Report on review of (food) waste reporting methodology and practice

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Reducing food waste through social innovation
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Colophon

Title	Report on review of (food) waste reporting methodology and practice
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Summary

The overall objective for the FUSIONS project (Food Use for Social Innovation by Optimising waste prevention Strategies) is to achieve a Resource Efficient Europe by significantly reducing food waste. This report is a based on the work carried out inthe FUSIONS Work Package (WP) 1 task 1.2 "quantitative techniques and data integrity" and is a literature review in order to explore the different methodologies which have been used for quantifying food waste in Europe and elsewhere. This report will together with the "Review of EUROSTATs reporting method and statistics" serve as a basis for development of a standard approach on quantitative techniques within the FUSIONS project.

As a basis for the literature review, an extensive literature search was carried out in February 2013, performed for each step of the food supply chain in order to examine different methods used and data sources. Then a working group selected *principal studies* for further review and evaluation, based on the findings in the extensive literature review and the summary reports for each step in the supply chain. This report gives a quantitative characterisation of the studies, according to data originality, methodological approach, waste categories etc., and a qualitative characterisation including experiences, data gaps and pros and cons of the utilized methods. The following methods were assessed:

- Direct measurement and scanning
- Waste composition analysis
- Mass- and energy balance
- Statistics from authorities or waste management companies
- Questionnaire
- Food waste diary
- Interview

The goals of this review were to clarify if the reviewed studies provide the necessary basis to develop harmonized and quantitative methods within FUSIONS as a basis for preventing food waste and to be able to measure and compare food waste levels between countries and over time; as well as to provide an overview of methods previously used and indicate data gaps. The review provides state of the art on waste reporting methodologies. Based on the review it was concluded that not one single method is applicable to all steps in the supply chain, covering all different purposes of studies with reliable data on food waste.

To fulfil the criteria it is therefore necessary to combine methods. The methods mentioned above have different focus, i.e. measuring and data gathering. The relevant methods for measuring food waste are direct measurement (weight or volume), scanning, composition waste analysis and diary. For data gathering the relevant methods are calculation methods from statistical data, interviews and surveys, mass- and energy balances and questionnaires.

Prevention of food waste is also an important issue but no of the above listed method have that as the main purpose. For most of the methods can be useful as a part of preventing food waste. The review showed also that to prevent food waste it is important

to perform weighing at an adequate level of detail, involve employees in defining the root causes of food waste, develop ideas to prevent waste and follow indicators documenting trends in reductions.

The review identified data gaps in statistics on food waste from national authorities, particularly from developing countries and for the step "wholesale and logistics". Data gaps have also been found in the different steps in the supply chain. A lot of data is available, but this varies widely through the supply chain. The quality of these data sets are also varying because the purpose of the data collection affects the extent and definitions, which in turn will affect the data. Methodological gaps have been identified for liquid food going down the drain and waste going to feed since these fractions can be difficult to measure by using the existing methods.

A limited number of studies have been conducted at an EU or global level using statistics as the data source. One of the conclusions from the review of the Eurostat waste statistics is that no common and harmonized methodologies for gathering of food waste data are prescribed, which makes it difficult to compare results from different studies and across national statistics. This literature review has shown that there are methods available which can deliver relevant and reliable data at a national level for each sector, but there is a need to harmonize those methods. To make statistics at EU level more comparable and transparent, it is necessary to describe methods and how to extrapolate these data sets for each sector to national figures for the entire value chain.

Looking at each step individually, the choice of the methods to be applied is related to the number of actors and the consolidation and structure of the food supply chain. Because of the wide variation in the number of actors along the supply chain it is necessary to adapt the quantifying method to each step. This implies that it is also necessary to adapt the extrapolation methods on the data for each step in the supply chain to obtain good and reliable data for the entire supply chain.

The waste categories used in the reviewed studies reflect the point in the supply chain the analysis is performed as food waste tends to become more heterogeneous as it progresses through the supply chain. In production and processing the amount of food waste is mainly characterised as products or product groups, whereas for food service and households it is characterised as edible/non edible food waste or total food waste. It is therefore also a need to get harmonised food waste categories.

Contents

Abbreviations

Short name	Name
BIOIS	BIO Intelligence Service
BOKU	BOKU-University of Natural Resources and Life Sciences Vienna
DLO	Wageningen UR - Food & Biobased Research
FAO	Food and Agriculture Organization of the United Nations
IFR	Institute of Food Research
IVL	IVL Swedish Environmental Research Institute
INRA	French National Institute for Agricultural Research
LCA	Life Cycle Assessment
MTT	MTT Agrifood Research Finland
SIK	SIK - The Swedish Institute for Food and Biotechnology
UNIBO	University of Bologna
WRAP	Waste & Resources Action Programme

1 Introduction

The overall objective for the FUSIONS project (Food Use for Social Innovation by Optimising waste prevention Strategies) is to achieve a Resource Efficient Europe by significantly reducing food waste. This will be accomplished by harmonisation of food waste monitoring, showing the feasibility of socially innovative measures for optimised food use in the food supply chain and by giving policy recommendations for the development of a EU27 Common Food Waste Policy. Further on, FUSIONS will enable, encourage, engage and support key actors across Europe in delivering a 50% reduction in food waste and a 20% reduction in the food supply chains resource inputs by 2020.

This report is a review carried out in the FUSIONS Work Package (WP) 1 task 1.2 "quantitative techniques and data integrity" and is an extensive literature review in order to explore the different methodologies which have been used in Europe and elsewhere. This report will together with the "Review of EUROSTATs reporting method and statistics" serve as a basis for development of a standard approach on quantitative techniques. The approach and findings in this report are also strongly related to the work carried out in FUSIONS WP1 task 1.1 on definitions and system boundaries.

2 Aim and goal

The aim of this literature review is to support the work on developing a standard approach on quantitative techniques, to be used in FUSIONS to estimate food waste levels across EU27. The review shall benefit from existing knowledge and collect best practise examples combining methodological approaches, food supply chain levels and data availability in different ways.

The goals of the literature review report are:

1. To give a characterization of the most relevant food waste studies identified, according to e.g. data originality, methodological approach, time scale etc., to help clarify whether the reviewed studies provide the required information needed, for developing quantitative methods within FUSIONS, in relation to the overall objectives of the project:
    - Prevent food waste
    - Measure and compare between countries and over time
2. To provide state-of-the-art knowledge by giving an overview of the different methods and data sources used for each step of the supply chain.
3. Identification of data gaps.

3 Procedure for literature review

3.1 Methodological terms

In the following sections, different "methodological terms" are used and therefore this section starts with a table explaining the "methodological terms" used in order to make the following sections easier to read (Table 1). Since no common defintion of wasted food has been agreed upon at the time of writing this report[1] we have choosen to refer to food waste in general in this review.

Table 1 Methodological terms and description

Term	Description
Primary data	Data measured directly, for example by weighing or by waste composition analysis
Secondary data	Data from an indirect source (mass balances, statistics, and economic transactions).
Literature data	Data from literature or databases.
Mass data	Data measured in a weight based unit (kg or ton).
Economic data	Data measured in economic value.
Food product group	A collection of foods that share similar nutritional properties or biological classifications
Scanning	In this context scanning is to capture and read information contained in a printed or digital bar code of a product.
Waste Composition analysis	Determine detailed data about waste at local or regional levels. Can be carried out routinely at regular or irregular intervals.
Waste audit	A waste audit is a formal, structured process used to quantify the amount and types of waste being generated by a company or an organisation.
Interview	A method based on a conversation where questions are asked by the interviewer to elicit facts or statements from the interviewee. Interviews can be both qualitative and quantitative.
Questionnaire	A questionnaire is a formal, structured data collection from respondents. In this context it is used as a structured way of getting figures for food waste and in some cases also additional information.
Diary	A daily record of experiences and observations. In this context, it is a method in which the household weighs food waste and makes a note on quantity, type and cause.
Bottom-up approach	Uses incoming information on sublevels to create an overall

[1] A genral technichal framework for establishing a standard approach on system boundaries and definitions of food waste and secondary recources will be an outcome from the FUSIONS porject. "Secondary reourceses" refer to "Any food and inedible parts of food removed from the food supply chain".

	top level
Top-down approach	Uses information at an top level and split it up into sublevels

3.2 Selection of studies

To facilitate the literature review, a FUSIONS data base was set up by the partners in WP1, growing to contain over 300 classified articles and reports. The reports were classified with regards to e.g. authors; year of publication; the food product(s) studied; the supply chain step(s) studied; whether any environmental or socio-economic/economic aspects of food waste were highlighted and whether the study provided important definitional choices and/or methodological approaches. The FUSIONS database was used to collect the references relevant for the literature review.

First an extensive literature review was carried out in February 2013. The literature review was performed for each step of the food supply chain in order to examine different methods used and data sources. The literature review for each step in the supply chain was carried out by different FUSIONS partners, see Table 2. The criteria that were used to select the first set of studies from the database to be reviewed, were "those providing important methodological approaches", but also studies classified as "key references for FUSIONS". Some of these *considered studies* were not found relevant after all and were not included in the review among the *relevant studies*. An analysis of the relevant studies were made with regards to e.g. pros and cons, type of methodological approaches used to characterize and quantify food waste and the main purpose of the study. Summary reports of the literature review were written for each step in the supply chain, see annex 1.

Secondly a working group selected *principal studies* for further review and evaluation, based on the findings in the extensive literature review and the summary reports for each step in the supply chain. A "principal study" is defined as a "study with a comprehensive methodological description, containing primary or secondary data and assessed for being relevant for the actual step in the supply chain". For information on the FUSIONS partners carrying out this task, see Table 2.

This review report is based on inputs from the extensive literature review (from February 2013); the further review and evaluation is carried out by the working group and additional comments from other FUSIONS partners are also included.

Table 2 The literature reviews within WP1 task 1.2 and the FUSIONS partners who carried out each literature review; (the responsible partner is underlined)

Part of supply chain	FUSIONS partners – extensive literature review	FUSIONS partners – selecting and describing principal studies
Production	UNIBO, INRA, MTT	BIOIS
Processing of farm staples	UNIBO, IFR	BIOIS
Processing	SIK, IFR	SIK
Wholesale and logistics	BOKU, OSTFOLD	OSTFOLD
Retail	OSTFOLD, BOKU	OSTFOLD
Markets	UNIBO, BOKU	OSTFOLD
Redistribution	BOKU, OSTFOLD	OSTFOLD
Food services	OSTFOLD, DLO	OSTFOLD
Households	WRAP, BOKU	IVL

Table 3 presents the number of references (from the FUSIONS database) which have been considered (column 2), numbers of relevant studies identified (column 3) and references from principal studies found for each step of the supply chain (column 4). The number of relevant studies is described in the extensive literature review in Annex 1 and in chapter 4; Overall characterization of the studies. The number of relevant studies identified may differ slightly from the extensive review, since some studies were added after February. The selected principal studies are described in chapter 5.

It should be noted that the review of different steps of the food supply chain may include the same references; thus the number of studies considered relevant for each step of the supply chain cannot be summed up to estimate the number of studies found relevant for all supply chain steps together.

The table also describes the relationship between the number of studies available and the number of studies found relevant to describe the methodological approach. Especially for production a large number of studies are reviewed, but only few were considered as principal studies.

Table 3 Number of references reviewed from the FUSIONS database

Step in the supply chain	No. of considered studies	No. of relevant studies	Reference no of principal studies
Production	89	40	Almeida, 2011 (98*) Beretta et al., 2013 (279*) Gustavsson et al., 2013 (328)
Farm staples	3	3	C-Tech_Innovation, 2004 (27*)
Processing	21	21	C-Tech_Innovation, 2004 (27*) WRAP, 2010 (70*) WRAP, 2011d (104*) WRAP, 2011e (105) Gunnerfalk, 2006 (111)
Wholesale and logistics	41	14	Kranert et al., 2012 (2) Stenmarck et al., 2011 (21) WRAP, 2010 (70*) Barilla, 2012 (92) Almeida, 2011 (98*) WRAP, 2011d (104*) Beretta, 2012 (146) Hanssen & Schakenda 2010/2011, (184/185*) Eriksson, 2012 (251*)
Retail and market	39	16	Buzby, 2009 (5) Mena & Yurt 2011 (24) Venkat, 2012 (40) WRAP, 2010 (70*) Hanssen & Schakenda 2010/2011, (184/185*) Eriksson, 2012 (251*)
Redistribution	11	4	Alexander & Smaje, 2008 (31) Schneider & Scherhaufer, 2009 (148)
Food services	29	26	Jensen et al., 2011 (20*) WRAP, 2011a (51) Engström & Carlsson-Kanyama, 2004 (53) Soethoudt, 2012 (102) Marthinsen et al., 2012 (123) Silvennoinen et al., 2012a (265) Beretta et al., 2013 (279*)
Households	32	26	Jensen et al., 2011 (20*) WRAP, 2011f (42) WRAP, 2009b (108) WRAP, 2009a (161) WRAP, 2011b (163) Silvennoinen et al., 2012b (169) Katajajuuri et al., 2012 (242) Mejdahl et. al., 2011 (107)

** The study is selected in more than one step in the food supply chain.*

4 Overall characterisation of the studies

A quantitative characterization of the relevant studies was carried out to clarify whether the studies provide the required information in relation to the overall objectives of methodology, prevent food waste and measure and compare it among countries and over time. This issue also connects to the "Criteria document" (Gustavsson et al, 2013), developed in T1.1 as a reference point for the Methodological Framework within FUSIONS, describing the mindset agreed upon for the methodological framework including, definition, quantitative methodology and indicators.

Figure 1 shows a major classification of the type of methods and type of data (quantitative and qualitative) they can provide in relation to the data source.

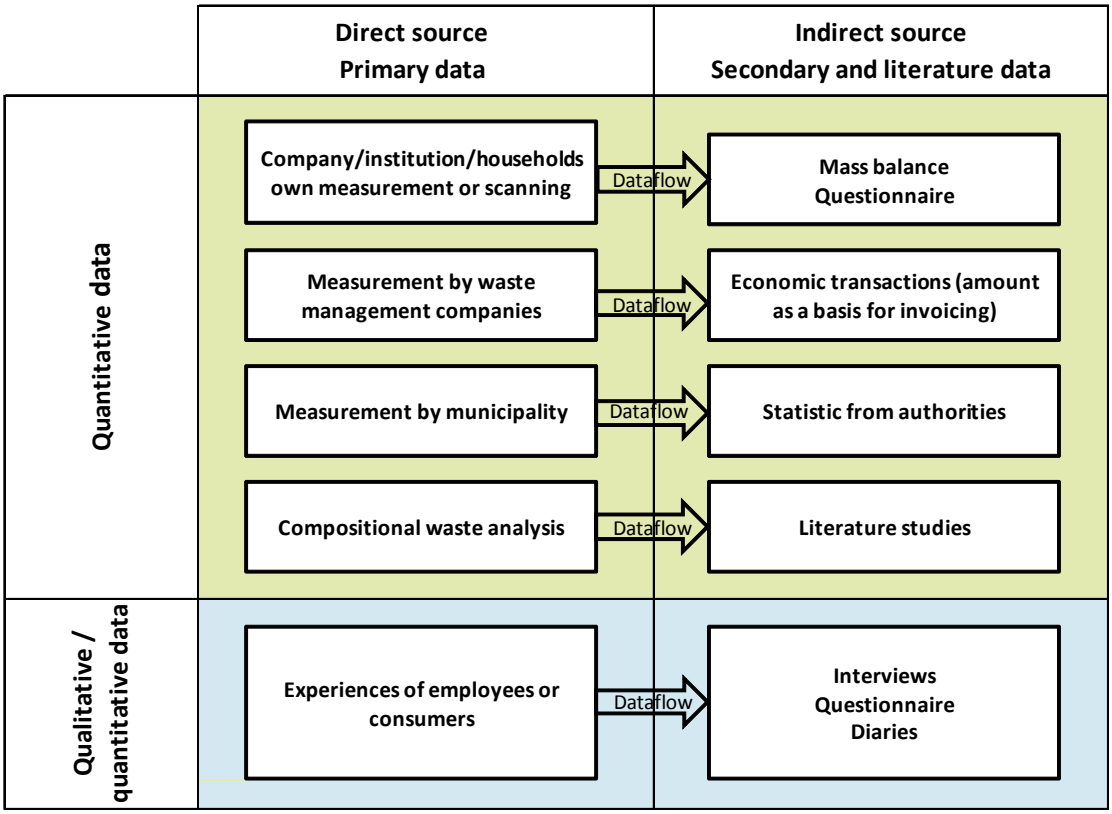

Figure 1 Methods and sources of data for food waste

As an example, a company`s own measurement of data is a direct source, but making this data available in a study requires some kind of data collection method. The data can be collected as a part of a questionnaire, or data from production (raw material input and produced amount) can be used in a mass balance to calculate food waste.

This chapter provides a quantitative characterisation of the studies, according to data originality, methodological approach, time scale, geographic area and waste categories. The studies were selected for each step in the supply chain as explained earlier. The numbers of studies are shown in percentage of the total number and in brackets behind the actual number of studies for each alternative.

4.1 Data originality

For data originality, one can use either primary or secondary/literature data (see Table 4). On average, the percentage of studies using primary data was quite balanced, but there is some variation throughout the steps in the supply chain. "Production" had a lower share of studies using primary data, which may indicate that there are fewer studies on a unit level where it is possible to make measurements. On the other hand "retail and market" had a high share of studies using primary data with conversely fewer studies using secondary data. For some steps in the supply chain the number of studies overcomes the total numbers of studies, since some of them have both primary and secondary data.

Table 4 Data originality in percentage (actual numbers in brackets) of the number of relevant studies

	Primary data	Secondary data or literature data
Production	45 % (18)	60 % (24)
Farm Staples	0 % (0)	100 % (3)
Processing	52 % (11)	57 % (12)
Wholesale and logistics	50 % (7)	50 % (7)
Retail and market	88 % (2)	13 % (4)
Redistribution	75 % (3)	25 % (1)
Food service	58 % (15)	50 % (13)
Households	50 % (13)	58 % (15)
Weighted average	*54 % (81)*	*51 % (77)*

4.2 Methodological approach

The methodological approach used can be based on mass data, economic data, surveys, combination of mass data and surveys or other approaches, see table 5. On average, most studies used mass data (59 %), but for "retail and markets" and "redistribution" the proportion was significantly lower. For "retail and market" economic data (19 %) and interviews/surveys (50 %) are used more often than in other steps of the supply chain. Some of the studies (19 %) used combined methods or other methods than the ones mentioned in the table. It is emphasized that the average does not provide a complete picture, but is included to provide an overview of approaches, and for the number of studies there can be some double counting since some studies are represented in more than one step of the supply chain.

Table 5 Methodological approach in percentage (actual numbers in brackets) of the number of relevant studies

	Mass data	Economic data	Surveys	Combinations or other approaches
Production	73 % (29)	3 % (1)	5 % (2)	20 % (8)
Farm Staples	100 % (3)	0 % (0)	0 % (0)	0 % (0)
Processing	71 % (15)	0 % (0)	5 % (1)	24 % (5)
Wholesale and logistics	43 % (6)	14 % (2)	29 % (4)	14 % (2)
Retail and market	25 % (4)	19 % (3)	50 % (8)	6 % (1)
Redistribution	25 % (1)	0 % (0)	25 % (1)	50 % (2)
Food service	62 % (16)	4 %(1)	12 % (3)	23 % (6)
Households	54 % (14)	0 % (0)	23 % (6)	15 % (4)
Weighted average	*59 % (88)*	*5 % (7)*	*17 % (25)*	*19 % (28)*

4.3 Time scale

Time aspect in this context includes whether the registrations are conducted over a shorter period (only counted once) or a longer period (same type of measurements made repetitive). The time scale for a food waste study can be repetitive, which means that it is longer than one year, in order to make it possible to measure and compare food waste over time. In Table 6, most of the studies had a time scale of one year or shorter (75%) and the proportion of studies conducted for more than one year was 25 % on average. It is important to mention again that some studies are represented in more than one step of the supply chain.

Table 6 Time scale in percentage (actual numbers in brackets) of the number of relevant studies

	Several years	One year or shorter
Production	31% (11)	69 % (25)
Farm Staples	33 % (1)	67 % (2)
Processing	30 % (6)	70 % (15)
Wholesale and logistics	23 % (3)	77 % (11)
Retail and market	17 % (2)	83 % (14)
Redistribution	0 % (0)	100 % (4)
Food service	13 % (1)	88 % (24)
Households	17 % (2)	83 % (18)
Weighted average	*25 % (26)*	75 % (113)

4.4 Geographic area

The majority of the studies cover a national level of a sector or a step in the food chain representing one of the countries in EU 27, see Table 7. These studies have either used national statistics or extrapolated data from waste composition analysis, weighing or other semi-quantitative methods.

A limited number of studies are available at the EU-level, except for "retail and market" and "redistribution". Studies from countries from other continents is represented in

"production", "retail and markets", "food service" and "households", covering on average 14 % of the studies reviewed. The global level is represented in 9 % of the studies, in total 14 studies, but some of them cover more than one step in the supply chain, and are therefore counted more than once.

Table 7 Geographic area covered in percentage (actual numbers in brackets) of the number of relevant studies

	National	EU	Nordic	Countries from other continents	Global
Production	55 % (22)	3 % (1)	0 % (0)	25 %(10)	18 % (7)
Farm Staples	33 % (1)	33 % (1)	0 % (0)	0 % (0)	33 % (1)
Processing	76 % (16)	14 % (3)	0 % (0)	0 %(0)	10 %(2)
Wholesale and logistics	64 % (9)	21 % (3)	7 % (1)	0 %(0)	0 %(0)
Retail and market	81 % 13)	0 %(0)	6 % (1)	13 % (2)	0 %(0)
Redistribution	75 % (3)	0 %(0)	0 %(0)	0 % (0)	25 %(1)
Food service	81 % (21)	4 % (1)	4 % (1)	12 % (3)	0 %(0)
Households	54 % (14)	12 % (3)	0 %(0)	23 % (6)	12 % (3)
Weighted average	*67 % (99)*	*8 % (12)*	*2 % (3)*	*14 % (21)*	*9 % (14)*

4.5 Waste categories

Food waste can be categorised into different product/commodity groups according to product, edibility or avoidability. For characterisation of the food waste the level of refined data decreases throughout the supply chain, see Table 8. In production 70 % of the studies specified the waste categories in product or product group, but at the household level, the corresponding figure was only 27 %. This reflects of course the fact that the composition of the food waste becomes more heterogeneous in the later parts of the supply chain. On the other hand the waste categories edible/ non edible are used in an average of 19 % of the studies. Also total food waste was used as a category, but often in combination with either products/products groups or edible/non edible waste categories. This is the reason why the sum of the percentages becomes more than 100 %.

Table 8 Waste categories covered in percentage (actual numbers in brackets) of the number of relevant studies.

	Product or product groups	Edible/non edible	Total food waste
Production	70 % (28)	5 % (2)	30 % (12)
Farm Staples	67 % (2)	33 % (1)	33 % (1)
Processing	57 % (12)	19 % (4)	43 % (9)
Wholesale and logistics	50 % (7)	36 % (5)	36 % (5)
Retail and market	69 % (11)	31 % (5)	25 % (4)
Redistribution	50 % (2)	0 % (0)	50 % (2)
Food service	38 % (10)	12 % (3)	54 % (14)
Households	27 % (7)	35 % (9)	73 % (19)
Weighted average	53 % (79)	19 % (29)	44 % (66)

When a study reports only on total food waste it is usually based on secondary data which are indirectly collected. When data are collected by direct weighing, it seems that

data at a product level is a common classification and the possibility of obtaining detailed data is exploited. This also applies when quantitative data are collected by interviews and diaries.

