in order to detect the presence of anomalies.
- Where practicable, results should be compared with the same results obtained on previous occasions or with similar results obtained by other processes.
- Moreover, quality indicators of the process should be calculated and analysed to assess the possible introduction of improvement actions on subsequent survey occasions. A*d hoc* analysis, as well as calculation of quality indicators, are aimed, in the first place, at ensuring the quality of the disseminated estimates and, secondly, at assessing the opportunity to adopt improvement actions for subsequent survey occasions.

2 Appendix Prevention methodologies and waste treatment

2.1 Food waste prevention in companies

Waste minimization is generally a concept and a strategy that was developed and described by the US EPA in the late 1980s, with both general and more branch specific guidelines for waste minimization assessments (US EPA, 1992). In most parts of Europe, waste minimization and pollution prevention programmes were implemented as strategies for coping with environmental challenges in the society, and with large programs with funding and capacity building. However, the programs that support the companies for preventing "food waste" are no longer funded.

Prevention of "food waste" is only a special case within this framework, and can thus build on all experiences and results that have been described from waste minimization over the last 30 years. Some important characteristics of a "food waste" prevention methodology within a company are described in the following:

In the Norwegian ForMat project (Hanssen & Schakenda, 2011), a methodology termed as the "Four-stage" model for food waste prevention has been developed for how companies can work systematically with food waste prevention in their own factories (*Figure 2.1*). After having commitment from the company management, a cross functional team should be established to do the work in Stage 1-3. The starting point is to get an overview about how much food is wasted in each of the main parts of the process. A good starting point is to make a coarse flow diagram of the main processes in the factory, from input and storage of raw materials and ingredients, to the final storage of finished products. Methods for quantifying any waste of resources from the process step are described in detail in Chapter 9.
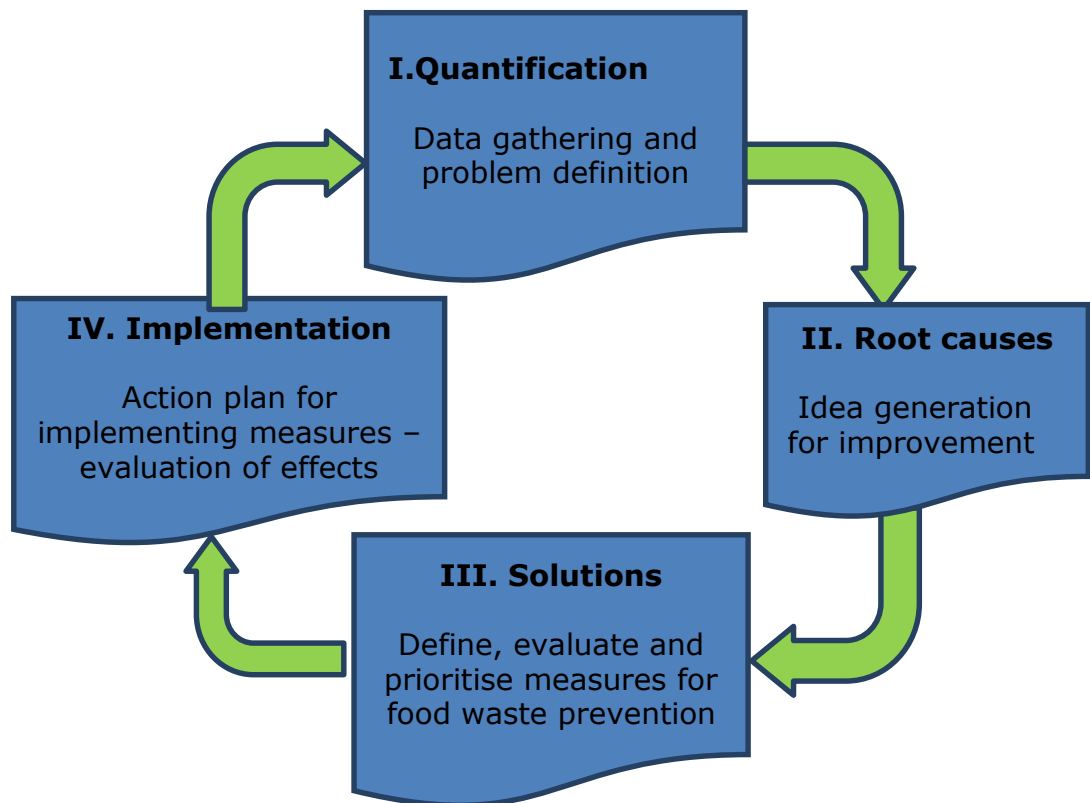
Figure 2.1 Four Stage model for food waste prevention in companies

"Food waste" prevention strategy/policy goes further than implementing activities within one`s own unit but can also involve suppliers and clients.