4.6 Extrapolation

Often the results from a study are based on data from a smaller sample and data are extrapolated to obtain results covering a larger area or group. When conducting a study the sampling method is important for reliable results. The sampling should be statistically representative for a geographic area (rural, urban), group of people (inhabitant, employees and pupils) or economy (turnover, market share or company structure). Examples for applied methods are further described under each method.

5 Description of methods

This chapter contains a description of all the methods described in the selected principal studies. At the end of each section the views and experience about the method, including pros and cons and possible data gaps are summarised.

5.1 Direct measurement and scanning

In practice there are two ways to measure food waste directly: i.e. weighing or volume measuring. Measuring of the volume is a method that is rarely used and no studies in this review describe this method. Weighing is therefore a fundamental method used in all quantifying of food waste. Weighing may be used as a stand-alone method or for use with another system approach ex waste composition analysis.

A study from Sweden shows examples of food waste from food service, by measuring losses from kitchens in two schools and two restaurants (Engström & Carlsson-Kanyama, 2004, ID 53). All losses were recorded, except for beverages. The losses were divided into five different origins: storage, preparation, serving, leftovers and plate waste. For storage losses, the kitchen staff recorded during two weeks every item from the pantry, fridge or freezer that was thrown away. All other types of losses during two days in each institution were weighed. All losses were divided into product groups as meat/fish, potatoes, rice/pasta and vegetables.

To measure the volume and composition of food waste in the Finnish food chain, weighing of food waste was conducted for food service (Silvennoinen et al., 2012, ID 265/173). The amount, type and origin of avoidable food waste was investigated in 72 restaurants, including schools, day care centres, hospitals, work place canteens, restaurants and fast food outlets. Restaurant chefs and workers kept a diary and weighed the food produced and wasted in a one week period. For weighing and sorting, the food waste was divided into three categories in accordance with its origins: kitchen waste, service waste, and leftovers. In addition the food waste was divided into two categories so that the edible waste was separated from inedible waste.

In catering companies in the Netherlands was food waste determined by weighing food that was left in the counters for selling at the end of the serving period; such analysis was conducted for two weeks at 200 catering locations from the top 8 Dutch catering companies (Soethoudt, 2012, ID 102). The purpose of the study was to quantify food waste in the Dutch catering (school, business, governmental) sector and identify potential improvement measures.

Scanning is used in retail and market to register the value or mass of waste flows. This method is used for measuring food waste in retail in Norway and Sweden (Hanssen & Schakenda, 2010/2011, ID 184/185; Eriksson, 2012, ID 251), using data from scanning of food that are being wasted combined with data on annual turnover for each product group. Food that was sorted out and discarded was recorded as part of a daily routine, and the products are considered unsellable if they have passed their best-before or use-by date or quality was too bad. Products from the deli, meat, dairy and cheese departments are recorded directly with a mobile scanner connected to the company

database and then discarded. Waste due to poor quality at delivery is financially reimbursed by the supplier if the member of staff indicates whether the waste is charged to the supermarket, the main supplier or other suppliers.

In a report from the United States Department of Agriculture, estimates for food loss were applied to adjust some of the assumptions used in constructing "Loss-Adjusted Food Availability Data" to see how they affected per capita estimates of the food available for consumption (Buzby et al., 2009, ID 5). For each store in the sample, supplier data were paired with point-of-sale data to identify food loss percentages for each covered commodity. The waste category used in the report is per capita food loss estimates for different product groups (fruit and vegetable, meat, poultry and seafood).

The three studies mentioned above (Buzby et al., 2009, ID 5; Hanssen & Schakenda, 2010/2011, ID 184/185; Eriksson, 2012, ID 251), base their work on quantitative measures of waste from a sample of shops or warehouses from the sector, covering different time periods and with different degrees of detail. The most comprehensive studies are probably the surveys of retail shops in Norway and Sweden carried out by Hanssen & Schakenda (2010, 2011, ID 184/185) and Eriksson (2012, ID 251), where all products being wasted over a year from 30 retail shops in Norway and 6 in Sweden have been scanned and registered in data bases. For pre-packed products this is easily done, whereas products that are sold without primary packaging (e.g. loose fruits and vegetables) have to be weighed when registered in the system. To get data for real food waste it was compensated for products that was not really wasted, but instead used in deli departments or own canteens or redistributed to charity organisations (Hanssen & Schakenda 2010, ID 184). It is also necessary to focus specifically on pre-store rejection of products which are not approved by the shop managers, and which are either returned to the supplier or eventually sold by other shops, to get a total overview and avoid double counting (Eriksson 2012, ID 251).

Views and experience about the method

Direct measurement (weighing) has been mostly applied at company or household level since it requires a good overview of product flow. "Company level", used in this context, also includes, for instance, institutions. Company level can be found at most steps in the supply chain; processing of farm staples, processing, wholesale and logistics, retail and food service. For processing the company data are used to present precise waste figures for individual companies. Different companies may have very different waste percentages in their production lines, even though they produce the same type of product. Therefore, company specific data are a key factor to develop preventative measures to reduce waste within a company.

The pros for the measuring method is that primary data are collected directly from relevant companies which can ensure that the data are fully relevant to the study and help improve consistency. However, primary data collection is costly and time-intensive. Further, caution must be taken to find representative companies and a large number of measuring points are necessary, if the results are intended to be extrapolated to more aggregated levels (company level, sector level). Data may not always be as reliable or accurate as required. It is also important to upscale the company data properly. The amount of waste as well as the root causes for waste varies between different companies and in order to know how to prevent waste in a certain context it is necessary to perform weighing at an adequate level of detail. A general problem is that many companies and supermarkets will not disclose their data on food waste.

Scanning is only suited for parts in the supply chain in which the product is packed, since the bar code is used for this purpose. That means that scanning is a method which can be suitable for wholesale, logistics and retail and to some extent also for redistribution and processing (packaged and stored products). Data from scanning are mainly second hand data, since they use the scanning to trace back already logged information. Thus, the scanning method is highly dependent on the set up of systems available. The reliability of the method is depending on how much conversion is needed to get waste data from scanning, often economic data are registered, which has to be transformed to mass data to quantify amount of food waste. If the traceability system is based on bar codes, it will in turn facilitate a system for registration of food waste.

5.2 Waste composition analysis

Waste composition analysis are studies where the components of the different fractions of the food waste are weighed and analysed with regards to types of food product or edible/inedible fractions etc. Waste composition analysis can be used for measuring food waste for short or longer times and for different levels of detail. 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. The results can be used to extrapolate by calculating the total amount via the total waste amounts of the studied sector.

This method is used in steps in the supply chain where food waste is collected, and usually where the number of waste 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.

To measure food waste in the food service sector, a composition analysis of mixed waste from 138 businesses across the UK was conducted together with site audits (WRAP, 2011a, ID 51). Before the analysis was initiated, information from literature was gathered for input in development of a sampling strategy. The aim of the study was to develop and test methods for quantifying mixed waste sent for disposal by businesses, using the UK hospitality sector as a test and to provide estimates of the amount of each type of waste found in the mixed waste that would normally go to landfill.

Waste composition analysis in households is a common method for estimating food waste. A waste composition study was carried out by WRAP (WRAP, 2011f, ID 42) to estimate the amount of food waste collected by local authorities from homes in the UK. The waste composition analyses were used in combination with total waste amounts to find the proportional amount of food waste. Data quality may not always be as reliable or accurate as required. WRAP has produced a description of the potential uncertainties associated with data for household food waste (underreporting, seasonal variation etc.) (WRAP, 2013). A waste composition study was also used together with a survey for measuring household waste in Norway (Hanssen & Schakenda, 2010/2011, ID 184/185).

In Austria, a composition analysis was carried out to analyse specific problems of the methodology (Lebersorger & Schneider, 2011, ID 147): sample size and representativeness, classification of food waste, food packaging and sieving of waste.

When conducting a waste composition study in households, the sample size is important, but not much discussed (Lebersorger & Schneider, 2011, ID 147). The sample size can be calculated by using a formula recommended by the Austrian standard for conducting waste composition analysis. In the case study carried out, the sampling took place at household level, meaning that collections were selected randomly and analysed separately (Lebersorger & Schneider, 2011, ID 147). The samples were split into an urban and a rural sample, since prior studies revealed significant differences between food waste composition from urban and rural areas.

The classification of food waste is discussed in Lebersorger & Schneider, 2011 (ID 147). The classification can be made via several different principles:

- Avoidability (avoidable and non-avoidable food waste)
- Recycling (possibly recyclable, i.e. suitable for home composting or bio waste collection, and non-recyclable food waste)
- Life cycle stage (preparation residues, leftovers, whole unused food, partly consumed food)
- Preparation state (fresh, ready to consume, cooked or prepared at home, tinned)
- Food category (fruit, vegetables, drinks, bakery, meat and fish, and others)

Some of the categories can be difficult to use: recycling depends on the local collection system, food categories are difficult to assign when classifying food from different ingredients (meals). Also the state of degradation can make the identification difficult (Lebersorger & Schneider, 2011, ID 147).

Views and experience about the method

One advantage of this method is that it provides a direct weighing of food waste, and is used where the number of waste points is large. Therefore one of the important issues is to find the right sample size and representative samples. National guidelines on how to conduct waste composition analysis according to sample size, representativeness and classification of food waste are available in some countries. Extrapolation of data from waste composition analysis needs to be done with care and literature data on waste amounts can validate data and give additional information.

This method is applied for "food service" and "households", thus showing that this method is the most relevant for these steps. It has, however, also been applied to other sectors (for example in supermarkets), but there is very little published work on this.

5.3 Mass- and energy balances

Mass balance is a way of structuring data from other sources, and not a data source in itself. It can be used to calculate food waste by using data for raw material input and produced amount. A mass balance is a method which 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.

The FAO study "Global food losses and food waste – extent, causes and prevention" estimates edible food losses and waste for the whole supply chain on a global level, based on a mass balance approach (FAO, 2011, ID 1). In the FAO study, statistics on the available volumes of food in different regions of the world and steps of the supply chain were collected from the FAO Stat's Food Balance Sheets, which presents the patterns of a countries food supply and utilisation during a specific period of time. Aggregated Food Balance Sheets for different regions of the world were collected. Data on average waste

percentages for different commodity groups, different steps of the supply chain and different regions of the world were collected from an extensive literature review. The quantifications of losses and waste were performed by a "top-down" approach, quantifying the masses of losses and waste from the total food supply presented in the Food Balance Sheets. Detailed descriptions of the calculation models for each commodity group and for each step of the food supply chain are found in SIK 2011 (Gustavsson et al., 2013, ID 328), a report describing the methodology of the FAO study. Performing quantifications on aggregated commodity groups and regions of the world presents great challenges in e.g. finding representative data on food waste and food loss percentages. Data are also lacking to a great extent for certain parts of the world, foremost developing countries, especially regarding waste percentages. Therefore, a number of assumptions and estimations had to be made.

In a country-specific study, mass balances have been used for quantifying food losses in Switzerland (Beretta et al., 2013, ID 279). Twenty-two food categories were modelled separately in a mass and energy flow analysis, based on data from 31 companies within the food value chain, as well as from public institutions, associations, and from the literature. In the food service industry, data from other studies were considered.

Also for the processing industry, where quantification of food waste is based on statistics from national authorities and waste management organisations, a mass balance of input and output flows in the UK Food and Drink Processing Industry has been calculated (C-tech Innovation, 2004, ID 27). The total number of people employed in the UK as a whole was used to calculate data from England and Wales proportional to a national level in the UK.

Views and experience about the method

A disadvantage of the method is that the calculation of food waste based on mass- or energy balances is demanding in having available representative and good quality data on food waste percentages per tonne of food produced or tonne of total waste generated. Assumptions and estimations have to be made if representative data are not available, which may decrease the quality of the results. If a mass balance is used to identify food waste for a production unit, such as in a dairy, it can be a major challenge especially because of the complexity between the water balance and food waste. In some cases, a proportion of the food waste might follow with the water flow out. It is therefore necessary to be extra careful when setting up assumptions and estimates.

Data gaps were apparent for certain parts of the world, particularly developing countries. When using mass balances as in FAO report a lot of assumptions are made based on literature data and extrapolation of these. Even though the statistics is updated, the base for calculation will be old and thus the results will still lean on old data and suffer from old estimates. To summarize the experiences it can be difficult to get detailed and updated information from using mass- and energy balances.

5.4 Questionnaires

A questionnaire is a formal, structured way to collect quantitative and/or qualitative data from respondents. In this context it is used as a structured way of getting figures for food waste and in some cases also additional information. A questionnaire is used when a contact person is available and is common methodology used for data collection from companies and institutions.

Questionnaires have been used in food processing companies to collect quantitative data in Norway (Hanssen & Schakenda, 2010/2011, ID 184/185). In the food service sector, questionnaires have been used in combination with public statistics and available reports in a Nordic pilot study (Marthinsen et al., 2012, ID 8/123). The questionnaires were sent to kitchen personnel in the four Nordic countries in both private and public organisations and covered certification, environmental targets and waste sorting information.

In the Swiss study (Beretta et al., 2013, ID 279) data are provided from 31 companies/public institutions within the food value chain. Data were compiled by using questionnaires combined with following up contact by email or telephone, on-site visits, and in 2 cases own weighing.

Views and experience about the method
The method is often used where a company contact person is available to facilitate the collection of questionnaires. It is often used in larger surveys covering several companies in the food supply chain, i.e. in processing, wholesale, retail and food service. A challenge of using the method may be that it is difficult to get a large enough proportion of responses and it imposes a major responsibility on the contact person to provide reliable data. This issue is particularly important when it comes to confidentiality, which may be a part of the explanation of a low response rate. This matter needs to be taken into account when using questionnaires.

Good question design is very important and it is not always straight forward to ensure that questions are clear and unambiguous. Also, the figures from questionnaires may not always be completely accurate, due to misunderstandings regarding what should be collected, i.e. the definition and classification of food waste and particularly in relation to outputs which are utilised as animal feed. There might be different views among the people performing the study and the people filling in the survey forms, and it can also be a gap between what people report and what they actually do. This may in turn give rise to data which are underestimated. This disadvantage can be reduced or even avoided by using specific flow charts in order to make sure that the terms are clearly understood by everyone. Clear definition of the different flows could be a good suggestion for improving the methodology.

5.5 Food waste diary

Food waste diary 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) and reasons for disposal. A food waste diary is implemented by one or more of the household`s member who weighs the food waste and makes notes on quantity, type and cause.

Surveys and diaries have been used in addition to waste data from municipal companies (WRAP 2009a, ID 161; WRAP, 2011b, ID 163) to estimate food waste from households. Diaries have been used in a Finnish study (Katajajuuri et al., 2012, ID 169/242) where 380 households weighed and recorded each day their avoidable food waste at disposal during a two-week research period. In another study which measured liquid food waste, a kitchen diary over a 1 week period was used (WRAP, 2009b, ID 108).

Views and experience about the method
The method is mainly used in households and to some extent in food service. Using diaries to collect data from households is both time-consuming and costly. It is a major

responsibility on the individuals who are writing the diary to provide precise and reliable data. People can be more focused on food waste and food waste reduction in a sampling period, and might thus not provide representative data from the collection period. Another reason is that the topic is sensitive and the people can be ashamed to waste so much food and report according to the ”social norm” habit which can lead to underestimation too. This issue needs to be taken into account when using diary for collecting data on food waste.

Since the method demands a lot of resources, it can only be used for short sampling periods and for selected areas with small sample sizes. On the other hand it can give more insight and valuable data with a great level of detail from day to day, waste categories and the reason for disposal of the waste. The reason for wasting food is not always the same as the root cause, for example a food product can have expired the use by date, but the root caused can be by buying too much due to lack of planning.

5.6 Interviews

Interviews can give best estimates or expert judgment of how much food is wasted within a given part of the food chain. An interview can also be conducted by using a questionnaire face-to-face or over the telephone. Interviews are often used in combination with other approaches in order fill data gaps or to have both a quantitative (amount) and qualitative (how often is food wasted, who is wasting food etc.) estimation of food waste.

In a study written by WRAP whose aim was to develop detailed UK ‘resource maps’ for fresh meat (WRAP, 2011d, ID 104), government statistics were used in combination with interviews of key personnel in companies. The project’s aim was to generate data on product waste, packaging waste, water and greenhouse gas emissions. The interviews were based on structured questionnaires that were developed and tailored to collect data from different parts of the supply chain, for example rendering, abattoirs, cutting plants and retailers, covering over 150 companies in the UK. Each interview enabled the project team to quantify waste for a specific company, determine its views on the causes of waste, and record how resource efficiency was approached within the business.

A study focusing on retail and wholesale supply chains for fish used interviews with key personnel for collecting data about processing waste. The data was extrapolated to give industry-wide estimates based on survey data (WRAP, 2011e, ID 105).

To estimate manufacturing waste in processing, a survey was carried out by the Food and Drink Federation (FDF) in UK (WRAP, 2010, ID 70). The results from the FDF survey were scaled up to produce results for the UK as a whole, based on the fact that the survey results represent 23 % of industry turnover. The key assumption that underlies the method used here is that the sample of manufacturers from the survey is representative of the food and drink manufacturing industry as a whole. Importantly, the sample encompasses the largest manufacturers, which previous reports suggest produce the majority of the waste. However, they may not be truly representative of the industry as a whole. In particular, the FDF sample represent manufacturers that might be more committed to waste reduction and thus have lower levels of waste compared to the industry as a whole. In addition, many of the large alcohol manufacturers in the UK are not members of the FDF. Therefore the final total estimates may be an under-estimate of waste in food and drink manufacturing in the UK (WRAP, 2010, ID 70).

Interviews were used to find the causes of wastage of beverages at Coca-Cola Sweden (Gunnerfalk, 2006, ID 111). A number of persons working within or close to the production facilities were interviewed. Those people had deep insight in how the production line was run and therefore also had the best knowledge about causes for the variations leading to wastage. By using interviews the employees unique and significant expertise could be collected and structured providing a source of first first-hand information. The different causes for variations were grouped together to see how they were connected to each other and to identify groups of causes. The findings from the interviews were combined with data on the costs of each cause of waste.

Interviews with key personnel have been used in retail and market companies to characterise food waste (Kranert et al., 2012, ID 2). To identify the root causes of food waste arising in the supplier/retailer interface, managers from food production, wholesaling and retailing were interviewed (Mena et al., 2011, ID 24).

Interviews were also used in redistribution to characterise and quantify food waste donated. Interviews with key personnel are often used in combination with estimates based on direct quantification and characterisation of food waste (Alexander and Smaje, 2008, ID 31).

Telephone interviews with individual businesses in the food service sector have been used in combination with other methods (composition analysis of mixed waste, literature review to gather information to help in the development of a sampling strategy, collation of waste data from hospitality chains) to measure food waste (WRAP, 2011a, ID 51). The aim of the study is to develop and test methods for quantifying mixed waste in the hospitality sector.

Observation interviews were applied in a study about food waste from households (Mejdahl et. al., 2011, ID 107). This type of interview gives an anthropological, qualitative knowledge and understanding of practices, such as behavioural patterns, causes, motivations and experiences, but does not lead to conclusions that could be applied to the entire population. Thus, the anthropological knowledge is not representative, but seeks to understand and explain a topic, phenomenon or object in depth. Observation interviews are carried out to get more insight about factors involved in how consumers manage, understand, feel and act in relation to food waste. The observation interviews last for approximately 5 hours and included close connections with participants when they went grocery shopping, cooked and ate food in their own homes. Interviews have been in-depth and semi-structured. Such more open interviews and behavioural studies have the strength to capture unexpected perspectives and angles on subjects because the participants increasingly engage in dialogue rather than respond briefly to the already defined questions. Investigation may therefore discover aspects that were not anticipated or assumed in advance.

Views and experience about the method

The strength of the method is that when working on issue for prevention of food waste the interviews can give a two-way communication and identify causes for waste.
The issue of secrecy in the food processing industry and retail sector regarding waste data might be a challenge when using a survey based on interviews or questionnaires. Waste data are sometimes regarded as sensitive information since they provide an insight into a company and its material flows and efficiency. It is not surprising that some companies do not want to expose their waste data because they may not be representative of the actual food waste occurring in the industry.

Another risk of using interviews is that the response rate might be low, and the companies/people who actually participate in such activities are those which already work well with food waste issues and therefore feel comfortable with participating in a survey since they have "nothing to hide". This might produce results which are unrepresentative for the industry as a whole.

5.7 Calculation methods from statistical data (top-down)

Statistical data from authorities or waste management companies represents a data source, which can be used as a top-down method for calculation of food waste.

Statistics are used in many of the selected studies, both as the main data source and in combination with other data sources. Statistics are mainly used in studies on a national or global level and for a sector or for the whole supply chain. The report "Preparatory study on food waste across EU27" (Monier et al., 2010, ID 87) uses official EUROSTAT statistics (complemented by national studies) for quantifying food waste in different steps of the food supply chain for different member states of the European Union. Waste volumes were extrapolated from EUROSTAT for the relevant European Waste stat Categories (EWC-stat) as well as relevant NACE branches (NACE - Nomenclature statistique des activités économiques dans la Communauté européenne), for each member state respectively. Results from national studies were used to complement the steps of the supply chain for which EUROSTAT did not present data.

In the FAO report "Global food losses and food waste – extent, causes and prevention" on global food losses and waste (FAO, 2011, ID 1) the physical mass of lost and wasted edible food was quantified using available data from FAO Stat's Food Balance Sheets, which presents the patterns of a country's food supply and utilization during a specific period of time, together with data on average waste percentages for different commodity groups, different steps of the supply chain and different regions of the world. Where data was not available, assumptions and estimates were made based on comparable data.

Quantification of overall food waste from food production in Switzerland (Almeida, 2011, ID 98) was based on data from the Swiss Farmers Union, the FAO and the Fifth Swiss Nutrition Report. By assessing food availability and waste in terms of energy content (using the unit of kcal/person/day), the study limited its analysis of total food waste to edible food waste only. The study also includes is a case-study analyzing bread waste, primarily based on firm surveys, through a value chain analysis.

Quantification for food waste from industrial processing is based on statistics from national authorities and waste management organisations, to make a mass balance of input and output flows in the UK food and Drink Processing Industry (C-tech Innovation, 2004, ID 27).

In a WRAP study (WRAP, 2011d, ID 104) government statistics have been widely used for context and to provide totals, both to check data from the survey and to provide a sampling framework. The project's aim was to develop detailed UK 'resource maps' for fresh meat that show how each animal is utilised, in order to generate data on product waste, packaging waste, water usage and greenhouse gas emissions. Extrapolation was

used to adjust data from samples onto a national basis to provide estimates for the meat processing industry as a whole. All the data and insights provided in the report were collected during the structured interviews, and thus their accuracy and completeness depends on the honesty and openness of participants.