The issue of "food waste" prevention is separate from that of data collection and calculation of indicators and using the indicators to calculate final amounts. However, it guides you in where to start working with waste prevention ("where are the largest amounts of wastes produced"?) and to see progress in reduction ("do the implemented measures have any effect"?). The questionnaires, interviews, surveys and other platforms for data collection can also contain advice on waste prevention strategies. If more "food waste" data is collected it can increase value chain actors' awareness. It is also important to give the indicator results back to informants as feedback so that they can check their waste rate compared to the average rate. To implement "food waste" prevention measures, the companies should have internal benchmarks and assess the differences between outlets more in detail considering individual outlet characteristics. The measuring and mapping method (Gunnerfalk, 2006; Svenberg, 2007) can be generalised and used on other steps in the supply chain than processing. To summarize, the "food waste" prevention program should follow the following steps:

1. Establish an internal cross-functional assessment team to describe the problem, identify and evaluate solutions. There should be a clear statement of the management that "food waste" prevention is an important issue
2. Map the process, by making a flow diagram describing the most important process steps within the unit to be studied, with material and waste flows included
3. Measure the "food waste" by weighing and find "root causes" in processes, operations and management, planning etc., and not only focusing on symptoms.
4. Define the problem and look for solutions that can prevent waste generation

5. Evaluate, discuss and prioritize the most important solutions to root causes in the process, and make a plan for implementing measures for prevention
6. Follow up with indicators documenting trends in reductions (municipal, company or household)
7. Perform measurements frequently enough and evaluate the effects of measures implemented, and make eventually a new plan for the next period

## 2.2 "Food waste" Prevention in the Food Value Chain

In many cases food is wasted not due to situations in one specific company in the food chain, but to causes related to larger parts of the food supply chain. This has been documented in several studies both in UK by WRAP and in Sweden and Norway through the ForMat project. Companies must thus often look both upstream and downstream of their own position when working with prevention of "food waste", and establish collaboration with both suppliers (e. g. production) and customers (retail) in projects with focus on specific products. The methodologies presented in Appendix 2.1.can be used as a basis for prevention projects also in a value chain, where the first point of action can be to quantify how much "food waste" is generated in the different steps of the food chain. This should be done based on absolute figures and not percentage of production or turnover, to focus on the products with high potential for prevention.

An important point in the value chain approach is to search for root causes to "food waste" that is a result of the interaction between companies, i.e. lack of information can be a reason for "food waste". Improved information sharing in planning and purchasing routines is typically a measure to prevent "food waste" both in food processing and in the retail sector. Choice of secondary packaging with the right size and the right number of units of consumer packaging is another example on improvement measure.

The most important point is that actors along specific food supply chains should work together based on the methodologies for quantifying waste and defining root causes, and identify measure to prevent waste through joint actions. Registration of "food waste" statistics should still be done separately based on the NACE codes and categories of "food waste" as described in Appendix 3.

2.3 Handling of food waste

According to regular waste hierarchies, prevention has highest priority and if not possible then recycling should take place. *Figure 2.2* shows a waste hierarchy for "food waste". According to this hierarchy when waste prevention in the food supply chain is not possible the waste should be utilized in some other way, preferably as food for human being, e.g. through redistribution. If this is not possible, the best option is to use the food in animal feed, then follows biogas or compost production and finally incineration as the last option. Landfilling is the least desirable option. Treatment is not regarded to be part of the FUSIONS methodology directly, as the main focus is to quantify "food waste" that should and could be used as food.

Figure 2.2 Waste hierachy
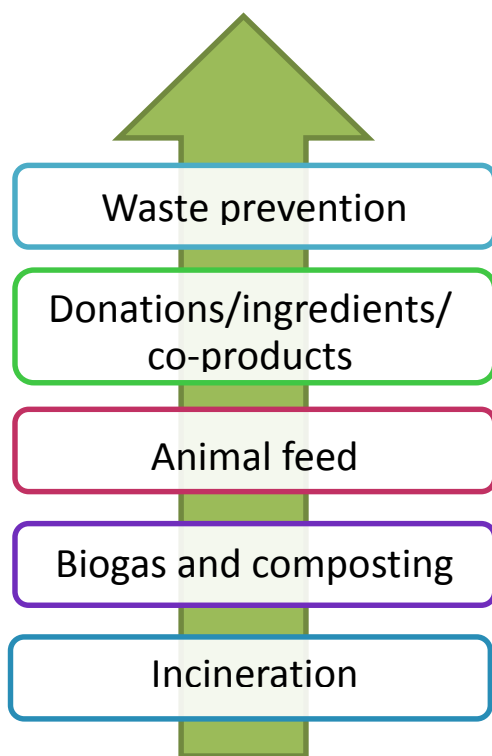
Waste that is sent to treatment is of interest due to the fact that it is often an important source for information and data about "food waste" from the food supply chain. Mixed wastefor treatment should thus be separated at source and registered accordingly to get a good basis for estimating the part that consists of food waste. Furthermore, a separate collection of "food waste" supports the execution of waste composition analyses and offers several disposal paths. The separated "food waste" could be used for animal feed if applicable to anaerobic treatment for production of biogas or to composting. Available information on used "food waste" treatment is essential for assessing the environmental impact and comparison of different available options.