Similar to the study above, a resource map for fish was created by using the following sources of existing data (WRAP, 2011e, ID 105): landings data by species are based on the Marine and Fisheries Agency (MFA); import & export data derived from Sea fish trade reports, which provide information on a species-specific basis; volumes of retail sales have been obtained from electronic point of sale (epos) information and volumes of sales in the food service sector based on consumer diaries of food eaten outside the home. Data for both retail and food service were sourced by marketing research. A combined estimation of the volumes of waste and co-products derived from processing was extrapolated from figures provided by telephone survey and interviews with the participating companies. This approach generated figures for the average percentage waste and co-products quoted by different types of processor. These average figures were then applied to the total volume of raw material entering processing. This estimate of the total volume of material entering processing is derived by using the following formula:

Raw material entering processing = Total supply chain inputs – direct exports

This accounts for the fact that, for some species, a significant proportion of material entering the supply chain undergoes minimal processing within the UK before being exported. However, this figure assumes that all remaining material passes through processing rather than wholesale. For most species this is a reasonable assumption, as the quantity of material that passes through wholesale is relatively low.

Food waste at the distribution, retail and consumer level (Venkat et al., 2012, ID 40) is estimated by using the loss-adjusted food availability data series from the US Department of Agriculture (USDA ERS, 2009). The data series provides annual per-capita food production, waste and availability data for a full spectrum of food commodities in the United States, adjusted for food spoilage and other losses to closely approximate per-capita intake.

Statistics at municipality level were used for estimating food waste in the food service sector (Jensen et al., 2011, ID 20). The SMED (Svenska Miljö Emissions Data) consortium contacted the municipalities that weigh collected food waste separately for each company and school to get the annual amount of food waste. A correlation factor including number of employees was tested to calculate the amount of food waste. It is assumed that there is a correlation between the amount of food waste and the number of employees of restaurants and grocery stores and for schools for a correlation between waste and the number of servings i.e. number of students.

Amount of food waste = waste factor * scaling factor

In Sweden the waste factor is calculated as the share of separated food waste per employee and the scaling factor is the number of employees in restaurants or grocery stores. For school kitchens the waste factor is calculated as amount of food waste separated per pupil and the scaling factor is number of pupils in Sweden. A regression analysis shows a good correlation between food waste and pupil, but a much lower correlation between food waste and employee. For restaurants, the type of restaurant

seems to be of importance. This can be addressed by distinguishing among restaurants categories (catering, fast food and dining restaurant).

Statistics on a number of companies, employees and turnover for the hospitality sector were used to give an overview of the structure of the sector (Marthinsen et al., 2012, ID 8/123). To find a best estimate on food waste in the Nordic countries, available statistics at national level (Miljøstyrelsen (DK), SSB (N), Naturvårdsverket (S), European level (EUROSTAT) and also other literature were used. The review of the statistics showed great variations in the estimates, due to differences in what was included in the total food waste and what was included in the hospitality sector.

Views and experience about the method

The most important issue when using statistics is the data quality. The data quality depends on the methods used for collecting the data in the national or regional databases. Statistics based on aggregated company data may have been collected by using different methods and various data sources. The statistics are usually based on different data sources (estimates, obligation to report, transformation of units necessary (e.g. volume in mass, money value in mass etc.).Therefore the national databases might not be transparent and have the sufficient data quality. The data can also be based on assumptions. These elements affect also the comparability of the different statistical data.

In some cases, national or regional databases, as well as large-scale studies, can provide large amounts of data collected in a similar way, which will increase comparability. But this might not be the case always. In Eurostat waste statistics the required data are the same, but all countries are free to choose their own method for collecting data, which makes it difficult to compare waste figures. This issue is discussed in the review of the Eurostat waste statistics and harmonised indicators for food waste are suggested (Hanssen et al., 2013).

Furthermore, data may generally be of good quality, with problems or missing data highlighted explicitly. However, large-scale studies may have a higher level of granularity, not taking into account certain distinguishing factors between different stages of the supply chain. Small-scale studies which are more focused on a specific region, product or supply chain stage, may be useful for obtaining what can be assumed to be relatively good quality data (if the study is reliable). However, the data in secondary literature may not always necessarily correspond to the boundaries and objectives of the study being conducted, and units, methodologies, etc. may vary significantly from one secondary source to another.

Data gaps have been identified in statistics on food waste from national authorities, especially with respect to the wholesale and logistics sector. Often this data source is only used for collecting general data for further processing of food waste data coming from another source. It seems that data on an (inter)national basis could be helpful for studies aiming to provide a general view on food waste but not for detailed investigations.

5.8 Combination of methods

Studies often use combinations of different methods. A literature review can be used in the beginning of a project to define the state of the art and identify gaps. Economic or

production statistics can be used to get an overview of the sector and total turnover as a starting point for identifying sample units, whether surveys, questionnaires or waste audits are used. If the whole value chain should be covered it is most likely the different methods will be necessary.

A study combined company data from a national waste survey with complementary data such as industry data and certain classes of outputs from PRODCOM (PRODucts of the European COMmunity) reports where wastes have some product value (C-Tech Innovation, 2004, ID 27). The primary source of information on waste were national statistics from "the Environment Agency (EA) 1999 National Waste Production Survey for England and Wales", which collected data from a sample of over 20 000 businesses across the full range of industrial and commercial activities, including Food and Drink manufacturing. The report presents the mass balance of the United Kingdom food and drink processing industry, sector by sector, which means that both inputs, outputs and wastes from the UK food and drink processing industry have been mapped using various data sources.

Most of the studies reviewed in this report used more than one method to achieve a larger picture of amounts, reasons, composition and other relevant information on food waste. Using a combination of different methods gives the possibility to validate and add additional information from elsewhere to see if the assumptions or calculations are correct.

6 Discussion of review

The main objective of this report is to characterise the most relevant food waste studies and clarify whether the reviewed studies provide the required information in relation to prevent, measure and compare food waste data among countries and over time. This includes providing an overview of different methods that have been applied and data sources available for each step of the supply chain, as well as identifying data gaps.

This review has been carried out based on the criteria for the methodological framework, listed in the criteria document included in D1.1 (Gustavsson et al., 2013). Some of the criteria state that methods should be applicable for all relevant *steps* in the supply chain and for all relevant *levels* (regional, national or single company). The results of this review show that there is no single method that is applicable to all steps in the supply chain providing relevant and reliable data on food waste. To fulfil the criteria it is therefore necessary to combine several methods.

A limited number of studies have been conducted at an EU or global level, then using statistics as the data source. One of the conclusions from the review of the Eurostat waste statistics is that no common and harmonized methodologies for gathering of food waste data are prescribed, which makes it difficult to compare results from different studies and across national statistics. This literature review has shown that there are methods available which can deliver relevant and reliable data at a national level for each sector, but there is a need to harmonize those methods. To make statistics at EU level more comparable and transparent, it is necessary to describe methods and how to extrapolate these data sets for each sector to national figures for the entire value chain.

Other criteria describe that the method should provide consistent and reliable *indicators* for monitoring food waste generation in order to be able to *compare* food waste on a consistent basis among parts of the value chain, different types of food, *changes over time* as well as among nations taking into account variation and differences in *consumption, population, production and import/export of food*. As for the criteria discussed in the section above, the existing official statistics do rarely provide the requested data quality as well as assumptions that will allow comparison of food waste between nations. Nevertheless there are good methods available on a national level, but they may not be consistent neither among steps in the supply chain nor among countries.

The criteria document also states that the method should be *manageable* for the food supply chain actors and *motivate* waste reduction. A general experience is that one cannot manage what is not measured; indicating that getting specific and detailed figures for food waste from own facilities is an important basis for food waste reduction (see Møller et al. 2011). It will however always be a balance between how much effort companies have to put into waste reduction audits, and the need for indicators that can document trends in food waste reductions. The majority of the studies are based on a *bottom-up* approach. Weighing, scanning, waste composition analysis and survey using questionnaires, diaries or interviews are all bottom-up approaches. Mass balances and statistics are in most cases based on a *top-down* approach, but can also be used as a bottom-up approach, depending on which level it applies to. Regarding the use of the methods it is important to distinguish between measurement methods and prevention

interventions. In order to prevent food waste, the most motivating approach is probably to involve employees in defining the root causes of food waste, develop ideas to prevent and reduce waste and follow indicators documenting trends in reductions (municipal, company or household). It is however not within the scope of this report to develop measures and regulations that can induce changes in wasting behaviour as this is to be considered in later FUSIONS reports specifically addressing policy recommendations.

Methods for analysing a big population need a sampling strategy to get representative data that allow extrapolation of data to a higher system level, by using either turnover, number of employees or other relevant factors. Looking at each step individually, the choice of the methods to be applied is related to the number of actors and the consolidation and structure of the food supply chain. At the production step the number of farmers is very high and also in the processing step there are a number of actors, since the majority of the food and drink industry are small and medium-sized enterprises (SME). For the wholesale and retail steps the number of actors is lower, i.e. many units belongs to large organisations which sometimes make it easier to get information from a large number of units. Finally at the household step there are obviously a large number of units. Because of the wide variation in the number of actors along the supply chain it is necessary to adapt the quantifying method to each step. This implies that it is also necessary to adapt the extrapolation methods on the data for each step in the supply chain to obtain good and reliable data for the entire supply chain.

The waste categories used in the reviewed studies reflect the point in the supply chain the analysis is performed as food waste tends to become more heterogeneous as it progresses through the supply chain. In production and processing the amount of food waste is mainly characterised as products or product groups, whereas for food service and households it is characterised as edible/non edible food waste or total food waste. In Eurostat the relevant categories are food waste from animal or vegetal food preparation and products; household waste and street cleaning waste. This means that the statistics are not separated in subcategories. There is a need to get a harmonised method especially at food service and household level.

One of the goals of the review is to indicate areas in which *methodological gaps* and *data gaps* exist. Data gaps have been identified in statistics on food waste from national authorities. That is especially with respect to certain parts of the world, particularly developing countries. But also liquid food going down the drain and fractions going to feed are food waste which only to a small extent have been identified. Data gaps have also been found for the step "wholesale and logistics". Often statistics are only used for calculate food waste data for a specific area so it seems that data on a national basis could be helpful to provide a general view on food waste but not for detailed investigations.

7 Conclusion

The studies provided a lot of information and gave a state-of-the-art, but there is no single method, which is applicable to all steps in the supply chain and covers the criteria. To fulfil the criteria it is therefore necessary to combine methods.

The following methods have been identified in this report and are listed below in terms of what the methods are focused on:

Measuring
- Direct measurement (weight or volume)
- Scanning
- Composition waste analysis
- Diary

Data gathering
- Calculation methods from statistical data
- Interview and survey
- Mass- and energy balance
- Questionnaire

Prevention of food waste
- Perform weighing at an adequate level of detail
- Involve employees in defining the root causes of food waste and develop ideas to prevent and reduce waste
- Follow indicators documenting trends in reductions (municipal, company or household)

The methods are applicable for the specific steps in the supply chain:

- Production step: Direct measurement and calculation method from statistical data are the most widely used method
- Processing / processing of farm staples: the methods used are direct measurement, scanning and questionnaires. Scanning is only suited for those parts in the supply chain in which the product is packed and has a bar code. This means that scanning can only be used at processing steps after the packaging line, e. g. storage. Scanning can therefore not fulfil the aim of quantifying food waste for the processing step alone, but in combination with weighing it can be a good additional method.
- Wholesale and logistics/ retail and market /redistribution: Methods for quantifying food waste is usually scanning, weighing or questionnaires. Scanning is a very precise method, with a high level of detail according to waste categories and geographic area. If the products do not have a bar code, weighing is the best available method
- Food service and households: Waste composition analysis or diaries represent the methods, which are usually used for these steps in the supply chain. Both of the two methods use sampling to get representative data, and for household it is common to extrapolate the data to a national level, based on assumptions

The review identified the following methodological gaps and data gaps:

- Statistics on food waste from national authorities, particularly from developing countries and for the step "wholesale and logistics"
- Liquid food going down the drain and fractions going to feed are food waste which only to a small extent have been identified
- Data gaps have also been found in the different steps in the supply chain. A lot of data is available, but this varies widely through the supply chain. The quality of these data sets are also varying because the purpose of the data collection affects the extent and definitions, which in turn will affect the data

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Annex 1 Extensive literature review – main findings

Procedure for extensive literature review

To facilitate the literature review a FUSIONS data base was set up by the partners in WP1, including over 300 classified articles and reports. The reports were classified with regard to authors, year of publication, the food product(s) studied, the supply chain step(s) studied and whether the study provided important definitional choices and/or methodological approaches.

The extensive literature review described here in annex 1 was carried out in February 2013. The literature review for each step in the supply chain was carried out by different FUSIONS partners, see table 9. The criteria that were used to select the *considered studies* were "those providing important methodological approaches", but also studies classified as "key references for FUSIONS". Some of the considered studies were not found *relevant* after all and were not included in the review. Analysis of the literature was made with regards to type of methodological approaches used to characterize and quantify food waste and the main purpose of the study. Summary reports of the literature review were written for each step in the supply chain (see below).

Table 9 Overview of the FUSIONS partners who carried out each literature review; (the responsible partner is underlined)

Part of supply chain	FUSIONS partners – extensive literature review
Production	UNIBO, INRA, MTT
Processing of farm staples	UNIBO, IFR
Processing	SIK, IFR
Wholesale and logistics	BOKU, OSTFOLD
Retail	OSTFOLD, BOKU
Markets	UNIBO, BOKU
Redistribution	BOKU, OSTFOLD
Food services	OSTFOLD, DLO
Households	WRAP, BOKU

Production step, plant production

More than 150 reports and articles were evaluated to find information about food loss in primary production. 89 were classified to cover aspects for food loss in primary production. However, most of the reports reviewed possible reasons for food loss in

primary production on the base of literature without any quantification or description of methodology used. 28 studies concerning plant production are evaluated in this report.

The studies reported were mainly from time period 2002-2013. The review is concentrated on European studies (50% of studies evaluated) but also some data from US and Canada as well as global reports were included. Many of the reports from developing countries also discussed the reasons of food loss in primary production of developed countries. Furthermore, a lot of food is imported to EU from developing countries so the global aspects should not be ignored.

Most of the studies evaluated (18) aim to measure food waste and find solutions to reduce food waste in the entire food chain. Only a few of the studies focus on primary production. In them food waste is mainly measured from individual cases and solutions are based upon these cases. The few global studies focus more on the whole food chain. The global reports give general recommendations for reducing food waste.
In evaluating different methodological approaches some generalization had to be done because some of the methods were overlapping like direct quantification and data collection. The main used methods were literary review (8), direct quantification (7), and the use of different available data (7). As mentioned, it is complicated to define the food loss in primary production, and thus it is demanding to quantify the pre-harvest food loss. Surveys and interviews seemed to give more information from the reasons behind the food loss. On the other hand experimental studies e.g. from the effect of harvesting time or handling of the fruits and vegetables on the post-harvest ripening and keeping could provide valuable qualitative and quantitative information for avoiding food loss.

In the present literature the food loss of fruits and vegetables was well presented in a number of studies whereas the primary production of crops was only discussed in general and the specific studies of their quantification was missing. However, this also reflects the quantity of food loss of different agricultural sectors. According to the results it could be summarized that in plant production the most problematic products are the fruits and berries which are sensitive to weather and are easily spoiled pre- and post-harvest. For cereals the average loss is 1-3%, and potatoes slightly more, (left in the field 1-15 %, mean5%). Indicators most often used in these reports are percentages of yield loss or food produced. In some of the studies the financial costs of loss were calculated. In primary production the waste is mainly classified according to the products or product groups.

It is complicated to define the edible food waste in primary production. It is common that the unharvested food is left to enrich the soil, and food harvested but not meeting the quality standard demands may be used as animal feed. Are fruits or vegetables that are spoiled pre-harvest due to plant pathogens still edible food waste? Should the amount of grain that is never harvested due to heavy rain or early winter be quantified? In many studies where the food loss throughout the whole food chain was reported the quantification of primary production was ignored because the methodology used in later steps of food chain were not usable in primary production. Statistical data from agricultural production has been used in some of the reports.

Table 10 Summary for "production, plant production" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
General and practical knowledge and information about the current and potential waste treatment methods	Literature search on disposal and utilization of solid vegetable, fruit and other organic waste. Describes the various waste treatment methodologies.	About 50% of the weight of citrus fruits is discarded as waste peel, membrane, juice vesicles and seeds when these fruits are squeezed (Crandall *et al.*, 1983).	Arvanitoyannis I.S. (2008) Waste Management For The Food Industries (ID 13)
Improved data on both of resulting in total and separately collected food waste throughout the chain	Surveys among user groups (phone calls)	No amount from farming	Jensen C., Stenmarck Å., Sörme L., Dunsö O. (2011) Matavfall i Sverige 2010 - från jord till bord (Food waste in Sweden 2010 - from field to fork) (ID 20)
Survey of fruits and vegetables sector in Croatia and Serbia and give recommendations for its improvement	Literature	Western Balkan Countries annual postharvest loss of fruits and vegetables is as high as 30-40% Postharvest loss of nectarines in Croatia caused by fungal pathogens can be as high as 80%.	Jemrić T., Ilić Z. (2012) Present state of cold chain and postharvest loss of fruits and vegetables in Croatia and Serbia (ID 22)
Investigate storage potential of onion cultivars during different storage conditions on long-time storage	Direct quantification	Prolonged storage in ambient conditions caused a significant decrease in marketable bulbs, up to 40–60%, and an increase of the amount of sprouted bulbs, up to 30–50%.	Z. Ilić, L. Milenković, M. Djurovka, R. Trajković (2009) The effect of long-term storage on quality attributes and storage potential of different onion cultivars (ID 286)
To examine the effect of hot water dips on superficial scald development and the concentration of α-farnesene and	Direct quantification	Fruit maturity was an important factor determining the response of fruit to heat and occurrence of superficial	Jemrić, T., Lurie, S., Đumija, Lj., Pavičić, N., Hribar, J. (2006). Heat Treatment and

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
its oxidative products of Granny Smith		scald.	Harvest Date interact in their effect on Superficial Scald of 'Granny Smith' Apple. (ID 287)
Reduce levels of fresh potato waste	Consumer survey, storage trials, packaging trials and in-store training and communications activity	The amount of waste in the supply chain is low compared to that arising from households and generally the level of waste at any particular stage in the supply chain is around 1% to 3%.	WRAP & J. French-Brooks. Reducing supply chain and consumer potato waste (ID 30)
Analyse the potential of decreasing the environmental impact of five food items through the development of packaging that reduces food losses in the consumer phase	Comparative Analysis	Packagings that reduce food waste can be an important tool to reduce the total environmental impact	Williams H., Wikström F. (2011) Environmental impact of packaging and food losses in a life cycle perspective: a comparative analysis of five food items (ID 44)
Mapping of food waste through the distribution and consumption stages of the product life cycle and the use of water footprinting to assess the impact on water resources	Data collection	Reducing waste was an effective way of reducing impacts on freshwater resources relative to other water efficiency measures	Ridoutt B.G., Juliano P., Sanguansri P., Sellahewa J. (2010) The water footprint of food waste: case study of fresh mango in Australia (ID 75)
Grains/ post harvest losses reduction	Policy-oriented research, lessons from past interventions. ad-hoc measurements	According to estimates provided by the African Postharvest Losses Information System, physical grain losses (prior to processing) can range from 10 to 20 percent.	World Bank (2011) MISSING FOOD: The Case of Postharvest Grain Losses in Sub- Saharan Africa (ID 80)
To examine the inefficiencies in the U.S. food system from the farm to the fork to the landfill	Overview for each stage of the food supply chain using the best available data	Grain products 2%, fruits & vegetables 20%	Gunders, Dana Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
			to Fork to Landfill (ID 93)
To report the economic impact of tomato production value losses due to Salmonella outbreak	Economic impacts estimated with input-output models	Total production values losses in the state are $13.9 million. Losses average $11,778 per acre for tomatoes not sold.	Flanders, Archie. Economic impact of Georgia tomato production value losses due to the U.S. Salmonella outbreak (ID 288)
To quantify the level of loss and waste of fruit and vegetables before they reach consumers, through the retail and wholesale supply chain	In-depth and semi-structured interviews. Quantitative and qualitative analysis of fresh produce waste and associated packaging waste arising through the retail and wholesale supply chains	Food loss generally between 1% and 3%.	Terry L.A., Mena C., Williams A., Jenney N., Whitehead P. (2011) Fruit and vegetable resource maps (ID 95)
Increase the knowledge on greenhouse gas emissions from Swedish production of some major types of fresh fruits and vegetables	Data have been collected from two to seven growers	There was a large variation in wastage between different crops, from 0 to 40 % of the harvested amount.	Davis, J. et al (2011). Emissions of greenhouse gases from production of horticultural products (ID 138)
Preventing waste in the fruit and vegetable supply chain	Data from suppliers**	Yield loss 1-21% UK only* Central range loss 3-5%** Between 5% and 25% of a fruit or vegetable crop might not get through the supply chain to retail customers – although the percentage will vary for different products and in different seasons	Wrap (2012) *Sector guidance note - fresh produce* (ID 164)
This literature review deals with food waste, its sources, reasons and	Literature	Kantor 1997: Farm and post-harvest Preharvest losses due to severe	Kantor (1997) Estimating and addressing Americas food

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
reduction options. The main focus is on avoidable food waste.		weather, disease and predation (e.g. 7 % average U.S. planted acreage was not harvested 1994-96)	losses (ID 85)
Waste minimization throughout the entire food system in order to identify primary causes of waste.	Statistic Canada	Field waste 9%	Gooch, M., Felfel, A. and Marenick, N. (2010) *Food waste in Canada Value Chain* (ID 180)
Estimation of Postharvest Losses, developed and developing countries	Literature	In the United States, the losses of fresh fruits and vegetables are estimated to range from 2% to 23%, depending on the commodity, with an overall average of about 12% losses between production and consumption sites (Cappellini and Ceponis, 1984; Harvey, 1978)	A.A. Kader (1997) Increasing Food Availability by Reducing Postharvest Losses of Fresh Produce (ID 289)
This article presents parts of the results of a research that reviews the existing literature on food losses and produces food loss estimates for primary production. Flanders	The methodology used combines statistical data from government and private data sources with expert estimates and own calculations. After the definition of the boundaries of the production systems, we identified possible types of losses.	Main losses in agriculture are losses during harvest and storage of cereals 2-3%, potatoes 5-15% and sugar beets 3-4%. Losses in horticulture (0-30%) manifest at both production and auction level.	Roels, K., Vangeyte, J., Linden, V. and Gijseghem, D. 2010. Food losses in primary production: the case of Flanders (ID 290)
Survey in July 2012 to gain a better sense of the volumes of fruits and vegetables lost and the drivers behind those losses	Small set of in-person interviews, conducted with growers and produce packers in Central California	Pre-Harvest 1-5% In situ Shrink 0-2% Packing Culls 2-30%	NRDS, USA (2012) *Left-Out: An Investication of Fruit and Vegetable Losses on the Farm* (ID 284)

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
	in July 2012		
Evalution of Olive damage during harvest in USA	Stereo video analysis based on two high-speed cameras operating during the harvesting process were used to identify the sources of fruit damage due to canopy-harvester interaction	Fruit mechanically harvested had 35% more bruising and three times as many fruit with broken skin as that of hand-harvested fruit. The main source of fruit damaged in the canopy was the strike-impact of fruit by harvester rods	Castro-Garcia, S., Uriel, A. R., Gliever, J.C., Smith, D., Burns, J.K., Krueger, H.W., Ferguson, L. and Glozer, K.(2006) *Video Evaluation of Table Olive Damage during Harvest with a Canopy Shaker.* (ID 285)
In this report, by-products are defined as the fractions produced in processing of potatoes	Information was collected from scientific articles, patent databases and web pages	Left in the field 1-15 % (mean 5%). The amount of the by-products varies depending on the process. For example, in peeling processes the amount of by-products can be as much as 50–100 % compared to that of the peeled product	Ahokas et al. (2012***)*** *Utilization of Byproducts from Potatoes and Vegetables for Value-Added Products (ID 282)*
The project to reduce waste, to allow growers, packer and retailer to benefit from improved efficiencies	The five-year project started in 2008 with 30 growers	About half the losses occurred directly on farm. Some 6 per cent were failed at field level before or soon after lifting began, due to size, quality or bruising problems. Defects removed during initial grading, including damaged, mis-shapen, scabbed and green tubers, resulted in a further 12 per cent loss while storage waste accounted for 5 per cent. During packing, size grading took out 2 per cent while post-washing defects removed 22 percent.	Potato Council (2012) War on waste in the potato supply chain (ID 281)