3 Appendix Economic sectors and food classification

3.1 Economic sectors

The definition of the supply steps is described by activities (when crops are mature for harvest and when animals are ready for slaughter). The definitions of the steps are differing from NACE – codes (NACE - Nomenclature statistique des activités économiques dans la Communauté européenne). One important reason for making the updated Guidance on waste statistics was the new version of the economic sector classification to the NACE Rev 2 (Eurostat, 2008) from reference year 2008 and the connections to the WStatR system with reference year 2010 (EU Comm, 2010). According to NACE Rev 2 the following NACE categories are relevant for "food waste" and "food waste" statistics reported from Member States, with the following subcategories being most relevant for the food supply chain (see more detailed overview in NACE Rev 2 from 2008; Eurostat, 2008).

- Agriculture and fishery (farm and fishing) (NACE 01-03)
    - o   01.1 Growing of non-perennial crops
    - o   01.2 Growing of perennial crops
    - o   01.3 Plant propagation
    - o   01.4 Animal production
    - o   01.5 Mixed farming
    - o   01.6 Support activities to agriculture and post-harvest crop activities
    - o   01.7 Hunting, trapping and related service activities
    - o   03.1 Fishing
    - o   03.2 Aquaculture

- Food manufacturing (NACE 10, 11)
    - o   10.1 Processing and preserving of meat and production of meat products
    - o   10.2 Processing and preserving of fish, crustaceans and molluscs
    - o   10.3 Processing and preserving of fruit and vegetables
    - o   10.4 Manufacture of vegetable and animal oils and fats
    - o   10.5 Manufacture of dairy products
    - o   10.6 Manufacture of grain mill products, starches and starch products
    - o   10.7 Manufacture of bakery and farinaceous products
    - o   10.8 Manufacture of other food products
    - o   10.9 Manufacture of prepared animal feeds
    - o   11.0 Manufacture of beverages

- Retail and wholesale (NACE 46 and 47)
    - o   46.17 Agents involved in the sale of food, beverages and tobacco
    - o   46.2 Wholesale of agricultural raw materials and live animals
    - o   46.3 Wholesale of food, beverages and tobacco
    - o   47.1 Retail sale in non-specialised stores

- 47.2 Retail sale of food, beverages and tobacco in specialised stores

- Food and beverage service sector (NACE 56)
  - 55.1 Hotels and similar accommodation
  - 55.2 Holiday and other short-stay accommodation
  - 55.9 Other accommodation
  - 56.1 Restaurants and mobile food service activities
  - 56.2 Event catering and other food service activities
  - 56.3 Beverage serving activities
- Households

National data collection and reporting of waste statistics must be connected to different economic sectors in accordance with the NACE2 classification. The categories for processing, wholesale, retail and food service are easy to connect to the food chain, which is the basis for the FUSIONS project. For production, the NACE categories that are used also contain large economic sectors that are not related to the food sector, especially the forestry sector. In up-scaling from smaller samples of units to economic sectors, it is thus important to exclude those subsectors that are not producing food, and which thus should not be part of the up-scaling. This will be further described in chapter 8.

3.2   Classification of food

There are a number of different approaches to classify "food waste" according to product categories, and the literature review showed a number of different classification systems. In Norway, the ForMat project (Hanssen & Schakenda, 2011) used nine main categories of products related to "food waste"(mostly solid waste), with 21 different subcategories. Similar classifications have been made by WRAP in their studies of food waste from households as well as from the food supply chain (WRAP, 2013). It would make comparisons between different studies as well as reporting to Eurostat and other organisations easier if it was agreed on one classification system for "food waste" related to products, and which is quite easy to connect to the NACE codes of the business sector internationally. One list that seems to be internationally accepted is the one used by FAO in their Code of Conduct for food classification (FAO 2004), with 16 main types of food products as a basis for classification of "food waste" and wasted food:

01. Dairy products
02. Fats and oils, oil based products
03. Ice cream, sorbets etc.
04. Fruits and vegetables, including nuts and seeds
05. Confectionery
06. Cereals and cereal products
07. Bakery wares
08. Meat and meat products, including game
09. Fish and fish products, including molluscs and crustaceans
10. Eggs and egg products
11. Sweeteners, including honey
12. Salt, spices, soups etc.
13. Food stuff intended for particular nutritional use
14. Beverages, excluding dairy products
15. Ready to eat food
16. Composite food not possible to include in other groups.

The list can be shorter and more aggregated by combining some food categories into higher classes, see recommendations below:

I.	Dairy products, ice cream and sorbets (01, 03)
II.	Fats, oils and oil based products (02)
III.	Fruits and vegetables (04)
IV.	Confectionery and sweeteners (05, 11)
V.	Cereal products and bakery wares (06, 07)
VI.	Meat and meat products (08)
VII.	Fish and other types of seafood (09)
VIII.	Eggs and egg product (10)
IX.	Food stuff, ingredients, spices, dry products (12, 13)
X.	Beverages excluding dairy products (14)
XI.	Ready to eat food (15)
XII.	Composite food (16)
XIII.	Prepared and mixed food from food service and households

Standard approach on quantitative techniques to be used to estimate food waste levels

Name
Address
Phone
E-mail
Website

FUSIONS