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
This report sums up the existing knowledge about "the hidden food waste" from field to shop to industrial kitchens	partly based on two analyses by Aarhus University (DJF) and the Copenhagen University (FØI) for the Ministry of Agriculture, Fisheries and Food in relation to this project, and partly on the basis of a comprehensive and a very constructive dialogue with key players in the food industry.	The largest waste of **fruits and vegetables** is found in the retail industry (DKK 428m), followed by the primary production (DKK 311m).	Denmark's green think tank, CONCITO (2011) *The Hidden Food Waste Mapping and Recommendations* (ID 291)
Food waste in primary production in Denmark	Food waste status in Holland, England and Sweden Food waste data in Denmark	Wastage of fruits and vegetables can be 30-40%	Mogensen, L., Hermansen, J. and Trydeman Knudsen, M. (2011***)*** Madspild i fødevareproduktionen fra primærproduktion til detailed (ID 292)
The study highlights the losses occurring along the entire food chain, and makes assessments of their magnitude. Further, it identifies causes of food losses and possible ways of preventing them	Available data, mass flow models, assumptions	Food losses in industrialized countries are as high as in developing countries, but in developing countries more than 40% of the food losses occur at post harvest and processing levels, while in industrialized countries, more than 40% of the food losses occur at retail and consumer levels. Food waste at consumer level in industrialized countries (222 million ton) is almost as high as the total net food	Gustavsson Jenny, Cederberg Christel, Sonesson Ulf, (2011) Global Food Losses and Food Waste (ID 1)

The main purpose of the study	Type of methodological approaches used to characterize and quantify food waste	The main finding in the studies; i.e. amount of food waste indicators used	References
		production in sub-Saharan Africa (230 million ton).	
This review considers priorities in relation to global food waste reduction, particularly in the context of food supply chains operating within the rapidly developing BRIC (Brazil, Russia, India and China) and transition countries. It considers the challenges in measuring progress towards global food waste reduction, and why knowledge on food losses within BRIC and transition countries represents such a significant gap in the evidence required to monitor global food waste reductions.	Literary review, interviews, expert workshops	At the grower stage, the highest priority areas included the development of locally appropriate information systems and education, technology and knowledge transfer and access to improved post-harvest infrastructure.	Julia Parfitt, Mark Barthel, (2011) Global food waste reduction: priorities for a world in Transition (ID 48)
The paper gives option for improving food security after the 2008 food crisis.	Literature review, expert workshop	Food losses in the field (between planting and harvesting) could be as high as 20–40% of the potential harvest in developing countries due to pests and pathogens	A UNEP RAPID RESPONSE ASSESSMENT, Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. G., Kaltenborn, B. P. (2009), The Environmental Food Crisis (ID 118)

Production, animal production

14 papers have been analyzed with respect to quantification of food losses and waste at primary production. All papers are classified as addressing primary production stage in the FUSIONS database excel sheet.

Purpose of the studies:

Most of these papers described the relevance of food losses and waste based on literature review and identified reduction measures (Brook Lyndhurst 2010 (ID 35); Gunders 2012 (ID 93); Hodges, Buzby, Bennett 2011 (ID 191); Parfitt, Barthel 2011(ID 48)). Some papers estimated the potential of loss and waste reduction with respect to food availability (Almeida, 2011 (ID 98); Beretta 2012 (ID 146); Smil 2004 (ID 86)) or with respect to environmental impacts and resource consumption (Kummu et al. 2012 (ID 23); Hospido, Sonesson 2005 (ID 129); Weidema et al 2008 (ID 116), although Weidema et al. 2008 did not specifically address loss and waste reduction at agricultural production, only at household stage).

Papers which study losses in animal production systems (Malena et al. 2007 (ID 134); Petracci et al. 2006, ID 132), McConnel et al. 2008 (ID 135); Ritz et al. 2005(ID 131) justify the relevance of research by animal welfare and by financial losses for farmers.

Original data gathering versus literature review:

Only a few papers did quantify amounts of losses or waste at primary production (preslaughter mortality) and generated original data (Malena et al. 2007; Petracci et al. (2006).

Other papers (McConnel et al. 2008; Ritz et al. 2005) did not quantify losses of animals, but identified and weighted factors leading to mortality of animals with the purpose to contribute to improved practices in animal production and preslaughter operations. One paper (Hospido, Sonesson 2005) compared the environmental impact of dairy herds which are subject to current level of losses of milk due to mastitis with dairy herds under improved management. For these papers which did not generate new data, national statistics and experts' personal advice were provided.

In papers where results are based on agricultural loss estimates from literature, papers refer to

- Gustavsson et al (2011)'s loss estimates (Kummu et al. 2012; Almeida 2011)
- interviews with producing/processing units, federations and branch statistics (Beretta 2012).

Time periods:

Gustavsson et al. (2011) study seems to have launched a research dynamic on the link between food losses/waste and food availability, food security, inefficiencies in food systems and associated resource use. Kummu et al.2012 , Almeida 2011, Beretta 2012, Gunders 2012 are all quite fresh papers (Smil 2004 is the exception). Those papers on the specific stage of animal production systems date back to the years 2005-2008.

Methodological approach:

As mentioned, few papers collected original data on agricultural losses or waste. Beretta (2012) conducted interviews with 31 food producing/processing/trading companies of which 5 agricultural producers. Almeida (2011), in addition to food availability approach, conducted a case-study on bread and gathered original data (to be confirmed). Otherwise, literature (Gustavsson et al. 2011), branch and national statistics, data from trade and producer associations are used.

Type of indicators used:

- TJ/year and % on a weight basis (Beretta 2012)
- Kcal/cap/day (Almeida, 2011; Kummu et al. 2012; Smil 2004)
- Percent on number of animals

Classification of the measured amount of food waste:
Beretta (2012) distinguished between *avoidable food waste*, *possibly avoidable food waste* and *unavoidable food waste*.
Distinction between edible/inedible or between end-of-life or waste management options has not been performed.
Losses (or waste) defined at primary production stage partly concern entire animals and whole plants which as farm staples/commodities become edible only after primary processing (slaughtering and cutting, milling, pressing etc.).
As highlighted in Report T1.1, the topic of losses at primary production stage has so far been studied with respect to financial losses or missing marketing opportunities for farmers, but not with respect to food security and resource efficiency in food systems. This can explain why literature on losses at primary production stage usually does not distinguish losses of edible and inedible parts of a food product. Another reason may be that in many cases farm commodities are not yet a food product as they require processing/refining to enter the way to become food products (slaughtering and cutting, milling, etc.).
Pros and cons with using different methodological approaches:
As highlighted, results in many papers are based on loss estimates from the literature (for example Gustavsson et al. (2011)'s pioneering study which provides loss estimates along the food supply chain at a regional level worldwide). Yet, data on regional levels may not take sufficient account of inter-country variability[2]. Neither do national data take into account the variety of production systems nor local specificities (weather conditions, etc.) which are related to agricultural losses.
When loss estimates are based on interviews, the question is to what extent the sample is representative of the product's market. We can assume that the purpose of a study partly determines the choice of methodology (whereas in many studies data availability seems to guide the choice of methodological approach).

Processing of farm staples

The three studies from 'Processing of farm staples' according to the narrower definition are as follows:
Gustavsson et al / FAO (2011), *Global Food Losses and Food Waste - extent, causes and prevention*. Rome, Food and Agriculture Organization of the United Nations (ID 1).
Agro-Food Waste Minimisation and Reduction Network (AWARENET) (2004) *Handbook for the Prevention and Minimisation of Waste and Valorisation of By-Products in European Agro-Food Industries.* EC: Depósito legal BI-223-04.(ID 76)
C-Tech Innovation (2004) *United Kingdom Food and Drink Processing Mass Balance.* C-Tech Innovation Ltd., Chester, UK (ID 27)

Processing

Company specific/national studies:
Carrying out studies in which primary data is collected is of course a very good alternative for collecting robust qualitative data. By collecting primary data, one can make sure that the data is representative for the study objective and that the study boundaries etc. correlate to the project aim and goal.
Studies in which primary data is collected are however costly, both regarding time and money and for data to be representative for a food product or sector in general, a large number of measuring points is necessary. In addition, estimated data is sometimes provided by companies with no indication of the likely accuracy of the provided data.
National/regional statistics:
Statistical databases often represent a large number of data from the same data source; something which makes comparisons between countries and regions possible.
As for all data sources, there might be inaccuracies in large databases; depending on how accurately the data has been collected/reported from the distributing partners.
Surveys:
A good thing with using a survey is that it is a relatively cost efficient method which reaches a large number of participants in a wide geographical area, e.g. by using email or telephone.
The issue with secrecy in the food processing industry, regarding waste data, is a risk with using the survey methodology (17). Waste data is sometimes regarded as sensitive information by many food producers and manufacturers since it gives an insight to the company and its raw material flows. It is highly likely that certain companies will not want to expose their waste data figures and surveys which collect secondhand data therefore risk collecting data which is not representative for the actual food waste occurring in the industry.
Another downside with using the survey methodology is that there might be misunderstandings regarding which raw material flows that (in the study) are classified as food waste. There might be different views among the people conducting the study and the people filling in the survey forms.
Literature studies:
Literature study is also a cost efficient method which can produce broad results with regards to time and geography depending on the availability of previous studies.
Literature reviews do however rely on secondary data; and therefore the quality of the results from a literature study is dependent on the quality of previous studies.
Most studies define food waste from the basis of environmental aspects as food waste represents a waste of resources and an environmental impact. Economic drivers are also important to stakeholders within the food supply chain – one study (89) includes

products not sold at full price as a food loss although, from a nutritional or environmental perspective, this would not be considered a loss.
When undertaking food waste monitoring studies comparing several studies over several years, it is of course important to use the same methodology with the same system boundaries so that the results can be compared. This is sometimes made difficult due to advances in methodology.
If the purpose is related to *waste prevention* and food security there is a need to quantify food waste in edible and non-edible forms to help identify different mitigation routes and approaches.
If the purpose of the study is instead to focus on *waste management*, separating edible and non-edible food waste is not necessarily important; however it is more necessary to include all waste flows since all waste flows are relevant for waste management.
Also, due to various *legal requirements* (which can change over time) there is a need to keep track of the entire mass balance including all waste flows, regardless of edible, non-edible, co-products and by-products etc…(17).
Limitations to different methodological approaches
Some statistics include packaging material from food products.
Some statistics do not separate edible and non-edible food parts, e.g. EUROSTAT. The EUROSTAT data may include by-products, green wastes and wastes from tobacco in some instances. In addition, the methodologies for collecting and calculating the food waste data submitted to EUROSTAT differs between member states, who are free to choose their own methodology (87).

Some companies regard waste data as confidential; therefore there are sometimes few respondents in waste data surveys (17). Waste from food manufacturing also shows large variations between sub-sectors – it is therefore potentially unreliable to extrapolate company survey data to a national or regional level (68).
Main findings:

- Waste studies from the UK & Northern Europe dominated the findings from the literature review for this food chain sector.
- The most commonly used method was collecting waste data from company specific interviews/questionnaire surveys.
- The broad definition of "waste" from the Waste Framework Directive was commonly used; therefore all types of organic waste were generally collected (including both edible and inedible parts) and sometimes packaging waste was also included.
- The EUROSTAT data may include by-products, green wastes and wastes from tobacco in some instances. In addition, the methodologies for collecting and calculating the food waste data submitted to EUROSTAT differs between member states, who are free to choose their own methodology.
- In those cases where national food waste statistics are quantified for the industrial food processing sector; there is a risk that certain processing waste is ignored (e.g. processing of fish at sea) since it may fall out of the geographical scope of the study.
-

Table 11 Summary for "processing" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
The handbook aims to prevent / minimize food waste through the dissemination of best practices and also to quantify food processing waste.	*Food waste calculated as a fraction of total production volumes (obtained from EUROSTAT and other sources).*	*An overall figure of around 222 million tonnes / year of generated food waste and by-products was obtained for 18 European countries. This figure was sub-divided by country and food industry sector.*	*Agro-Food Waste Minimisation and Reduction Network (AWARENET), (2004). Handbook for the Prevention and Minimisation of Waste and Valorisation of By-Products in European Agro-Food Industries. EC: Depósito legal BI-223-04. (ID 76)*
The study firstly estimates total food losses and wastes in the Swiss Food Supply Chain using both available kilocalories and estimated calorific intake. The second assessment is a case-study analyzing bread wastage, primarily based on firm surveys, through a value chain analysis.	*Calorific value of waste estimated by taking waste as difference between farm production data (national study) and nutritional intake data (national survey). Loss rates along the food supply chain taken from Gustavsson et al (2011).*	*Approximately one-third of the total edible food production in Switzerland is either lost or wasted along the food supply chain.* *For the bread case study, it was estimated that 37% by weight of all bread (or ingredients) were wasted from farm to fork.*	*Almeida, J. (2011). M.Sc. thesis - Food losses and food waste: a quantitative assessment for Switzerland. Universität Basel, Switzerland.*(ID 98)
The study aims to provide information on the amount and geographical distribution of food and packaging waste arising across member sites along with how this waste is being managed.	*Questionnaire to industry members requesting actual tonnages of food, packaging & mixed wastes together with disposal route. Not extrapolated to whole industry due to differences between sub-sectors. Returns were received equating to*	*481,000 tonnes of waste were produced in 2009 by the 149 responding sites - only 43,000 tonnes (9%) was sent to landfill, with 435,000 tonnes (90.3%) recovered or recycled in some manner. In both the reporting years,*	*Bartlett, C. (2010). Mapping waste in the Food and Drink Industry. Defra / Food and Drink Federation, London, UK.(ID 68)*

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	approx. 20% of the UK food processing industry.	*FDF members produced over 340,000 tonnes of by-products and surpluses, with a significant tonnage (approx 98% of total] going to animal feed.*	
To model mass and energy flows in the food system (from primary production to consumption to waste management) with focus on food waste for 22 food categories; detailed analysis of food supply chains and of types of typical industries and recommendation elaboration.	*Data based on both approaches : a micro approach (data from 43 food companies across the supply chains of the selected food categories) and a macro approach (data from branch and national statistics); data gaps filled by literature review.*	*The important role of households in generating/reducing food waste is confirmed; about one third of edible calories is lost in total along the supply chain.*	Beretta C. (2012) M.Sc. thesis - Analyse der Nahrungsmittelflüsse in der Schweiz und Ermittlung von Strategien, Nahrungsmittelverluste zu vermindern und die Nahrungsmittelverwertung zu optimieren. ETH, Zurich, Switzerland (ID 146)
The study details resource flows within the EU food industry and provides recommendations for improved resource efficiency.	*Data from BIO Intelligence Service (2010) Preparatory study on food waste across EU27 based on 2006 EUROSTAT data and other available recent data.*	*Of the estimated total 89 Mt EU food waste, households produce the largest fraction (37Mt; 42 % of the total), representing 179 kg per capita, with evidence showing that over 60% of it may be avoidable. Significant industrial (30 Mt; 39%), wholesale/retail (4 Mt; 5%) and food service sector (12 Mt; 14%) food waste also occurs.*	BIO Intelligence Service (2012). Assessment of resource efficiency in the food cycle. Draft report for European Commission (ID 124)
The study quantifies total food waste	*EUROSTAT data was used, for the*	*Annual food waste generation in*	BIOIS (2010). Preparatory

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
*(edible and non-edible) in the **EU27 countries**.*	*NACE branch ""Manufacture of food products; beverages and tobacco".*	*EU27 is **89 Mton or 179 kg per capita, reference year 2006**. Manufacturing food waste was estimated at almost **35 Mt per year** in the EU27 (**70kg per capita**), although a lack of clarity over the definition of food waste (particularly as distinct from by-products) among MS makes this estimate fragile.*	study on food waste across EU 27. Paris, BIO Intelligent Services (ID 87)
The study aims to provide a detailed mass balance of input and output flows within the UK Food and Drink Progressing industry.	*Quantification based on statistics from national authorities and waste management organisations.*	*The UK Food & Drink Processing Industry produces external wastes of approx. 5.8 million tonnes p.a. of which 1.8 MT is biodegradable waste. In addition, approx. 3.4MT of biodegradable waste is re-utilised in the food chain.*	C-Tech Innovation, (2004) United Kingdom Food and Drink Processing Mass Balance. C-Tech Innovation Ltd., Chester, UK (ID 27)
Estimate the global food losses and waste and point out main differences between low and medium/high income countries.	*Data based on macro approach; data derived from national and/or regional Food Balance Sheets which map out the national/regional food supplies for different commodity groups. One utilization element of the FBS refer to processed commodities.*	*1, 3 billion tonnes of food waste each year (avoidable food losses and waste), reference year 2007*	FAO (2011). Global Food Losses and Food Waste - extent, causes and prevention. Rome, Food and Agriculture Organization of the United Nations (ID 1)
The goal of the study is to collect data on avoidable food waste for the Norwegian food supply chain in order to follow up amounts on a sector basis	*Data based on micro approach. Data has been collected through a questionnaire from 11 manufacturing businesses in*	*Data represents 2009 (for the 2010 study) and 2010 (for the 2011 study). Main results are presented as %/tonnes waste in each step of the*	Hanssen, O. J., Schakenda, V. (2010). Nyttbart matavfall i Norge - status og utviklingstrekk 2010. Oslo,

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
and in total between the years 2010-2015.	*Norway. Data is based on tonnage and the waste percentages are calculated based on waste and the production volumes respectively.*	*supply chain (many different results).*	Østfoldforskning. (ID 184)
The goal of the study is to collect data on avoidable food waste for the Norwegian food supply chain in order to follow up amounts on a sector basis and in total between the years 2010-2015.	*Data based on micro approach. Data has been collected through a questionnaire from 11 manufacturing businesses in Norway. Data is based on tonnage and the waste percentages are calculated based on waste and the production volumes respectively.*	*Data represents 2009 (for the 2010 study) and 2010 (for the 2011 study). Main results are presented as %/tonnes waste in each step of the supply chain (many different results).*	Hanssen, O. J., Schakenda, V. (2011). Nyttbart matsvinn i Norge 2011 - Analyser av status og utvikling i matsvinn i Norge 2010-11 – Rapport fra ForMat-prosjektet. ISBN: 82-7520-655-3. Oslo, Østfoldforskning. (ID 185)
The study is focused on retail and wholesale supply chains for fish, and presents resource maps for 17 individual finfish and shellfish species and aims both to characterize and quantify food waste & prevent/minimize food waste.	*Data for processing waste derived from interviews with key personnel and extrapolated to give industry-wide estimate based on survey data.*	*Total volumes of waste and co-products generated within the UK fish processing industry were estimated at 133,100 tonnes per year. However, this figure cannot be robustly sub-divided into wastes and co-products for all species – approx. 105,200 tonnes can be attributed to finfish processing and 27,900 tonnes to shellfish processing. Note: Wastes from processing at sea and discards disposed of at sea are excluded.*	James, R., Archer, M., Henderson, J., Garrett, A. (2011). Resource maps for fish across retail & wholesale supply chains. Waste & Resources Action Programme, Banbury, UK (ID 105)
To generate better data on the production of total food waste in the Swedish supply chain. The purpose is	*Data based on micro (from businesses) surveys scaled up to total Swedish food processing sector*	*171 000 tonnes of food (avoidable and non-avoidable) was produced in the Swedish manufacturing business*	Jensen, C., Stenmarck, Å., Sörme, L., Dunsö, O. (2011). Matavfall 2010 från jord till

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
to be able to use this statistics for following up volumes of food waste in relation to national political target goals.	*based on the number of employees in the food processing sector as a whole.*	*year 2010 (total food waste was 1 010 000 tonnes).*	bord. SMED Rapport Nr 99 2011. Norrköping, Sveriges Meteorologiska och Hydrologiska Institut. (ID 20)
This literature review deals with food waste, its sources, reasons and reduction options. The main focus is on avoidable food waste. The aim of this study was to find out what kind of methods have been used to study food waste in the whole food marketing system and what are the pros and cons of different methods.	*Literature review*	*Results on food waste at household level vary between 17 and over 80 kg per person and year most of the results being between 50 and 80 kg per person and year. According references that were considered most reliable 14 – 20 %, according to some researches even 25%, of purchased food is lost in households.*	*Koivupuro, H.-K., Jalkanen, L., Katajajuuri, J-M., Reinikainen, A., Silvennoinen, K. (2010). Food Waste in the Supply Chain, Literature review. Jokioinen, MTT.(ID 170)*
The study aims to develop a method for quantifying food loss in the food processing industry applicable to Norway and Europe.	*Data (either calculated or estimated) is provided by the individual food manufacturer / processor.*	*Food loss is defined as food not suitable for sale at the full price i.e. price reductions for near expiry date food is treated as a form of waste management. Key data on food loss is related to both amount and value. This study excludes non-edible food loss e.g. peels, bones, etc.*	*Møller, H., Vold, M., Schakenda, V., Hanssen, O.J. (2012). Mapping method for food loss in the food processing industry – summary report. NOFIMA. (ID 89)*
In October 2007, FDF (Food and Drink Federation) in UK set a number of environmental target goals, among others to send zero food and packaging waste to landfill from 2015. This study	*Questionnaires were sent to all FDF members to survey their food and packaging waste arisings at food production sites in the UK for 2006, along with disposal and recovery*	*Total food waste arising unmixed was 604,883 tonnes (it includes any inedible fraction, possibly also some materials considered as by-products utilized for e.g. in animal feed or*	*Morley, N., Bartlett, C. (2008). Mapping waste in the food industry, Defra and the Food and Drink Federation. (ID 245)*

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
gives a snapshot of the level of food and packaging waste arising across FDF member companies in the UK.	*routes for each type of waste created. Food waste (604 883 tonnes); packaging waste (94 900 tonnes); mixed food and packaging waste (134 819 tonnes).*	*human food, but not food waste mixed with packaging waste. Mixed food & packaging waste was 134,819 tonnes. Reference year 2006.*	
The overall aim is to understand the current situation with regard to industrial organic waste management at the regional and national level. The projects objectives were to quantify organic waste arising within the North East England; evaluate its form and composition; establish the disposal methods employed and ascertain barriers to its recovery, reference year.	*A survey questionnaire and covering letter was drawn up after consultation with the project partners. Information included in the questionnaire was the firm's contact details, number of employees, the number of employees, type of organic waste produced, the quantity of organic waste disposed of annually, waste disposal methods and barriers to organic waste recovery.*	*In total, 68 businesses were surveyed and the main results for these companies were; food waste segregated 83 722 tonnes and non-segregated 1 370 tonnes. To extrapolate the results for the whole North East region "waste/company" statistics were produced for each company size and multiplied with the number of companies of each size in the region, main results; food waste 184 473 tonnes.The waste data covered 2006-2007.*	*Organics_Report (2009). Organics report - a study of organic waste arising from the food and drink manufacturing sector within North East England, The environment agency; the National Industrial Symbiosis Programme and RENEW@CPI.(ID 17)*
The aim of this project research was to identify the volume of Finnish food waste, and its distribution among parties involved in the food supply chain. The study specifically targets households, food services, retail sector and the food industry in Finland	*The generation of food waste in the Finnish food industry was studied by collecting information on the amounts of food waste from companies taking part in the Foodspill –research project. In addition, information on the generation of food waste was collected from some other companies of the Finnish food industry, corporate responsibility*	*The results of the project suggest that every year consumers, food services, retailers, and food industry combined waste over 335 to 460 million kg per year of food in Finland, 62–86 kilograms for every Finnish citizen.* *The main result for the processing stage:*	*Silvennoinen, K., Koivupuro, H-K, Katajajuuri, J-M, Jalkanen, L., Reinikainen, A. (2012). Food Waste Volume and Composition in Finnish Food Chain. Jokioinen, MTT.(ID 265/169)*

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	reports of food companies, and other literature. In addition to industrial food processing also the amount of food waste from the production of vegetables in greenhouses was included in the study.	*75 -140 Total m kg/year* *14-26 Per person kg /year*	
The aim of the study is to examine the by-products ("resprodukter") within the bakery industry and to give suggestions on how these can be used and to financially examine the suggestions. Data was collected from the Swedish bakery Lantmännen Axa.	*A large part of the data was collected through interviews and on-site observations.*	*Total volume of by-products 14 900 tonnes, year 2007.*	*Söderlund, M. (2007). Hantering av restprodukter inom bageriverksamhet – fallstudie Pågen AB (examensarbete), Lund University.(ID 109)*
The aim of the study is to examine where in the production line waste occurs and the reasons why. Prevention methods were suggested.	*Waste was measured in the production line (by the Six Sigma methodology) in the bakery (primary data from one bakery, Lantmännen Axa).*	*Data is from three weeks of measurements at Lantmännen Axa in Sweden during 2006.* *The wasted products were defined into different categories; variations in weight, defects and spillage.*	*Svenberg, S., Torgå, K. (2007). Waste analysis - an application of the DMAIC methodology at Lantmännen Axa. Master of Science, Luleå Universitet.(ID 110)*
The project's aim was to develop detailed 'resource maps' for fresh meat that show how each animal is utilised, in order to generate data on product waste, packaging waste, water usage and greenhouse gas emissions.	*Data obtained from telephone interviews and industry / national data sources.*	*The amount of residual material arising from the fresh meat retail supply chain in the UK is in excess of 1.4M tonnes per year, of which 97% is derived from abattoirs and cutting plants, with the remainder from*	*Whitehead, P., Palmer, M., Mena, C., Williams, A., Walsh, C., (2011). Resource maps for fresh meat across retail and wholesale supply chains. Waste & Resources Action Programme, Banbury,*

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
		retailers.	*UK.(ID 104)*
The objectives of this study were to determine: • *waste arisings across the UK food and drink supply chain and link this up with household waste;* • *material composition of the waste;* • *disposal routes for each waste stream;* • *potential resource efficiency saving opportunities;* • *associated financial cost savings; and* • *recommendations for reducing waste and using resources more efficiently within the chain.*	*The estimates for manufacturing waste are based on a survey carried out by the Food and Drink Federation (FDF) in 2006 and scaled up to account for non-FDF members. The results from the FDF survey were scaled up to produce results for UK as a whole based on the fact that the survey results represent 23 % of industry turnover.*	*UK food and drink manufacturing industry produce 2.6 Mton of food waste (avoidable and unavoidable) per year (2006).*	*WRAP (2010). Waste arisings in the supply of food and drink to households in the UK. Banbury, WRAP.(ID 70)*

Wholesale and logistics

The wholesale and logistic sector of the food supply chain is not featured very prominently within the reviewed literature. Although it is mentioned in some research, information on the specific methodologies which were used in this part of the food supply chain is missing or is not relevant for the review in most cases or at the end no relevant data could be found for that part of the chain. This means, if references e.g. conducted an environmental assessment within wholesale and logistics only some energy demand was calculated for storage and transport taken from inventory data base. Thus, wholesale and logistics are considered in the reference but the methodological approach of the reference is not relevant for the review (e.g. Sonigo et al., 2012; WRAP, 2011d; Silvenius et al., 2011). Other references model or discuss the food supply chain with respect to food waste in general and there is no specific information about wholesale and logistics in detail (e.g. Nellemann et al., 2009; Redlingshöfer and Soyeux, 2012).
Due to the limited number of references, some non-European literature was also reviewed and used for this report if relevant, e.g. Mason et al. (2011) from Australia. Others (e.g. Gunders, 2012; Weber and Matthews, 2008) were not included as the main focus was on European literature.

In the FUSIONS database 52 studies were classified as "wholesale and logistics" studies at the beginning of the review. Some of the references were listed twice, e.g. ID 87 is equal to 99 or ID 168 is equal to 93. Unfortunately, the reviewers had no access to some literature (Silvennoinen et al., 2012). Within the 41 studies which were reviewed 2 were in German, 2 in French, 2 in Norwegian, 1 in Swedish and the remaining in English language. The reviewed references also included studies which were not originally ticked as "wholesale and logistics" (e.g. WRAP, 2011a) and vice versa studies were excluded which were wrong classified in a first course (e.g. Glanz, 2008). In addition, in the reference list of this report also other studies are listed which were reviewed with respect to other food supply chain parts and were found to include no information about wholesale and logistics.

In most studies the time period is not mentioned very clear as often a literature review or analysis of statistical data was conducted and in this case the most actual data – sometimes representing different years - were used for calculation or estimation. But it seems that the main focus of the studies affects data origin from the time period 2001 to 2010.

The relevant literature covers studies from UK (WRAP, 2010a; WRAP, 2011a; WRAP, 2011b; WRAP, 2011c), Germany (Kranert et al., 2012), EU (Monier et al., 2010 (ID 87); Barilla, 2012; Weidema et al., 2008), Australia (Mason et al., 2011 (ID 88), Switzerland (Beretta, 2012; Almeida, 2011(ID 98)) and Northern Europe (Sweden, Norway, Denmark, Finland - Stenmarck et al., 2011; Hanssen and Schakenda, 2010; Hanssen and Schakenda, 2011). It has to be mentioned that not all available non-European studies were reviewed due to an agreement of the consortium to focus on European studies.
The main purpose "characterize and quantify food waste for one specific year" applies to Kranert et al. (2012), Barilla 2012, (ID 92), Stenmarck et al. (2011), Beretta 2012 (ID 146), Almeida 2011 (98), WRAP (2010a) and WRAP (2011c). Barilla (2012) and Stenmarck et al. 2011(ID 21) summarise data from some countries in their report while the others focus on one country. The characterization and quantification of food waste is therefore the most relevant purpose of the relevant literature which was reviewed. In

most cases, in addition to the generation of food waste also other issues were mentioned (e.g. causes, disposal paths, environmental issues).

Monier et al. (2010) aimed "regulations and policy development" within their study, WRAP (2011a), WRAP (2011b) as well as Hanssen and Schakenda (2010) and Hanssen and Schakenda (2011) focused on "develop or test of methodologies". Further aims were classified as "others" e.g. Mason et al. 2011 (ID 88) who collated relevant information about food waste data, identified key knowledge holders, assessed quality of available data, studied links between food waste and packaging and looked for key gaps. Also Weidema et al. 2008 (ID 116) were classified as "other" aim as the estimation of environmental impact of products was the main focus of the study.

The most important approach found for characterization and quantification of food waste at wholesale and logistics was method of "estimates based in Interviews with key personal" (Kranert et al., 2012;Stenmarck et al., 2011; WRAP, 2011c; Beretta, 2012), "direct quantification and characterization of food waste"(only few samples could be used by Kranert et al., 2012 (ID 2), "Statistics from national authorities" (Barilla, 2012), "Data based on a micro (business) approach"(Beretta, 2012; WRAP, 2010a) and "other approaches" (literature research - Stenmarck et al., 2011; Almeida, 2011). It seems that on the one hand useful data for characterization and quantification of food waste at wholesale and logistics are not available from literature or statistics and on the other hand direct measurements are also not easy to conduct. Therefore, the researchers have to use information from key personnel to receive additional information as basis for estimations (e.g. share of food waste within organic waste, share of donated food).

Most of the studies use mass based indicators which represent total amount of food waste worldwide (Barilla, 2012), in EU (Monier et al., 2010; Weidema et al., 2008) or in a specific country (Kranert et al., 2012; Stenmarck et al., 2011; WRAP, 2010a; WRAP, 2011a; WRAP, 2011b; WRAP, 2011c; Stenmarck et al., 2011; Hanssen and Schakenda, 2010; Hanssen and Schakenda, 2011), amount per capita and year (Barilla, 2012; Weidema et al., 2008) or amount per shop and year (Stenmarck et al., 2011; Hanssen and Schakenda, 2010; Hanssen and Schakenda, 2011). Hanssen and Schakenda (2010) as well as Hanssen and Schakenda (2011) gives information on the percentage of food waste to total sale for 9 different food product groups. Barilla (2012) provide their results also as share of food loss worldwide as well as share of loss with respect to a specific food supply chain step. WRAP (2011a) gives a volume based percentage loss of different fruits and vegetables. WRAP (2011c) also provides economic value of food waste. Beretta (2012) and Almeida (2011) presented their results in energy units using total energy loss per year in TJ respectively in kcal per capita and year.

Especially with respect to the wholesale and logistics sector poor data on food waste are available via statistics from (inter)national authorities, which is e.g. mentioned by Monier et al. (2010). Often this data source is only used for achieving general data on the branch for further processing of food waste data coming from another source. It seems that data on an (inter)national basis could be helpful for studies aiming a general view on food waste (policy, recommendations, environmental impact) such as Monier et al. (2010), Mason et al. (2011) or Weidema et al. (2008) but not for detailed investigations.
Existing statistical data often do not serve the aim to provide information for food waste prevention measures. Often only general data about food waste in total are provided and there is no further information on the characteristic of single waste streams which are included (e.g. Monier et al., 2010). Thus, the share of avoidable or edible parts of the total amount is unknown. In order to estimate the share of avoidable or edible food waste the researcher have to conduct small-scale investigations by conducting waste

sorting or screening analyses (e.g.Kranert et al., 2012) or have to ask experts (e.g. WRAP, 2011a; Kranert et al., 2012). The first option is time and labour consuming and at the end the representativeness can be scrutinized critically. The second option could cover a broader scope but one has to rely on participants from the investigated sector. This could be the reason why most of the references reviewed combine two or more approaches.

The main finding from the literature review is that food waste data for the wholesale and logistics sector are limited and national statistics are mostly not available. Also results from sorting analyses are not so common and thus, reliable data seems to be lacking. In most cases the included waste streams are not described in detail within the reviewed reports.

Table 12 Summary for "wholesale and logistics" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Develop of methodologies; Characterize and quantify food waste for one specific year(also causes, disposal paths)	Estimates based in Interviews with key personal(In total 45 interviews were conducted with fresh produce companies, including suppliers (34 interviews), retailers (seven interviews) and wholesalers (two interviews), in England, Scotland and Wales.)	Quantitative estimates based on interviews: percentage loss and waste for eleven different fruits and vegetables for different stages of food supply chain; total amount in t; carbon equivalents and economic value In addition to the interviews, secondary data on waste was collected by tracking specific fresh produce consignments through the supply chain to trace and quantify „real time" loss for specific fresh produce types. For this task, 25 companies were approached out of which 10 responded and provided waste data. Loss data classified to grading, storage, packing but not "wholesale" – it is not clear where wholesale begins or where it ends; at storage loss largest loss for potatoes (up to 25 %)	WRAP 2011a (ID 51)
Characterize and quantify food waste for one specific year(also causes)	Other approaches (literature research) Estimates based in Interviews with key personal (interviews, results of interviews commented by interviewees again)	Different depending on country: kg per shop and week, total tonnes per year; total tons edible food waste for 30 shops in Norway; In Denmark and Sweden data are not public but data from Norway could be used to characterize the situation within Nordic countries with respect to composition but not with respect to amounts which varies more	Stenmarck et al. 2011 (ID 21)
Develop/test of methodologies (The purpose of the studies have been to develop a standardized methodology for documentation of food waste in the Norwegian Retail Sector, to get detailed data about mass and economic value of the food waste, data about the most	Data based on a micro business approach (All data are on a detailed micro level, where all products that have been wasted in 13 large wholesale and distribution centers in Norway have been registered. The 13 centers	Data on food waste has been combined with data on annual turnover for each product group and each centre, with net mass per unit of product and with data on price per unit or mass. The same centers have been studied for four years with the same methodology, to get a good overview of trends in food waste generation. Several statistical tests of the relationships between food waste and type of shops/type of products have been carried out. Estimated amount of food	Hanssen and Schakenda (2010), Hanssen and Schakenda (2011), (ID 184/185)

important causes of food waste and to follow trends in food waste amounts and compositions over a longer time period.)	cover about 40% of all food being distributed in Norway.	waste from the wholesale/distribution sector in Norway in 2011 was 2000 tons. Detailed data on 9 different food groups are available both regarding percentage waste to total sale and total tons of food waste. The 2011 report also shows trends in development of food waste from 2010.	

Retail and market

Number of studies reviewed

In the FUSIONS data base we found 52 references to studies which had connections to ”Retail” and of those 39 studies had been remarked as ”provided important methodological approaches”. All of those 39 studies were reviewed by BOKU and Ostfold Research, and it was found that only 16 studies were highly relevant for the work with reviewing methodological approaches.

The 39 studies that were sorted out were all rather new, as only 1 was from 2002, 5 from the period 2005-2009 and 33 were from 2010-2012, showing that the focus on food waste in the retail sector has ”exploded” over the past years. 27 of the 39 studies that were reviewed were from EU27, Western or Northern Europe.

Originality of data

The review of literature showed that there were only 15 studies available in the database that provided primary data from own studies of food waste from the retail sector, whereas 16 studies not referred to any data for food waste in retail sector at all. Most of the studies (24) were based in secondary data and literature data, often referring to a few basic literature references (e.g. USDA ERS 2009, Gustavsson et al. 2011). The most important reports available are thus the 15 that contain primary data from studies involving the retail sector.

Main methodological approaches

The two main methodological approaches that have been applied and described in the 15 studies to quantify and characterize food waste are quantitative studies (9 of 15 studies reviewed) and qualitative studies (8 of 15 studies reviewed), or a combination where qualitative data are analysed in a semi-quantitative approach where 7 of 8 qualitative studies seemed to be semi-quantitative).

- A qualitative approach has normally been carried out through interviews among key persons in the retail sector or in specific retail shops, giving indications about how much food waste are generated in specific shops or in retail companies. Estimates are normally given within percentage intervals for food waste in relation to turnover in product groups (e.g. Mena et al. 2011, Terry et al. 2011, Whitehead 2011, James 2011). In most reports it is not described in detail how the interviews have been carried out and how the retail shops have prepared themselves for the interviews or questionnaires to estimate food loss from the shops.
- In a quantitative approach, waste generation has in most cases been quantified in a smaller number of retail shops (Hanssen & Olsen 2008, Hanssen & Schakenda 2010, 2011, Jensen et al. 2011, Buzby et al. 2011, Beretta 2012 and in some cases characterized to specific product groups (Hanssen & Olsen 2008, Hanssen & Schakenda 2010, 2011, Buzby et al. 2011, Venkat et al. 2012, WRAP 2010,). In most references, the specific methodological approach to gather data about food waste from the specific shops is not described in detail. Both Hanssen & Schakenda (2010, 2011) and Eriksson et al (2012) have got access to detailed data where each food item has been scanned by the shops and where data on food loss have been compared with turnover data for each product group. With modern stocking and logistic systems, such data are probably available from a number of retail companies, both from each shop and more aggregated data. As mentioned by Stenmarck et al. (2011), access to such data is often difficult for confidentiality reasons.

Several studies have used the quantitative data on losses from the specific retail shops to upscale to figures for the whole retail sector in the country (e.g. Hanssen & Olsen 2008, Hanssen & Schakenda 2011, Jensen et al. 2011). Up-scaling factors have been either

based on economic data based on turnover for each shop and for the whole retail sector (e.g. Hanssen & Schakenda 2011) or based on amount of waste per employees (Jensen et al. 2011).

Indicators for food waste reporting

Most of the studies report waste figures based on mass flows (tons of waste), some studies are base on economic value of waste and quite a few studies report both economic and mass weights (e.g. Hanssen & Schakenda 2011). Waste figures are reported both as total weight or total value, as percentages of food waste in relation to total turnover (mass or economic value). Other indicators related to the retail shops are food waste per unit of turnover (e.g. tons of waste per mill €) or per employee in the shop or in the sector in total. Those studies that have up-scaled data to national aggregates, do also often use mass of waste or economic value of waste per capita in the geographic area of the study (Finnish), making it easier to compare figures between countries.

Time scale of studies

Most of the studies that have been carried out in the retail sector has been related to a single year, and with the scope of making one detailed study of food waste from the sector (13 of 15 studies). Some studies are only reporting on food waste generation in a limited number of shops for a shorter time period, without ambitions to upscale figures to annual waste figures or to more sector-wise reports. The only studies that have been identified with the clear ambition to follow food waste generation in retail shops or the total retail sector over several of years are the Norwegian ForMat project, where data are systematically gathered from 30 representative retail shops each year to study trends and variation over time (Hanssen & Schakenda 2010, 2011).

Scope of the studies – range of products and product groups

Most studies reviewed contained data and statistics for the whole retail sector (11 of 15 studies). Some studies differentiated between specific product groups with specific data for each product group (e.g. Hanssen & Schakenda 2010, 2011; Whitehead 2011, James et al. 2011, Terry et al. 2011, Lee et al. 2010, Buzby et al. 2011, Eriksson 2012; Venkat et al 2012). In other studies it had not been possible to get access to specific data for each product groups, where only total figures for food waste were presented (e.g. Jensen et al. 2011). Specific studies have been carried out for bakery products (Schneider & Scherhaufer 2009), the fruits & vegetables products, fresh products (Terry et al. 2011), fresh meat (Whitehead 2011), fish (James et al. 2011) and horticulture (Gustavsson et al 2010).

Mass of waste is used in more or less all the reviewed studies from the retail sector (17 studies), whereas economic value of waste was used in only 3 studies. This is probably due to the fact that it is far more difficult to get access to economic values, both of waste flows, but even more for turnover (see Stenmarck et al 2011). Only 2 of the reviewed studies included environmental impacts as a method for characterization of food waste, and the same number of studies used caloric value or energy content as a basis for reporting (e.g. Beretta et al. 2012).

More or less all studies reviewed had a purpose to get a better overview of characterization and quantification of food waste. About 10 studies focused on identification of causes for food waste, or the so-called ”root caused” (e.g. Whitehead 2011, James 2011, Mena et al. 2011, Ericsson 201) and about the same number of

studies on prevention of food waste (11 studies). Comparisons between different food sectors (e.g. fruits and vegetables, fresh bakery products, fresh meat etc) or between the retail sector and other parts of the value chain are explicit purposes in 8 and 5 studies, where detailed data are available (e.g. Eriksson et al. 2012, Eriksson 2012, Buzby et al 2012, Venkat et al. 2012, Mena et al. 2011, Lee et al. 2010, Hanssen & Schakenda 2010, 2011, Whitehead 2011, James et al 2011). Only the two studies from Norway focus on time series studies that shall follow trend for several years (Hanssen & Schakenda 2010, 2011).

Table 13 Summary for "retail and market" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
The purpose of the studies have been to develop a standardized methodology for documentation of food waste in the Norwegian Retail Sector, to get detailed data about mass and economic value of the food waste, data about the most important causes of food waste and to follow trends in food waste amounts and compositions over a longer time period.	All data are on a detailed micro level, where all products that have been wasted in 30 retail shops in Norway has been registered. Data on food waste has been combined with data on annual turnover for each product group and each shop, with net weight per unit of product and with data on price per unit or weight. The same shops have been studied for four years with the same methodology, to get a good overview of trends in food waste generation. Several statistical tests of the relationships between food waste and type of shops/type of products have been carried out, and will be published in scientific journals in 2013.	Estimated amount of food waste from the retail sector in Norway in 2011 was 68000 tons. Detailed data on 21 different food groups are available both regarding percentage waste to total sale and total tons of food waste. The 2011 report also shows trends in development of food waste between different types of retail shops, for the 30 shops and for the 21 product groups.	184+185: Hanssen & Schakenda
Characterize and quantify food waste for one specific year	Other approaches (literature review: one study by EHI retail institute from Germany; other studies from EU), Estimates based in Interviews with key personal, Direct quantification and characterization of food waste (only few samples)		Report 02 M. Kranert, G. Hafner, J. Barabosz, H. Schuller, D. Leverenz, A. Kölbig (ISWA, University Stuttgart) F. Schneider, S. Lebersorger, S. Scherhaufer (ABF-BOKU)
To give an overview of total amounts of avoidable food waste in Sweden for 2010	Estimated total amount of food waste from retail shops per employees based in figures from a number of Swedish retail shops. It is not shown how the data gathering from the shops have been done, nor if the factors	Estimated total amount of food waste from Swedish retail sector about 39 000 tons or about 4% of total avoidable food waste in Sweden	Report 20 Jensen et al

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	differ between types of shops.		
The main purpose of the study has been to document impact of global food loss on cropland, water footprint and fertilizer use.	Estimates of food loss in the total value chain as well as in the retail sector were based in the data on percentage waste in different regions from Gustavsson et al. 2011 (report 1). There were thus not collected any specific primary data on food loss in this study, nor is the methodology described in detail.	Data on cropland, water resources and fertilizer use to produce food that are wasted from the distribution phase compared to other parts of the value chain in different regions of the world. Assessment of food waste based on literature data.	Report 23 M. Kummu et al. 2012
Carbon and water footprint tradeoffs in fresh tomato production	No data or analyses of food waste included	No results	Report 75 Page et al 2012
The main aims of this research were to identify the root causes of food waste arising in the supplier/retailer interface and to highlight some potential good practices in terms of waste prevention and management.	In total, 43 interviews were conducted with managers with responsibilities in food production, wholesaling and retailing. Of these, 24 took place in the UK and 19 in Spain. Interviewees in all cases were middle to senior managers with responsibility for managing waste across their organizations. Contact details and demographics: covering details about the company and the product under review Quantitative waste data: specific data concerning waste volumes and percentages Causes of waste and good practices: discussion on the main areas of waste. Destination of waste: discussion of how waste is managed Interviewees were asked to select from pre-determined ranges of waste (<1%; 1–3%; 3–5%;	Data on food waste as percentage of turnover are shown in the Figure. It is not clear from the paper if the percentages is in relation to total waste or in relation to total turnover. It is also not clear if it is related to mass or to economic value of the food. The paper has a very good description and analyses of root causes for food waste in the value chain from production to retail.	Report 24 Mena et al. 2011

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	5–7%; >7%) based on actual waste records. It is not described in the paper how the primary data were recorded, if they are based on real recordings or best estimates.		
The main purpose of the study has been to estimate the value of food loss in US households and retail sector, to identify the most important products for reduction of food waste.	In general, food waste measurements in the United States rely on structured interviews, measurement of plate waste, direct examination of garbage and application of inferential methods using waste factors measured in sample populations and applied across the food system (Hall et al. 2009). The value of fruit and vegetable losses are estimated using national retail prices from Nielsen Homescan data and loss estimates derived from the US Department of Agriculture's Economic Research Service's (ERS) Loss-Adjusted Food Availability data (ERS 2010a).	Food loss at the retail and consumer levels in the United States includes 14.8 billion pounds of fruit and 23.4 billion pounds of vegetables, valued at $15.1 billion and $27.7 billion, respectively, in 2008 retail market prices. The total value of these losses is $42.8 billion per year, or roughly $141 per capita. To most efficiently reduce the annual food loss, it may be beneficial to focus efforts on the four fruits (fresh apples, grapes, peaches and strawberries) and four vegetables (fresh and canned tomatoes and fresh and frozen potatoes) that have the greatest amount of loss.	Report 33 Buzby et al.
The main purpose of the study has been to estimate the environmental impacts of total food loss in the US based in LCA data for the food products.	The loss-adjusted food availability data series from the US Department of Agriculture (USDA ERS, 2009) is the basis for the food waste analysis in this study. The USDA maintains the sole national database of food availability and food loss data in the US. The data series provides annual per-capita food production, waste and availability data for a full spectrum of	Retail waste – including waste in institutional food service – amounts to 34% of the total. Figure 2 illustrates this in terms of absolute quantities (MMT). Our total estimate of avoidable food waste in the US is 55.41 MMT/year for 2009, which amounts to 28.7%	Report 40 Venkat et al. 2012

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	food commodities in the United States, adjusted for food spoilage and other losses to closely approximate per-capita intake. Food waste is further broken down into waste at the distribution, retail and consumer levels.	of total annual production by weight. This translates to 180 kg/year of total avoidable waste on a per-capita basis – this is less than the 280-300 kg/year reported for Europe and North America by Gustavsson et al. (2011) because it excludes both production losses and the unavoidable consumer waste.	
Study of the relationship between packaging optimization and food waste reduction	No data on food waste from specific shops, value chains, regions nor nations given	Main scope of the study to see how much packaging weight can be increased if food waste is reduced	Report 44 Williams & Wikström (2011)
	The estimates of waste arisings given within this study are „best" estimates, and were derived from existing datasets as well as data collected by DHL in the initial study. Four of the largest UK retailers, representing over 60% of the UK market by turnover in 2007-08, participated in the DHL 2009 study (see Section 2.3). The data supplied by participating retailers varied, although all produced total store waste figures, broken down by key waste management routes, and by material type for recycled waste. Landfill data were captured only as total figures, except for one retailer which had undertaken a skip analysis to ascertain how much of the food, drink and packaging waste being sent to landfill was recyclable. On the assumption	The main results from the study are shown in the Table A, showing distribution of food waste over the main parts of the value chain of food in the UK.	Report 70 WRAP (2010)

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	that the data were representative, (which may not be the case as data was obtained only from the four largest retailers, all of which fall within the „multiples" category - Figure 32) the findings of this analysis were applied to the other retailers" waste. None of the participating retailers were able to provide data on product damage, as this is typically reported as a financial loss rather than an amount of waste.		
Regulations and Policy development: Preparatory Study on Food Waste Across EU 27	Statistics from international authorities (EUROSTAT). Other approaches (national studies from UK for Wholesale/Retail; National data on Wholesale/Retail sector food waste were particularly lacking, with only four national studies identified.)		Report 087: Monier V., Escalon V., O'Connor C.
Characterize and quantify food waste for one specific year (time period is not mentioned clearly, also causes)	For Italy: Statistics from national authorities ISTAT (National Statistics Institute) Other data from other international studies. Nothing in detail.		Report 092: Barilla Center for food & nutrition
Develop of methodologies (also quantity, causes, disposal paths)	Estimates based in Interviews with key personal (In total 45 interviews were conducted with fresh produce companies, including suppliers (34 interviews), retailers (seven interviews) and wholesalers (two interviews), in England, Scotland and Wales.)		Report 095: Terry L.A., Mena C., Williams A., Jenney N., Whitehead P.

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Literature review and status of knowledge in Nordic Retail sector	Other approaches (literature research). Estimates based in Interviews with key personal (interviews, results of interviews commented by interviewees again)	No primary data from the study, only reference to other studies	Report 097: Stenmarck Åsa, Hanssen Ole Jörgen, Silvennoinen Kirsi, Katajajuuri Matti, Werge Mads
Food losses and food waste: a quantitative assessment for Switzerland. Characterize and quantify food waste for one specific year (in kcal/person/day)	Data calculated from previous stages; Other approaches (FAO study)		Report 098: Almeida J.
Resource maps for fresh meat across retail and wholesale supply chains. Characterize and quantify food waste for one specific year (generate data on product waste, packaging waste, water usage and greenhouse gas emissions)	Estimates based in Interviews with key personal (more than 50 interviews with 45 separate organisations in the fresh meat retail supply chain, including all the major multiple retailers; ; Each interview enabled the project team to quantify waste for the particular company, establish its views on the causes of waste, and record how it approached resource efficiency within the business)		Report 104: WRAP
Resource maps for fish across retail & wholesale supply chains. Develop/test of methodologies (also quantification tonnage, economic value and carbon equivalents)	Estimates based in Interviews with key personal (detailed interviews was carried out with 20 companies, among them six multiple retailers and a wholesale market) Surveys among user groups (270 in total, included primary processors, secondary processors, wholesalers and small retailers. Statistics from national authorities		Report 105: WRAP
Environmental Improvement	No information about single sectors		Report 116:

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Potentials of Meat and Dairy Products. Other (estimation of environmental impact of products)			B. P. Weidema, M. Wesnæs, J. Hermansen, T. Kristensen and N. Halberg
Household Food Consumption: Trends, Environmental Impacts and Policy Responses		Focus of study on households – no further information with respect to food waste methodology on retail, wholesale and logistics or redistribution	Report 117: OECD
Other (estimate of the potential constraints of environmental degradation on future world food production and subsequent effects on food prices and food security)	No specific methodology mentioned, other (literature)		Report 118: UNEP
Other (resource use and emissions to the environment throughout FSC): Assessment of resource efficiency in the food cycle		No information for each stage of FSC	Report 124: Sonigo, P., et. Al.
Others (examine the climate change impact of producing certain horticultural products sold in Swedish retail stores): The climate change impact of retail waste from horticultural products	Surveys among user groups (30 retail stores filled in a questionnaire and data sheets)		Report 128: Gustavsson et al.
Emissions of greenhouse gases from production of horticultural products - analysis of 17 products cultivated in Sweden. Other (greenhouse gas	Other approach (Data on food wastage for retail was taken from literature (Gustavsson J., 2010))		Report 138: Davies et al.

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
emissions from Swedish production of some major types of fresh fruits and vegetables consumed in Sweden and some important flowers, that can be grown in Sweden)			
Other (to identify what potential actions, undertaken by the different actors in the postfarm milk chain, lead to the greatest life cycle improvements)	Other approaches (literature review)		Report 139: Berlin, J. et al
Other (discussion of definition, data, approaches)	Other (literature review)		Report 143: Redlingshöfer, Barbara and Soyeux, Annie
Characterize and quantify food waste for one specific year; in addition also quantify the energy flow of the food waste (mass was calculated into energy)	Data based on a micro approach (retail data based on estimations from 5 companies)		Report 146: Beretta, Claudio
Characterize and quantify food waste for one specific year (as well as disposal paths, implemented and planned prevention measures)	Estimates based in Interviews with key personnel, Other approaches (literature review)		Report 148 Schneider F., Scherhaufer S
Regulations and policy development (topics addressed are the links between water, food and development)	No separate methodology for sectors		Report 159: Lundqvist J., de Fraiture C., Molden D.
Characterize and quantify food waste for one specific year (main	The study was focused on the carbon and water foot print of household food waste.		Report 162: WRAP

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
topic was quantifying carbon and water foot print of hh food waste)	Retail was only involved within the calculations of the foot prints.		
Sector guidance note - fresh produce (Sector Guidance Note: Preventing Waste in the Fruit and Vegetable Supply Chain)	no specific methodology for sectors, more summarizing best practice and findings of research		Report 164: WRAP
Sector guidance note – fish (Sector Guidance Note: Preventing Waste in the Fish processing Supply Chain)	No specific methodology for sectors used		Report 165: WRAP
Preventing Waste in the Fresh meat Supply Chain)	Not mentioned in detail		Report 166: WRAP
Other (estimate the potential amount of food waste which is associated with inadequate heat seals created in the food packaging process)	Not covered by study		Report 167: WRAP
Characterize and quantify food waste in time series studies Prevent/minimize food waste	Are only mentioned indirect as they implemented the measures		Report 223: WRAP
Other (aimed to determine data availability and the potential for investigating product life on a wider scale as well as lessons that might be drawn on feasible ways to extend shelf life without compromising food safety)	Not covered by study		Report 239: WRAP
Others (study to identify energy use, at both product and market scale, and energy use hotspots within the agri-	Not mentioned in detail		Report 243: Carla Sarrouy, Joe Davidson, Rob Lillywhite

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
food supply chain)			
Characterize and quantify food waste for one specific year (to quantify food wastage from large retail outlets and to analyse systematic causes)	Data based on a micro (from business unit) approach (recorded food waste) Direct quantification and characterization of food waste (measurement of unrecorded waste)		Report 251: Mattias Eriksson
This literature review deals with food waste, its sources, reasons and reduction options. The main focus is on avoidable food waste. The aim of this study was to find out what kind of methods have been used to study food waste in the whole food marketing system and what are the pros and cons of different methods. An additional goal was to examine the amount of food waste and its variation between different stages of the food supply chain, different food groups, and different countries. The goal was also to study which aspects affect the amounts of food losses and what kind of measures have been proposed and successfully used to reduce and prevent food loss.	Literature review. A number of international and Finnish studies are referred and summarized.	It seems that clearly lower percentage of food is lost in retail, especially in bigger super- and hypermarkets, than in household level. Retail stores however handle very large volumes of food so even a loss of only few percentages equates remarkable amount of avoidable food waste. At both household and retail level most of avoidable food waste seems to consist of fresh vegetables, fruit and bakery products.	Report 170: Heta-Kaisa Koivupuro, Lotta Jalkanen, Juha-Matti Katajajuuri, Anu Reinikainen ja Kirsi Silvennoinen 2010 MTT
The aim of this project research was to identify the volume of Finnish food waste, and its distribution	The project was carried out by interviewing various parties in retail chains, waste management, and other associated actors.	The results of the project suggest that every year consumers, food services, retailers, and food industry	Report 169: Silvennoinen, Koivupuro, Katajajuuri,

The main purpose of the study	Type of methodological approach(es) used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
among parties involved in the food supply chain in Finland . We have specifically targeted households, food services, retail sector, and food industry.		combined waste over 250 to 320 million kilograms of food in Finland, 62–86 kilograms per every Finnish citizen. 2010-2012. 65–75 Total m kg/year 12–14 Per person kg /year The main product groups causing food waste in stores are fruits and vegetables, and bread. Other products resulting in waste are dairy products, fresh meat and fish, and convenience food.	Jalkanen, Reinikainen 2012

Redistribution

Each co-worker conducted the review and filled in one standardised template per literature. The information from these templates was summarized after the review process in the present report.
The redistribution sector of the food supply chain is not mentioned very prominent within the reviewed literature. Although it is mentioned in some research, information on the specific methodologies which were used in this part of the food supply chain during assessments is missing or at the end no relevant data could be found for that part of the chain.
In the FUSIONS database 9 studies were classified as "redistribution" studies at the beginning of the review. Within the 11 studies which were reviewed 2 were written in German, 2 in French and the remaining in English language.

In some studies the time period is not mentioned very clear as a literature review (e.g. Redlingshöfer and Soyeux, 2012) was conducted. But it seems that the main focus of the studies affects data origin from the time period 2001 to 2010 (Alexander and Smaje, 2008; Schneider and Scherhaufer, 2009) respectively later (Beretta, 2012).
The relevant literature covers studies from UK (Alexander and Smaje, 2008), Australia (Mason et al., 2011), Switzerland (Beretta, 2012) and Austria (Schneider and Scherhaufer, 2009). Redlingshöfer and Soyeux (2012) are not country-specific.

The main purpose "characterize and quantify food waste for one specific year" applies to Beretta (2012), Alexander and Smaje (2008) as well as Schneider and Scherhaufer (2009). The characterization and quantification of donated food is therefore the most relevant purpose of the relevant literature which was reviewed. In most cases, in addition to the donation of food also other issues were mentioned (e.g. causes, other prevention measures, disposal paths).

The most important approach found for characterization and quantification of donated food was the method of "data based on a micro business approach" (Beretta, 2012; Schneider and Scherhaufer, 2009; Alexander and Smaje, 2008). Alexander and Smaje (2008) also used "direct quantification and characterization of food waste"(only 2 days fieldwork) and "estimates based in interviews with key personal". While most of the mentioned studies above used only data from the redistribution organisations, Schneider and Scherhaufer (2009) tried to combine information from both donating business companies and receiving social organisations.

Most of the studies use mass based indicators which represent total amount of food donated within a certain time period (Alexander and Smaje, 2008; Beretta, 2012; Schneider and Scherhaufer, 2009). Alexander and Smaje (2008) also provide the percentage of donated food mass which is going to specific usage or disposal within the social organization (e.g. given to clients, distributed to other projects, discarded at FareShare etc.). Beretta (2012) presents his results also in energy units using total energy loss per year in TJ per year.

Although food donations should be edible to 100 %, not the whole amount can be handed over to people in need. Reason for this is that sometimes e.g. whole packages of overripe fruits and vegetables are donated and the social organisations have to sort out the spoiled ones. Alexander and Smaje (2008) report the share of food which is taken over by FareShare as well the share of food which is handed over to clients at the end. Thus, also losses within the redistribution organization are mentioned.

The literature review showed that there is only a small number of references with respect to redistribution. Most references reviewed dealt with the topic more in general than providing real data or methodological input to the review so that they were classified as not relevant for the review.

Table 14 Summary for "redistribution" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Characterize and quantify food waste for one specific year (as well as disposal paths, implemented and planned prevention measures)	Data based on a micro (from business unit) approach (donation statistics from one food bank as well as lists from several bakery companies)	Amount of waste bread and pastry in tonnes donated to one charity organization by retail and bakeries was included for one year. In addition, bakeries recorded the tonnes of donated waste bread and pastry respectively shares of donated bread and pastry to social organisations with respect to total wasted bread and pastry within one year.	Schneider and Scherhaufer (2009)
Characterize and quantify food waste (food waste not correct as the food is donated – therefore the amount of donated food was recorded as well as logistic system, food flow with respect to different usage etc.)	Direct quantification and characterization of food waste(2 day fieldwork at the food bank), Data based on a micro (from business unit) approach(other data from FareShare),Estimates based in Interviews with key personnel (interview with retail store managers and depot managers, FareShare and recipient projects workers and directors)	Results are given in kg, percentage of donated food mass which is going to specific usage or disposal (e.g. given to clients, distributed to other projects, discarded at FareShare etc.)	Alexander and Smaje (2008) 31

Food services

The number of studies evaluated for food services was 22 in total. Half of the studies (11) included primary data, and half used secondary data and literature data. 2 of the studies did not have any description of data or methodology.
If there are several statements in the table describing the study, it is possible to put more than one mark. This means that the total number of studies is not necessarily the same as the sum of the bars in the figure. Then some studies used secondary data from different sources without a good description.
13 of the studies had characterization and quantification of waste as the most important purpose, but some also wanted to indentify causes for food waste and prevent food waste.
Most of the studies had a quantitative (15) or semi-quantitative approach (4). Most of these approaches used mass data as input, but also interviews (3) and economic data (1) have been used. Most of the studies had a short time dimension as time period for the data gathering (12), but the ones using statistics usually have a time dimension of one year (6) or longer.
Most of the studies include the whole food service sector (11) and some focus of specific sectors in the food service (9). Only 2 studies focused on specific products.
All of the studies using primary data use a micro approach to find indicators to representing the whole sector. Selection of sectors is not based on representativeness, but seems arbitrary and it is often small scale studies on the basis of available resources (e.g. measurements in 2 schools and 2 restaurants).
The studies of food services evaluated covers very different regions (or parts of); Great Britain (6), Scandinavia (3), the Netherlands (2), France (2), other EU countries (2) and regions outside EU (7)
The indicator used is waste flows (17) or economic value (2).The indicators used is ton per year, kg per habitant, g per meal and person and kg per flight.
The advantage of using a quantitative approach are that empirical data is collected, but the problem is that the data is not representative for the value chain or the sector, since it does not cover a representative part of the food service sector. The activities producing food waste in the food services, is predefined as restaurants, catering and canteens. But also the public sector consisting of hospital, schools, universities, prisons and institutions produces food waste. In some cases the operation of the canteens in the public sector is outsourced to the private sector. The sector is complex and there are big variation the amount of food waste. Since the sector is wide it is difficult to find a comprehensive approach including all aspects of food waste. The limitations in the evaluated quantitative studies is that the data gathering is not based on a representative selection, both in term of parts of the food services step included and selection of companies/locations.

Table 15 Summary for "food service" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Characterize food waste - questionnaire	Eight hundred and ninety three customers in 21 restaurants and public houses filled in a questionnaire after dining.	The responses revealed that customers who left food were more likely to be female, younger and have a general tendency to leave food when eating out or eating at home. Excess quantity was an important factor in determining waste, whereas poor quality had a relatively small effect.	ID 11: Food waste in public houses and restaurants and customer attitudes
Develop/test of methodologies	Data for 2010, but the aim is to be able to collect data at regular intervals. Waste quantities are calculated by collected amounts of food waste from individual companies.	There seems to be a connection between the number of employees and amount of waste, but there are other factors that also explains the differences between the various companies	ID 20: Matavfall 2010 från jord till bord
Estimate from statistics	For France, the European study was based on data from EUROSTAT and ADEME In terms of school catering, three stages are source of food wastage. In the catering sector, including kindergarten and primary school, even if a quality set is proposed, the more food remains if the offered dish is new or unusual for children. On average, it's needed to introduce 7 to 8 times a new dish before it's actually eaten. There is much ignorance of the products from children, to whom we tend to give too large portions and new dishes without preparing them to it.	Eating out: 1,080,000 tons : 12.5% (17.4kg/capita/year).	ID 41: Food wastage study - Mid-term report
Single measurement	All food supplied and wasted where measured over a period for 28 days.	Waste rate was more than 40% of the hospital food.	(ID 49) High food wastage and low nutritional intakes in hospital patients

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
Single measurement (2 days in each hospital) in total 3 hospitals	Hospital. Food waste was measured; plate waste and trolley waste.	The average of food waste was 24% - 39%, but big variations	(ID 50) Food waste, catering practices and public procurement: a case study of hospital food systems in Wales
Single measurement	Two schools and two restaurants		(ID 53) Food losses in food service institutions. Examples from Sweden.
Single measurement 2009 in combination with surveys	Schools and colleges, Hospitals, Prisons, Leisure facilities. Various conventions for grossing up have been used, based on waste generation coefficients such as: • Waste per employee • Waste per premises • Waste per unit floorspace • Waste per unit of production • Waste per unit of financial volume (e.g. Gross Value Added).		(ID 54) A study of public sector food waste arising and processing options within the North East region
Mapping food losses throughout the entire food supply chain. The focus is on losses in foodfor human consumption in Flanders. — Consultation with stakeholders. — Investigating possibilities for policy	on the one hand research into literature and sources, and, on the other hand, the consultation of stakeholders (representatives of economic sectors, from consumer and environmental associations, research institutes andpublic authorities).	Total amount of food waste (they have their own definition) from the food service is estimated to 160.000 ton/year.	91: Willy Sarlee (2012), Voedselverlies in ketenperspectief

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
innovation			
Causes for food waste	Data is based on literature survey	Large and inflexible portions. Expansive menu options. Unexpected sales fluctuations. Rigid management. Fast-food time limits. School lunch timing.	Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill (ID 93)
Capture real, measured data about restaurant food waste over the course of one day, separated for 10 restaurant in London, UK (single measurement)	Food waste separated into three streams: customer plate waste; prep waste and spoilage.	65% of food waste comes from preparation – peelings, off cuts and anything ruined while cooking 30% of food waste comes back from customers' plates. 5% of food waste is classified as 'spoilage' – out-of-date or unusable items	(ID 100) Too good to waste, Restaurant food waste survey report 2010
Quantify the food waste in the Dutch catering (school, business, governmental) sector and identify improvement measures	food waste was determined by weighing on product level what is left in the counters for selling at the end of the meals; this is done for two weeks at 200 catering locations from the top 8 Dutch catering companies	Total amount of food waste from the described catering sector is measured to be 5000 ton/year. Figures on product level are also available	102: Han Soethoudt (2012), reductie voedselverspilling van de Nederlandse catering-sector
Quantify the food waste in the Netherlands	In this document a new framework is introduced to consider food waste. The food waste is calculated based on a definition agreed upon by government and companies. The endpoint of the food flows can be composting or any other part of the waste hierarchy. Statistics on these flows are the starting point for the calculations above	Total amount of food waste in the Netherlands is between 1.4 and 2.5 million tons in 2009.	103: Han Soethoudt (2013), Transitiemonitor voedselverspilling
EU-27: • Household improvements, mainly to reduce food losses	Out of the process 'restaurants and other catering, not incl. food', only a part should be ascribed to the preparation of meat	the 18 % share for meat and dairy products becomes EUR 61 billion	116: B. P. Weidema, M. Wesnæs, J. Hermansen, T. Kristensen and N. Halberg

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
(wastage) and to reduce car use for shopping; • Agricultural improvements, mainly to reduce water and air emissions (in particular nitrate, ammonia and methane) and land requirements; • Power savings in farming, food industry, retail, catering, and for household appliances.	and dairy products. Failing to find any physical causality, the same share of the process has been applied as the economic share of meat and dairy products in the food inputs to 'restaurants and other catering' from the Danish NAMEA. This share is 18 %, and the total economic output of the service process 'restaurants and other catering, not incl. food' is EUR 340 billion		(2008),Environmental Improvement Potentials of Meat and Dairy Products
not relevant	not relevant	no specific data on food service	117:OECD (2002),Household Food Consumption: Trends, Environmental Impacts and Policy Responses
The purpose of this study was to conduct exploratory research on consumer-level food loss to help inform the development of a complete study to develop estimates of food loss for individual food categories.	The exploratory research included reviewing published literature on consumer-level food loss, conducting interviews with foodservice establishments since less information is known about away-from-home food loss than at-home food loss. In total 14 interviews with kitchen managers from two quick service restaurants, seven family dining restaurants, two fine dining restaurants, and three cafeterias.	Estimates on some food categories: meat,poultry and fish /dairy / fruit and vegetables /grains and bread / fat and cooking oils / sugars and sweeteners. Results vary a lot per interviewer and per category (too much to put here)	119: Muth, M., Kosa, K., Nielsen, S., Karns, S. (2007), Exploratory Research on Estmation of Consumer-Level Food Loss Conversion Factors
not relevant	not relevant	no specific data on food service	120: Verdicité (2011), Résultats des

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
			caractérisations du gaspillage alimentaire dans les ordures méangères et assimilées
This paper presents findings from a recent survey of household food waste in Australia.	In the month October in 2009 1603 grocery buyers were asked to reply to a questionnaire, including two questions about the restaurant and take-away sector. In these 2 questions people were asked to estimate the amount of money that is related to the food not eaten	a little less than 1,1 million AUS $ of restaurant and take-away food is wasted	121: Baker, D., Fear, J., Denniss, R. (2009), What a waste: An analysis of household expenditure on food
not relevant	not relevant	no specific data on food service	122: Weber, C., Matthews, H. (2008), Food-Miles and the Relative Climate Impacts of Food Choices in the United States
The purpose of the study is to reduce food waste in restaurants, hotels, canteens and catering	Questionnaires, public statistics and available reports	Total amount of avoidable food waste from the hospitality sector is estimated to 450 000 ton - 18 kg /habitant.	123: Marthinsen, J. , Sundt, P., Kaysen, O., Kirkevaag K. (2012). Prevention of food waste in restaurants, hotels, canteens and catering
not relevant	not relevant	no specific data on food service	124: Sonigo, P., et. Al. (2012), Assessment of resource efficiency in the food cycle
not relevant	not relevant	no specific data on food service	141: Ademe (2007), La composition des ordures ménagères et assimilées en France
provide the qualitative and quantitative elements related to losses and food	Comprehensive literature review, collection of quantitative data in a one week data collection at several food	Generally, catering generates waste per guest at every meal 167g, the commercial catering 211g.	142: Supkova, Marketa (2011), Pertes et gaspillages alimentaires,

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
waste in the fields of direct delivery to the consumer and foodservice in France. What are the volumes of food lost or wasted?	service locations. And a Delphi approach with experts in the foodservice sector on qualitative data in France.	However, the volumes vary more strongly in catering (SD 75g) incommercial catering (SD 32g) which is explained by the disparity between the types of guests. In all areas of catering, health and medical-social catering records the highest volume of losses and wastage (264g/pers/meal average, SD 139g). Patients in short stay (in hospital) produce two times more loss and wastage per meal that residents in long stay (hospital or nursing home). In all areas of catering, business catering generates the lowest volume loss and waste per guest per every meal (in 125g/pers/meal average with SD 35.4 g.In school canteens, canteens, colleges and high schools record larger volumes of food waste and loss (179 - 200g/pers/meal) were recorded while primary schools had the lowest volume loss and waste per guest per meal (110 - 130g/pers/meal).	marges de manœuvre et verrous au stade de la remise directe au consommateur (distribution et restauration) et en restauration collective
not relevant	not relevant	no specific data on food service	146: Beretta, Claudio (2012), Analyse der Nahrungsmittelflüsse in der Schweiz und Ermittlung von Strategien, Nahrungsmittelverluste zu vermindern und die Nahrungsmittelverwertung

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
			zu optimieren
The present study aimed at classifying economy class solid wastes resulted from in-flight catering	Twelve representative Egypt Air flights were selected for the analysis. Three flights representing the four types of trips (local, morning short trips, night short trips, medium haul trips) were chosen. A thorough analysis was carried out to evaluate the quantity and composition of waste generated from in-flight catering services. Three fresh clean different food packages (snack, hot breakfast, hot lunch or dinner, and cold lunch or dinner) were unpacked. Every serving item (tea cup, spoon, fork, knife, tissue paper, plastic or aluminium container,etc.) and packaging item was weighed. Real solid waste samples were collected and hand sorted to separate aluminium foil, paper, plastics and food wastes from the different flights and meals. Aluminium and plastic containers were thoroughly washed and dried with a dry cloth. Then each waste item was weighed.	Waste generation rates for the different meals servedon flights were recorded. The rate was 61.3, 265, 131, 166, and 126 g for local snack, externaltrip snack, hot breakfast, hot meal (lunch or dinner), and cold meal (lunch or dinner), respectively. It is noteworthy to mention that the snack served for the external short trip generates the highest rate of waste, as the generation rate was 265 g/meal. The total weight of mixed wastes recorded 725 tons annually for the different types of meals.	155: El-Mobaidh A.M., Taha M.A.R., Lassheen N.K. (2006), Classification of in-flight catering wastes in Egypt air flights and its potential as energy source (chemical approach)
In this study, a waste composition analysis was conductedfor in-flight service waste, and potential waste minimisation measures were evaluated	Eight representative CPA flights were selected for the analysis, including two long-haul (European and North American routes), two medium-haul (Australian and New Zealand routes) and four short-haul flights (Asian routes). Food waste and packaging materials in meal trays are kept	Food waste can be found on product level for the various flights and split up by class. This is to much data to put here. The waste is total per flight and not per passenger, but can be calculated from figures in the article.	158: Li X.D., Poon C.S., Lee S.C., Chung S.S., Luk F.(2003), Waste reduction and recycling strategies for the in-flight services in the airline industry

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
	in food carts and transported directly to the washing lines of the caterer after landing. A separate analysis was carried out in this study to evaluate the quantity and composition of food waste generated from inflight services.		
not relevant	not relevant	no specific data on food service	159: Lundqvist J., de Fraiture C., Molden D.(2008), Saving Water: From Field to Fork – Curbing Losses and Wastage in the Food Chain
cannot find reference https://portal.mtt.fi/portal/page/portal/mtt/hankkeet/foodspill/Food%20Waste%20Volume%20and%20Composition%20Focus%20on%20Food%20Service%20Sector.pdf	Food service sector • The amount, type and origin of avoidable food waste were investigated in 72 restaurants in Finland. • Weighings in a one week period • 3 Personnel workshops	The amount, type and origin of avoidable food waste was investigated in 72 restaurants including schools, day care centers, hospitals, work place canteens, restaurants and fast food outlets. Restaurant chiefs and workers kept a diary and weighed the food produced and wasted in a one week period. For weighing and sorting, the food waste was divided into three categories in accordance with its origins: kitchen waste, service waste, and leftovers. In addition the food waste was divided into two categories so that the edible waste was separated from inedible waste. According to the results around 75–85 million kg of food was wasted annually in the Finnish food service sector; 12–14 kg per Finnish	173:Silvennoinen Kirsi, Koivupuro Heta-Kaisa, Katajajuuri Juha-Matti, Jalkanen Lotta, Reinikainen Anu (2012), Food waste volume and composition in the finnish supply chain: special focus on food service sector

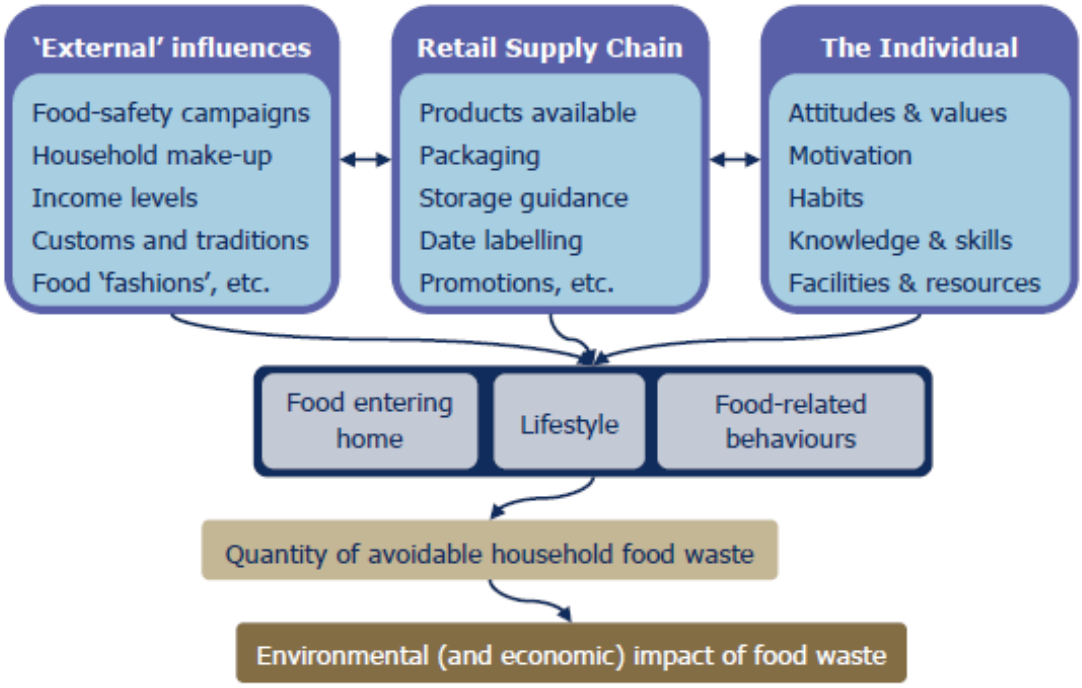
The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s)
		citizen. This covers about 20% of all food handled and prepared in restaurants and catering businesses. The findings also suggest that the main reason for food waste in the sector is serving waste from buffet and overproduction of food.	

Households

The generation of food waste in the home can be thought of as a complex interplay between food purchased, people's behaviour in the kitchen and whilst shopping, and their lifestyle (Figure 1).

Each of these elements is influenced by a large number of factors. The result of this complexity is that measurement is not straightforward – different quantitative techniques are more suitable depending on the objective under research.

Figure 1 – Influences on the quantity of food waste in the home



Source: Dr Tom Quested, WRAP

Furthermore, measuring the amount of food waste generated in the home can be difficult to achieve for the following reasons:

- As activities in the home around food are highly habitual, people are often unaware of the quantity of food they throw away. In addition, once food has entered a bin, it is often forgotten. This means that asking people how much they throw away is not as reliable as direct measurement of food waste.
- Due to the complexities around food waste, it is currently not possible to estimate the reduction in food waste from a change in behaviour(s).
- Food is disposed to several different routes and therefore several strands of work are required to estimate all waste arising.

Several techniques have been developed to deal with this complexity, and these are described in this report. Inputs from wider literature have also been used / described where possible, but it's fair to say that there are few reports in the literature database that comprehensively describe their quantitative techniques. Most refer to data from other research, notably WRAP reports. Therefore, the majority of this report describes in

detail the approaches developed and used by WRAP, alongside methodologies developed by other people and organisations.

Two elements to quantifying waste arisings are important, but not discussed in detail here:

- Conversions - A range of options were described in the literature to convert waste arisings to e.g. financial impact (using food prices, waste disposal costs), nutritional loss, embedded carbon, embedded water, volume equivalents etc.
- Contextual factors - Important when making comparisons between waste arisings in different geographical areas e.g. adjusting for population size, socio-demographics, culture all of which can have both an indirect and direct effect on arisings.

Compositional analysis[3] (ref 161, 108, 154, 147, 149, 153)

Waste composition analysis is the analysis of domestic, industrial and commercial waste streams. Waste streams can be characterised by a range of factors to give detailed information e.g. on the types of food wasted, its 'avoidability' and its preparation state.

Project steps

- Design sampling regime – for budgetary reasons this is likely to include clustered sampling to reduce travel and set-up costs of the sorting
- Select collection routes and properties.
- Survey potential participants to gather contextual information about their household, their attitudes and behaviours around food, and obtain consent for waste collection phase of research.
- Use completed questionnaires to develop collection record sheet.
- The route and approximate timings of the collection are agreed with the local authority. Households selected for study would usually be drawn from the middle of a route to ensure waste can be collected ahead of the usual local authority collection round.
- All collection staff display photographic identification, and carry a letter of authority from the council explaining that they are authorised to carry out the work.
- Collect materials in non-compacting vehicle.
- Sort, analyse and record materials collected from each household (see below).
- After the analysis, collected waste will be disposed of in the usual way, just as if it had been collected as normal by the local authority.

Things to consider:

- The sample needs to include at least a few hundred households – the exact number depends on the level of detail required in the results and the use to which the results will be put: tracking trends over time will require relatively high numbers of households.
- Sampling of households (e.g. rurality and social grade), local authorities & waste collection rounds needs to reflect the overall geographic region of study e.g. be nationally representative.
- How flats or properties with shared waste collection will be included in the research[4] or controlled for if excluded (e.g. through analysing differences between flatted properties and houses in diary research / surveys).
- Where collection of residual or organic material is fortnightly or monthly, all materials should be collected over a complete collection cycle to take account of any variation in behaviour within this period.
- It is recommended that signed consent is given by the householder from whom waste will be collected for analysis.
- Any information collected about the householder should be treated as strictly confidential.

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[3] This would seem to be the same as what is occasionally referred to as waste morphology (ref 154, 147, 149, 153).

[4] For many studies, it is necessary to link food waste to individual (yet anonymous) households to help establish the link between demographic information and waste. This means that households for which waste cannot be identified (in a shared bin or waste receptacle) may have to be omitted from the research. Omission of flats will be partially counteracted by weighting of the calculations, which takes into account that flats generally have fewer occupants than houses. However, weighting does not take into account any other differences between flats and houses that impact food and drink waste generated.

- Any waste collected from households should be disposed of in the usual way, just as if it had been collected as normal by the local authority.
- Which member of the household will be invited to participate in the pre-survey (if undertaken) e.g. adults who are either solely or mainly responsible for food shopping or food preparation.
- It is important to recognise that a pre-survey (if undertaken) could affect actual behaviour to some extent. In order to mitigate any research effect, a period of least two weeks should be left between the end of the survey period and the waste collection data.
- Materials will need to be accurately specified during the sorting / analysis stage to ensure results aren't misleading e.g. cooked pasta will weigh more than dry pasta because it has absorbed water. When compared to purchasing data, adjustment for cooking may need to be done.
- Assumptions will need to be made relating to whether the effect of particular weather conditions /season[5] on extent to which results are representative of e.g. a whole year. For example the types of foods available & eaten / rate of spoilage may differ according to the weather, and the extent to which people eat at home will differ in holiday periods.

Food waste diary (ref 161, 108, 174, 242, 76)

Food waste diaries enable researchers to determine quantities, disposal routes and reasons for disposal. This includes disposal to waste streams that are hard to measure from compositional analysis (e.g. what is poured the kitchen sink, home composted or fed to animals).

Diary research is able to obtain approximate estimates for quantities of food waste, but appears to suffer from under-reporting. For instance, analysis of food waste diaries and compositional analysis in 2007 in the UK suggests the diaries were under-reporting by around 40%[6]. The degree of under-reporting appears to be dependent on many factors including type of food, number of people in the household, length of the research and design of the diary.

It is suggested that each household is surveyed before and after the diary research via a questionnaire, giving information on attitudes, stated behaviours, demography etc.

There can be an element of underreporting and diaries may also influence people's behaviour. Therefore any estimates obtained need to be treated with caution. The degree of under-reporting, and the extent to which this can be quantified and corrected for will be investigated at the analysis stage (for example through post-diary surveys).

Project steps

1 Design sampling regime.

2 Develop survey and diary materials (see below).

3 Recruit householders to participate in the diary.

4 A telephone survey with the diarists three weeks prior to the diary completion. To gather contextual information about their household, their attitudes and behaviours around food.

5 Diary fieldwork: One-two weeks in which households complete the diary.

6 Post-diary questionnaire: A telephone interview with the diarists after diary completion. The main purpose of this will be to identify any shifts in the baselines recorded from the pre-diary questionnaire and to understand how respondents now view different food and drink waste issues.

The main feature of the diary will be to enable householders to record their food and drink waste throughout the week on a daily basis (to allow for an understanding of the impact of weekend or any daily activities/celebrations). For each item of food or drink waste, the following information will be recorded:

5 A review of single phase data from the Defra WR0119 project indicates that there is limited seasonal variation in food waste, though with slightly higher arisings in autumn.

6 MSc thesis " To what extent are quantifications of the level of household food waste from a seven-day, self-recorded diary method comparable with those from a compositional analysis method?", Høj, S., University of South Australia, available from WRAP on request.

- Description of the food or drink waste; this will allow analysts to assign a food group and food type category to each item and the 'avoidability' group.
- The brand of item or if it is home-made; this will allow more accurate allocation of pricing.
- The original state of the item; this allows more accurate pricing and possible analysis by items that are dried, chilled, tinned, processed, fresh or frozen.
- Source of the food; home grown (this is important to understand the extent to which the cost of food waste relates to items that were not originally purchased), home-made, pre-prepared, ready-to-eat, take-away.
- The amount of waste; where this is not by weight, analysts will convert the volume or description (e.g. litres, ounces or cupful) to grammes.
- The pack category of waste – this is to identify items that have been disposed of in a pack (for example, a pack of six rolls).
- The extent to which the item is whole (unused) or partially consumed (e.g. a whole apple or half an apple) or by pack (e.g. unopened/full pack of six rolls or three rolls in a pack that originally held six).
- Method of disposal; including mixed waste, composted, sink, drain, toilet, garden, fed to animals.
- Reason for disposal; including: Cooked too much. Served too much. Past best (mouldy, air-damaged, sprouting, damaged packaging, smelt or looked bad). Ruined (dropped, burnt, melted, fridge or freezer failure, too much salt, contamination). Did not like taste/look. Past food date (with note of use by / best before). Leftovers kept too long or inadequate to make a new meal. Clear out (no longer wanted after shopping for new/ items, 'spring'-cleaning). Illness / health issues (e.g. sore throat – can't swallow, baby off food). Not normally eaten (potentially avoidable food waste, such as pie crusts, soft fruit and vegetable peelings). Not possible to eat (unavoidable food waste such as bones, used tea bags and hard fruit and vegetable peel).

The diary will also capture a daily review: a closing entry for the day in which the respondent records:

- Lifestyle and health issues that may affect the type or amount of household food waste.
- Relevant social or lifestyle issues (for example, the children had friends over for tea or they hosted a dinner party).
- State how they feel about the day's waste – are there any waste items that they regret / are unconcerned about (and why).
- Daily shopping activity that has occurred including how much was spent.

Things to consider:

- The sample needs to include at least a few hundred households.
- Sampling of households (e.g. rurality and social grade), local authorities & waste collection rounds needs to reflect the overall geographic region of study e.g. be nationally representative.
- Any information collected about the householder should be treated as strictly confidential.
- Which member of the household will be invited to participate in the diary (and both surveys; if undertaken) e.g. adults who are either solely or mainly responsible for food shopping or food preparation.
- It is important to recognise that a survey (questionnaire) of waste disposal behaviour could affect actual behaviour to some extent. In order to mitigate any research effect, a period of least two weeks should be left between the end of the survey period and the diary period.
- To help householders complete the diary accurately, a pack could be provided containing the professionally printed diary which includes full instructions, pen, self-addressed envelope to return the diary, fridge/bin magnet (reminding diarists of daily completion), measuring jugs/spoons.
- There may be benefits to starting the diary week mid-week as there may be some level of respondent drop-off as time passes and it will be important to capture weekend vs. weekday data.
- Throughout the fieldwork it is suggested the researcher maintains regular contact (phone, email and text) with each household to resolve any issues, encourage participation and full, accurate completion of the diary.
- The act of weighing / recording may in itself also reduce waste.
- Assumptions will need to be made relating to whether the effect of particular weather conditions / season on extent to which results are representative of e.g. a whole year. For example the types of

foods available & eaten / rate of spoilage may differ according to the weather, and the extent to which people eat at home will differ in holiday periods.

- Households that take part in the full research programme (diary and surveys) could be offered a financial incentive.
- It's suggested a small-scale pilot is conducted. This will inform the development of the final version of the diary and questionnaire.

Local authority synthesis (ref 42)

A local authority (LA) synthesis is a method for collating compositional analyses performed by municipalities (local authorities).

In many countries, municipal and regional governments will commission studies to examine the waste they collect (or is collected on their behalf by waste contractors). These studies classify the waste into different materials, usually 15-40 depending on the detail required and the amount to be sorted. Food waste is usually one of these categories and sometimes this is further subdivided: e.g. home compostable / non-home-compostable; packaged / non-packaged.

A LA synthesis study is a secondary piece of research that collates information from a large number of compositional analyses (primary research). These are combined to obtain estimates of food over a greater geographic area (usually a nation). They also have the advantage of greatly decreasing the confidence intervals around estimates – effectively by increasing the sample size.

Many LA synthesis studies combine compositional analysis data with waste-monitoring data from municipalities. For instance, in the UK, all local authorities must record the amount of waste collected from households and submit it to the WasteDataFlow[7] system. This information includes quantities for individual waste streams and materials. Once checked, the data is published and can be used in these synthesis studies, often negating the need for all waste streams to be sampled: for instance, local authorities which have separate food waste collections will record the amount in WasteDataFlow and therefore do not need further sampling to determine the quantity of waste.

Ref 42 - The methodology consists of collating compositional datasets for local authority collected waste, carried out in the *England* from *2008* onwards (Figure 3).

These datasets were analysed alongside WasteDataFlow tonnages for all local authorities in *England* for *2010/11*. Although many of the waste audits were carried out outside this period, a single WasteDataFlow year had to be selected in order to build national estimates, and 2010/11 was the best fit year for the data available. Care was taken to avoid double counting of waste or recycling streams by waste collection and disposal authorities in two tier areas.

Waste audit data on residual streams was used to estimate the arisings of different components in the residual streams reported in WasteDataFlow. Average arisings for residual waste across the studies available were calculated. Alternative approaches for weighting, particularly, for kerbside residual waste, were tested for the project, but it was found that these only had marginal effects on the results. Furthermore it is considered that the coverage for kerbside residual datasets is good and that weighting the results would not increase the robustness of the estimates produced.

Summary

As indicated at the beginning of this report, the generation of food waste in the home can be thought of as a complex interplay between food purchased, people's behaviour and their lifestyle, each of which is influenced by a large number of factors.

Furthermore, measuring the amount of food waste generated in the home can be difficult to achieve for several reasons. A key one being that food is disposed to several different routes and therefore several strands of work are required to estimate *all* waste arising (Table 1).

[7] *http://www.wastedataflow.org/*

Table 1 - Data sources used to estimate household food waste arisings by WRAP (ref 161)

→Objective of study ↓Disposal route	Amount of food wasted	Type of food wasted	Reason for waste
Residual waste	Local authority synthesis	Detailed compositional analysis	Kitchen diary
Council food waste collections (inc. mixed with garden waste)			
Kitchen sink	Kitchen diary	Kitchen diary	Kitchen diary
Home composted			
Fed to animals			

Source: Dr Tom Quested, WRAP

A LA synthesis research will have the largest coverage of compositional analyses (and therefore the most accurate estimates), but won't have sufficient detail on the types of food and drink wasted. This will be supplied by detailed compositional analysis, focusing on different types of food waste. However, compositional analysis is a poor research method for determining why food is thrown away – it's often not possible to tell why food is in the bin just by examining the waste. The reasons why food is wasted will be supplied by the kitchen diary research. It is not possible or practical to use compositional analysis to analyse material poured down the kitchen sink, home composted or fed to animals. Therefore, these estimates will also come from kitchen diary research.

For example, to calculate the amount of bread waste collected by local authorities (in the residual bin and collections):

- An estimate will be made of the total amount of food and drink waste collected by local authorities from the local authority synthesis research.
- The % of local authority collected waste that is bread will be calculated from detailed compositional analysis research and this % will be applied to the total food waste previously calculated.

For both of the points above, each estimate should be weighted in the most appropriate way for that research. For instance, the amount of food waste (from the LA synthesis research) will likely be weighted by (amongst other factors) presence of a food waste collection. The compositional analysis will be weighted by household size (amongst other factors).

The reasons for throwing away food will be calculated from the kitchen diary and applied to the total amount of food (across all disposal routes).

Other quantitative techniques

Ethnographic research (ref 106)

Ethnographic studies involve observation and discussion of food- and waste-related practices in the environment in which they occur. This can include in-home interviews / discussion, accompanied shops, and discussions around the contents of a fridge. These provide very detailed understanding of food waste behaviours and some of the underlying reasons why food is thrown away. However, they are rarely suitable to quantify household food waste arisings as the number of households researched is usually small (usually much less than fifty). It also has the potential to suffer from the research effect (i.e. the researcher influencing behaviour and quantities of waste produced).

Also similar in scope is 'plate examination' research (ref 76, 78). This method involves examining what people are throwing away from their plates (and often what is put on their plates in the first place). It is often used in hospitality / catering settings, but can also be applied in the home. This enables researchers to understand waste arising at a

specific point in time – after serving – but does not give an overview of all waste in the home. It also has the potential to suffer from the research effect.

Surveying consumers (ref 179, 121, WRAP unpublished)
There are two main ways in which surveys might be used to estimate waste arisings:

1. Directly asking respondents how much they think they waste; and
2. Estimating the potential trend in household waste arisings by analysing responses to a suite of behavioural questions.

There are a number of different forms of the question that can be asked to elicit the level of food waste. Important considerations are:

- The time period over which the estimate if being made;
- Whether the estimate is being made for an actual period of time (e.g. last week) or a typical or average period of time (e.g. 'in a normal week');
- The units of estimation: monetary, weight, volumetric or equivalents (e.g. shopping bags).
- The level of disaggregation of food waste – whether asking about total quantities, types of food and drink, the preparation state of the waste, the reasons for the waste, etc.

For example, the questionnaire associated with the *Love Food Hate Waste* campaign in New South Wales, Australia (ref 179) asked for monetary and volumetric estimates over a 'normal week'.

"In a normal week, please estimate how much of the following food types your household throws away (including going to the compost, worm farm or pets). Please use a 4 Litre (4L) ice cream container as the way of measuring this total, and include the amount, if any, that you composted or fed to animals.

"In a normal week, please estimate the dollar value of each food type that your household purchased but threw away without being consumed (including going into the compost, worm farm or fed to pets). Please make your best estimate in whole dollars."

Reference 121 also asks for monetary and volumetric estimates, but asks about 'the **past** week'. Both this and ref 179 give information on the types of food and drink being thrown away.

WRAP has used a more general question in the past:

"Thinking about the different types of food in the previous question, how much uneaten food, overall, would you say you generally end up throwing away?

- Quite a lot
- A reasonable amount
- Some
- A small amount
- Hardly any
- None
- Don't know"

The question does appear to segregate the population relatively effectively. Those responding 'Hardly any' or 'None' do was substantially lower amounts from those responding 'Quite a lot' or 'A reasonable amount'.

Given this segregation, this question was deployed to track food waste levels without having to use compositional analysis. However, as the discussion below indicates, the question was not able to provide a reliable tracking measure. This is most likely as awareness of food waste is likely to change due to campaigning on food waste and broad

financial conditions (e.g. a recession). This means that people may choose a higher level of waste in the survey even if they are wasting the same amount.

However, directly asking respondents how much they think they waste is problematic for the following reasons:

- Respondents may not understand the question in the way the researchers want it to be understood. For example, 'the past week' may be the last seven days, the last full week (e.g. Monday – Sunday), or since last Monday (i.e not a full seven days).
- Respondents may give what they believe to be the 'right' (sociably desirable) answer (particularly when questioned face to face).
- In relation to asking about waste arisings specifically, respondents may have a different idea of what is 'waste'. For example, it is common for unavoidable waste, and food fed to pets or home composted not to be considered as 'waste'.
- Respondents may not have an accurate picture of the amount of food thrown away in their home. They may quickly forget about material in the bin and they may be unaware of food thrown away by other members of the household. Recall of past waste will be increasingly inaccurate as the period of recall extends.
- Even if respondents remember all that they have thrown away, they may not be able to accurately express how much they waste. For example, some people think in terms of number of items, others shopping-bags full, others volumetric measures such as cups: including multiple measures can circumvent this to some extent. Furthermore, pictures of different food waste amounts or descriptive comparisons could be used to help improve accuracy e.g. 'number of heaped dinner plates'.

Given the shortcomings of an accurate survey-based method for tracking the amountof food waste generated at a population level, WRAP (Dr Tom Quested, Dan Stunell, Dr Andrew Parry) developed a method to assess changes in behaviours related to household food waste. This 'behavioural scorecard' measures the extent of behaviours associated with food waste prevention in the home.

The scorecard draws together a large amount of information on a number of behaviours, allowing an 'at-a-glance' assessment of current behaviours. The scorecard also provides a clear link to more detailed information on individual behaviours. The scorecard is composed of nine behaviours selected for their relevance to household food waste. These were selected on the basis that they were likely to be applicable to large parts of the population, are legitimate for WRAP & its partners to try to influence and are likely to have a large impact on food waste arisings.

Questions for each of the behaviours were drafted and then cognitively tested to ensure that they obtained information on the behaviours of interest from the vast majority of respondents. In some cases, different variants of the questions were tested and the one producing the highest quality response was selected. The final behavioural questions were also tested to see if there were differences between responses when administered online or face-to-face.

The overall behavioural score for a population is determined by taking the average of the scores for the nine constituent behaviours. Scores are calculated only for respondent for whom they are relevant – for instance people without freezers are excluded from calculations on freezer use.

The score for each behaviour ranges from zero to ten, where zero is the behaviour most likely to lead to food waste, and ten the least likely. Therefore, an increase in any behavioural score would represent a higher level of waste-preventing behaviours.

WRAP undertakes an online survey for around 3000 UK adults twice a year to calculate the behavioural score.

The overall behavioural score – the average of the nine behaviours – is intended to give a headline indication of changes in behaviour of the population and is used to monitor progress against WRAP's targets. There is evidence that improvements in the scorecard behaviours, both individually and collectively, have a positive impact on food waste

reduction. However, this evidence does not allow us to quantify the scale of food waste reduction at present, given the complex interaction of behaviours in this area, and the fact that these behaviour are representative rather than comprehensive.

Example behaviour from WRAP's scorecard - Meal planning behaviour

Question – To what extent do you decide what you are going to eat for main meals in advance (tick one statement only)

I know what almost all the main meals will be for the next week (Behavioural score of 10)

I know what most all the main meals will be for the next week (Behavioural score of 7)

I know what a few of the main meals will be for the next week (Behavioural score of 3)

I usually decide on the day (Behavioural score of 0)

Don't know / can't remember (Excluded)[8]

Secondary data analysis (ref 1, 18, 82, 84, 87, 98, 124, 168, 78, 92)
Secondary data analysis is the use of data that was collected by someone else for some other purpose. In this case, the researcher poses questions that are addressed through the analysis of a data set that they were not involved in collecting.

In determining food waste in the home, some examples of using secondary data include:

- Using national consumption studies to understand how much food is consumed (compared to how much is purchased; the difference is assumed to be the amount of waste). This consumption data is often obtained from diary keeping research. There may sometimes be misinterpretations of what"consumption" refers to in consumption statistics; is it purchase or actual intake? Sometimes "consumption" may be the same as purchase?
- Using purchase data (see above for one major use). This data may come from Governments (trade or tax data, diary research), market research companies, or grocery trade bodies.
- BMI (body mass index) data to help understand consumption levels. This data usually comes from Government research projects (e.g. ref 84).

When using secondary data in an analysis, it is important for the researcher to become familiar with the data set, including how the data was collected, what the response categories are for each question, whether or not weights need to be applied during the analysis, whether or not clusters or stratification needs to be accounted for, who the population of study was, etc.

Advantages

- Economic: Someone else has already collected the data, so the researcher does not have to devote money, time, energy, and other resources to collection of primary data.
- Breadth - The government, for example, conducts numerous studies on a large, national scale that individual researchers would have a difficult time collecting. Many of these data sets are also longitudinal, meaning that the same data has been collected from the same sample or population over several different time periods. This allows researchers to look at trends and changes of phenomena over time.

Disadvantages

A major disadvantage of using secondary data is that it may not answer the researcher's specific research questions or contain specific information that the researcher would like to have. Or it may not have been collected in the geographic region desired, in the years desired, or the specific population that the researcher is interested in studying.

[8]There is a strong correlation between shopping frequency and the responses to this question – people who shop daily are more likely to decide what to eat on the day. For this reason, shopping frequency needs to be controlled for when analysing trends in the behavioural score.

A related problem is that the variables may have been defined or categorised differently than the researcher would have chosen.

Another major disadvantage to using secondary data is that the researcher/analyst does not know exactly how the data collection process was done and how well it was done. The researcher is therefore not usually privy to information about how seriously the data are affected by problems such as low response rate or respondent misunderstanding of specific survey questions.

The next two sections give examples of secondary data use within the household food waste literature.

Using waste data

The most comprehensive in terms of geographical coverage (EU-27) is provided by the Preparatory Study on Food Waste (ref 87)[9].

Ref 87 - The principle source of data on food waste generation was EUROSTAT27, which lists data for the 27 EU MS in the following categories:

- (EWC_09) Animal and vegetal wastes
- (EWC_0911) Animal waste of food preparation and products
- (EWC_093) Animal faeces, urine and manure

From these a further waste stream, more pertinent to the current study, can be calculated:

- (EWC_09_NOT_093): Animal and vegetal waste excluding slurry and manure

The NACE sector for households = HH

EUROSTAT (EWC_09_NOT_093) data for the (HH) sector, as well as the data produced by MS studies. EUROSTAT data for households contains discrepancies that cannot be explained by other factors, such as differences in GDP or environmental awareness. As methodologies for collecting and calculating household data seem to vary so widely among MS EUROSTAT disclosures, a minimum scenario has been used to compare with both EUROSTAT and national data.

Important limitations accompany this work of quantification, resulting from the variable reliability of EUROSTAT and national data. Methodologies for collecting and calculating the food waste data submitted to EUROSTAT differs between MS, who are free to choose their own methodology. Limitations in the reliability of EUROSTAT data, due to a lack of clarity on the definition and methodology, may be significant. Implications may involve the inclusion of by-products, green waste or tobacco in the data disclosed in some instances.

Additionally, data is missing for some sectors in some MS. These issues have been ameliorated using national studies, plausibility checks and informed assumptions as far as possible in an effort to present the best available data; however, these limitations nevertheless present an important issue for data reliability. The level of risk depends on how the estimates are used:

- Lower risk – estimates are used to identify the potential scale of food waste arisings.
- Higher risk – estimates are used to make comparisons between different geographical regions.

Using purchase and / or consumption data

Other approaches use purchase and / or consumption data, which are described below:

Ref 98 - The first step of the procedure calculates available kcal quantities at the beginning of the food supply chain, at stage (1; Agricultural Production). The analysis uses the available kcal/person/day quantities of Switzerland, which correspond to availability at stage (3; Processing and Packaging).

[9] *The LA synthesis method described above could also be classified as secondary research, but is included above because of the way WRAP uses it with other methods such as compositional and diary research.*

Loss rates add up to the available quantities in stage (3): firstly adding the losses occurring at stage (2; Postharvest Handling and Storage); secondly, losses happening in stage (1) are calculated, adding up to the newly calculated quantities available in stage (2). This yields total quantities available at the beginning of the Swiss food supply chain, in other words, the kcal/person/day available at stage (1).

The second step is to merge the data of the first stages of the food supply chain with the information of caloric intake per person and day in Switzerland. This corresponds to the last stage of the FSC, stage (6; Consumed). The difference between quantities at stage (1) and at stage (6) are defined as the total food waste quantities taking place in the Swiss food supply chain.

According to the authors, the analysis uses the quantities of available calories in Switzerland as well as the estimated average caloric intake (both expressed in quantities per person and day). The difference between supply and intake is assumed to account for food waste. The used procedure is partially adapted in order to also assess for losses occurring before the stage where available kcal have been assessed.

Ref 124 - The difference between the total amount of commodity used by the food system (supply) and the total amount of food eaten (intake) is an indicator of the potential waste.

Ref 76 - Household food consumption estimates can be made of nutrient intake per capita by multiplying average food consumption data by nutrient values of foods from nutrient data tables.

Ref 78 - Inferential waste estimation uses food waste factors derived from diary, plate analysis, and material culture research to calculate food waste. These factors are assumed to present an accurate representation of food waste. The inferential method is nonreactive—consumers are unaware their food behaviours are being examined and therefore do not alter their behaviours.

Where estimates of household food waste are derived from subtracting consumption estimates from purchase estimates, care needs to be taken that uncertainties in the consumption and purchasing estimates are sufficiently small to allow such a comparison.

Table 16 Summary for "households" step in the supply chain; purpose, approach and main finding of the reviewed studies

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
The study highlights the losses occurring along the entire food chain, and makes assessments of their magnitude. Further, it identifies causes of food losses and possible ways of preventing them.	• Food waste as fraction of total waste flows (examples; figures based on economic data/invoices, municipal statistics)	Per capita food wasted by consumers in Europe and North-America is 95-115 kg/year, while this figure in sub-Saharan Africa and South/Southeast Asia is only 6-11 kg/year. More than 40% of the food losses occur at retail and consumer levels. Food waste at consumer level in industrialized countries (222 million ton) is almost as high as the total net food production in sub-Saharan Africa (230 million ton).	1
How can waste reduction help to healthily and sustainably feed a future global population of nine billion people?	• Food waste as fraction of total waste flows (examples; figures based on economic data/invoices, municipal statistics) • Estimates based in Interviews with key personal	Brazil - The current wastage rate of purchased food is estimated to be 20-40% of the food bought by the average household, with an estimated value of US$2 billion per year. Total post consumer food waste is estimated to be 26 million tonnes/ year, sufficient food to feed 15 million (equivalent to the total number of Brazilians with high food insecurity). The total vegetable waste is estimated to be 37 kg per year and consumption per capita is 35 kg per year, so there is more wasted than consumed. China - About 40% of dishes are left at the dinner and lunch tables uneaten when eating out. India - There is no culture of food waste outside the top 30% income group. UK (WRAP) - About 5.3 million tonnes of food/ drink waste in the UK is regarded as avoidable, with an equivalent value of £12.2 billion (or £680/family household/ year).	18
Estimate food and drink waste	• Data based on a micro (from business unit/municipality) or	It is estimated that 8.3 (±0.31) million tonnes per year of food and drink	161, 42, 163,

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
arising in the home.	macro approach (branch or national statistics) • Food waste as fraction of total waste flows (examples; figures based on economic data/invoices, municipal statistics) • Surveys among user groups (examples; toll studies of representative number of persons, focus groups) • Statistics from national authorities or waste management organizations	waste is generated by households in the UK. This is the equivalent to 330 kg per year for each household in the UK, or just over 6 kg per household per week. Of this, 5.8 million tonnes per year (70%) is collected by Local Authorities (Figure C) – mainly in the residual waste stream (general bin) and food-waste kerbside collections. A further 1.8 million tonnes per year is disposed of via the sewer. Of the avoidable food and drink waste, 2.2 million tonnes is leftover after cooking, preparing or serving and 2.9 million tonnes is not used in time (Figure E). As an overview, the amount of food (including liquid and solid foods but excluding drink) wasted per year is 25% of that purchased (by weight). For food **and drink,** the 8.3 million tonnes per year of waste represents 22% of purchases (again, by weight). November 2011 Update WRAP announced a reduction in total household food and drink waste of 1.1 million tonnes in November 2011. Avoidable food and drink waste reduced by 950,000 tonnes, and the associated value and environmental impact figures have been updated. Research to update our estimates for individual food and drink categories has not yet been carried out, and therefore all figures relating to the breakdown of avoidable food waste should be regarded as approximate. These remain however the best estimates currently available. (Refer to: 42 (synthesis) & 163 (new estimates). Total household LA-collected food waste arisings for the UK, in 2010,	108

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
		were 4,620,000 tonnes per year (± 160,000 tonnes), or 172 kg/hh/yr (±7).	
The objectives of this study were to: Identify the key causes of food waste in all sectors Establish a baseline of food waste data for the EU27 Quantify the environmental impacts of food across its lifecycle	Food waste as fraction of total waste flows	Households produce the largest fraction of EU food waste among the four sectors considered, at about 42% of the total or about 38Mt, an average of about 76kg per capita. The total quantity of household food waste for the EU, based on this selection, is found to be 37.7Mt, and 76kg per capita.	87
This paper examines the inefficiencies in the U.S. food system from the farm to the fork to the landfill. By identifying food losses at every level of the food supply chain, it provides the latest recommendations and examples of emerging solutions	Statistics from national authorities or waste management organizations	Getting food from the farm to our fork eats up 10 percent of the total U.S. energy budget, uses 50 percent of U.S. land, and swallows 80 percent of all freshwater consumed in the United States. Yet, 40 percent of food in the United States today goes uneaten. This not only means that Americans are throwing out the equivalent of $165 billion each year, but also that the uneaten food ends up rotting in landfills as the single largest component of U.S. municipal solid waste where it accounts for almost 25 percent of U.S. methane emissions. Reducing food losses by just 15 percent would be enough food to feed more than 25 million Americans every year at a time when one in six Americans lack a secure supply of food to their tables	168
The objectives of this research component were to: • provide a benchmark of community knowledge, attitudes and behaviour around food waste and food management at the household level	• Surveys among user groups (examples; toll studies of representative number of persons, focus groups) • Prevent/minimise food waste	Respondents estimated the average weekly value of the food they threw away: • fresh food, $6.60 • leftovers, $5.40 • packaged and long-life food, $2.90	179

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
• develop a segmentation of the NSW community based on food waste knowledge, attitudes and behaviours and identify the key target audiences for the program		• drinks, $1.80 • frozen food, $1.80 • home delivered/take away food, $1.40. The total value of food items wasted was $19.90 per average household, per week in NSW. Over one year, this amounts to $1,036 per household or $2,556 million for all of NSW (projection based on 2006 Australian Bureau of Statistics (ABS) census estimating 2,470,451 occupied households in NSW).	
Sixty-one families measured their amount of food waste during seven days and noted in a diary why each item was wasted. Thirty of the families had participated earlier in an environmental project including education in environmental issues of everyday life. About 20–25% of the households' food waste could be related to packaging.	Surveys among user groups (examples; toll studies of representative number of persons, focus groups) Prevent/minimise food waste	On average, the households discarded 1.7 kg of waste/household/week (*SD*=1.2). About two thirds of the food waste came from storage and one third from meals. Both groups state that almost 50% of the total amount of food is wasted because the food has gone bad. About 25% of the food is wasted because the households have prepared too much food.	174
Mapping the volume and composition of avoidable food waste in the Finnish households 380 families, (1054 persons) Two weeks study period (diary study	Surveys among user groups (examples; toll studies of representative number of persons, focus groups) Characterize and quantify food waste for one specific year	During the two-week study period the amount of avoidable food waste per person ranged from 0 to 23.4 kg. When extrapolated to describe the food waste over one year, the average annual avoidable food waste ranged from 0 to 160 kg per person, on average corresponding to about 23 kg of food waste per person each year (Silvennoinen et al., 2012a). On average 23 kg of food per person per year was wasted (and which was avoidable) in households based on this Foodspill study. In our study we calculated average household food waste from diary entries, and established that the *per capita* values were significantly lower than for	242

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
		other industrialised countries (e.g. Jones 2005, Knudsen 2009 and KFS 2009). However, the results from other studies are not directly comparable due to differences in methodologies - The act of weighing may in itself also have reduced waste. In addition, the respondents comprised more families with children and households with multiple people than the Finnish average. The average household size in the sample, 2.8, was markedly higher than that of an average Finnish household, which in 2009 was 2.08 (OSF 2010).	
Estimate the food wastage occurring between acquisition and food preparation; between food preparation and food serving to household members; and after food serving (plate waste) in the household	Surveys among user groups (examples; toll studies of representative number of persons, focus groups) Statistics from national authorities or waste management organizations	An average of 318.8g of food was discarded per day. The average daily discard per household and per person was 816.4g and 318.8g, respectively. The average amount of food discarded between food preparation and service was found higher (121.5g/person) than between acquisition and preparation (85.4g/person) and plate waste (111.8g/person). Where it is not possible to measure waste directly, an estimate should be made so that a correction factor could be used. According to this survey, conducted during the summer, this correction factor for food wastage was estimated as an average of 9.8% of the daily energy intake per person and an average of 8.9% of energy consumption.	76
The focus of the study is on methodology for conducting a community food waste analysis	Direct quantification and characterization of food waste (examples; scanning of wasted products (from bar codes), waste morphology studies based in samples and extrapolates (number of samples), mass balance estimates, municipal statistics)	Approximately 10,205 tons of food waste was generated annually in this community food system. Of all food waste, production waste comprised 20%, processing 1%, distribution 19%, and 60% of food waste was generated by consumers. More than 8.8 billion kilocalories of food were wasted, enough to feed county residents for 1.5 months. An estimated 6,146 tons of food waste was generated at the consumer level, more than any other stage in the county food system.	78

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
	Surveys among user groups Statistics from national authorities or waste management organizations	We doubled Rathje's estimate of 2.5 ounces/person/day to 5.0 ounces/person/day, and multiplied this factor by 365 days/year to estimate the amount of food waste per consumer.	
To develop & justify several recommendations for government	• Statistics from national authorities or waste management organizations	Looking only at waste in the home, and using various national data sources (which are not always entirely comparable), we find that the amount wasted per person per year is: 110 kg in Great Britain, 109 in the United States, 108 in Italy, 99 in France, 82 in Germany and 72 in Sweden. Waste at home contributes the most significant percentage of food waste: it is equal to 42% of the total (25% of the food expense per weight) and amounts to about 76 kg/year/person (60% of which could be avoided).	92
An analysis of household expenditure on food	Surveys among user groups (examples; toll studies of representative number of persons, focus groups)	Across Australia, households with an income of $40,000 or less reported wasting food worth $518 a year. This compares with food waste of $635 a year for households with an income between $40,000 and $80,000. Australian households earning more than $80,000 a year are wasting $803 in food annually	121
To evaluate the amount and composition of food waste	Direct quantification and characterization of food waste (examples; scanning of wasted products (from bar codes), waste morphology studies based in samples and extrapolates (number of samples), mass balance estimates, municipal statistics)	The sorting analysis showed a wide range (300 kg/cap.y) within the specific amount of residual waste for the different investigation areas. The difference between the maximum and the minimum edible related waste generation amounts to 200 kg/cap.y. This range can be seen as a maximum theoretical waste prevention potential. However, not all of these wastes can be prevented. On the one hand there are non avoidable fractions such as preparation residues. The proportion of easily avoidable edible waste (spoiled foods and leftovers) ranges between 10 % and almost 25 % of the total residual waste from Viennese households	154

The main purpose of the study	Type of methodological approach(es) has been used to characterize and quantify food waste	The main finding in the studies; amount of food waste, indicators used,	Reference(s): FUSIONS ID
This paper presents results from a driver review of food waste issues, combining information on food waste from the international literature and interviews with supply chain experts	Statistics from national authorities or waste management organizations		82
The aim of the work is to provide an appraisal of the production and consumption cycle for food used in Europe in relation to sustainable development and to provide recommendations on policy actions	Statistics from national authorities or waste management organizations	An average of at least 1.9 t CO2 eq./t is estimated to be emitted in Europe over the whole life cycle of food that is wasted. The overall environmental impact is at least 170 Mt of CO2 eq. per annum. The main life cycle environmental impact of food waste is considered to be GHG emissions, predominantly methane. The impacts of food waste on water use are also significant, with WWF and WRAP estimating that producing the food that is wasted in the UK consumers 6,200 million cubic metres of water per year, about six percent of all water used for food eaten in Britain. Three quarters of this water use occurs abroad.72 In addition, according to UK estimates, over a quarter of avoidable food waste thrown away is still in its original packaging and the total annual financial loss per household is approximately £480 or 565 Euros.	124

Annex 2 References for extensive literature review

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