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Food waste and climatic impacts of food consumption – the case of Sweden.

Master's thesis in Industrial Ecology

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2015
Report No. 2015:20

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Acknowledgements

I would like to thank my supervisor Fredrik Hedenus (Chalmers University of Technology) for his guidance, motivation and inexhaustible patience during this project.

Many thanks to the MIND Professors Ulrika Lundqvist (Chalmers University of Technology) and Ralf Aschemann (Karl Franzens Universität Graz) for encouraging me to complete the MIND experience, during the happiest but rather complex period of my life.

This Master's Thesis is part of the MIND Program (Erasmus Mundus MSc in Industrial Ecology - http://www.emmind.eu/).

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Abbreviations

AW: Avoidable Waste
AW-Emissions: GHG Emissions attributed to AW
CFWA: Compositional Food Waste Analysis
FAO: Food and Agriculture Organisation of the UN
FAOSTAT: FAO, Statistics Division
FBS: Food Balance Sheets
FSC: Food Supply Chain
FW: Food Waste
GHG: Greenhouse Gases
LAFA: Loss Adjusted Food Availability
LC: Life Cycle
LCA: Life Cycle Assessment
SEPA: Swedish Environmental Protection Agency
SIK: Swedish Institute for Food and Biotechnology
WRAP: Waste & Resources Action Programme, UK

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ABSTRACT

Global food losses and waste have been estimated to constitute 1/3 of global food production. The creation of unnecessary wastage and the pointlessly produced greenhouse gas (GHG) emissions are among the crucial impacts of this phenomenon. Consumers in developed countries produce a significant proportion of "avoidable" food waste (AW) (i.e. dispose of edible portions of food), while they could play a key role in limiting it, by adapting their consumption behaviour & habits.

This thesis investigates the impacts of Swedish food consumption in terms of AW and GHG emissions and potential ways to achieve reduction of both. Waste and emissions are calculated, by making use of data on dietary choices, proportions of wastage and lifecycle emissions. Two scenarios of AW and AW-emissions reduction are examined: A. the maximum reduction potential, if zero AW is produced, and B. a reduction potential as a result of the implementation of an action plan aiming at the major reason of AW observed in the commodity groups with the highest AW and AW-emissions.

The results show that if all avoidable waste is eliminated, the yearly per capita edible portion of purchased food would be reduced by 16% and the corresponding GHG emissions by 14%, while the total quantity of food waste may be reduced by 64% (Scenario A). By researching a practical way to limit the studied impacts, an action plan is recommended targeting at two factors: major contributors in AW and AW-emissions and their principal reason of disposal. Six commodity groups (like "meat & meat products", "fruits and vegetables", "cereals", etc.) were identified as "major contributors" in AW and/or AW-emissions; the majority of the detected food items were disposed of because they were "not used in time". A series of measures against those two factors may reduce the yearly per capita edible portion of purchased food up to 9%, the corresponding emissions by 8% and the total waste up to 38% (Scenario B). The proposed measures (e.g. on labelling or expiration dates) are to be taken within a wider strategy aiming to limit FSC impacts, involving consumers, food industry and other stakeholders.

Key words: food waste, greenhouse gas emissions, food consumption, and food consumption impacts.

1. INTRODUCTION

Background

Food waste is nowadays a hot topic in food-related research: it has been found that 1/3 of global food production (1.3 billion tonnes) is lost or wasted unconsumed every year (Gustavsson et al. 2011). The identification of losses throughout the Food Supply Chain (FSC) has triggered a series of reactions from the global community. Scientists (e.g. Vermeulen et al. 2012), activists (e.g. Food Cycle Charity/UK[1], Food Rescue Project/ Chalmers Students for Sustainability/Sweden[2]) and other stakeholders (e.g. FAO/UN, SIK/SE, WRAP/UK) are working on identifying, quantifying and limiting this phenomenon and its impacts.

Food losses and waste occur at all stages of Food Supply Chains (FSC) and are influenced by factors like the economic status of an area, the agriculture and market practices, the cultural habits, etc. As described in literature (Gustavsson et al. 2011; Vermeulen et al. 2012; FAO 2013; Parfitt et al. 2010), food wastage is interestingly related to regional affluence: high-income areas present higher wastage at retail and consumption phase (e.g. around 34% of wastage in Europe occurs at consumption level, FAO 2013); while in developing countries this percentage is much lower (4-16%, FAO 2013), but the main losses appear at postharvest handling and storage FSC stages, mainly due to limited techniques/systems used (Parfitt et al. 2010; Gustavsson et al. 2011).

Modern Food Systems

Nevertheless, the issue of food waste should be examined by considering the status of the contemporary food system, including the principles of demand and supply and the coverage of a basic need, that of nutrition.

UN initiatives, like "Zero Hunger Challenge" and "Millennium Development Goals"[3] stress the importance of availability and affordability of nutritious food for the growing human population (UN-DESA 2013) to safeguard human health and well-being. In parallel, increasing food demand also occurs due to the expansion of urbanisation, the consumption habits and dietary shifts towards higher-calorie diets (Pradhan et al. 2013b) and products with higher environmental impact and waste production (Parfitt et al. 2010) by populations in wealthy and emerging economies.

To cope with these challenges, food industry introduces more efficient or new production techniques, new products (sometimes ultra-processed), new delivery processes and more effective marketing/retail methods (Parfitt et al. 2010; Monteiro & Cannon 2012; Vermeulen et al. 2012).

[1] http://foodcycle.org.uk/
[2] http://www.chalmers.se/sv/nyheter/Sidor/Chalmerister-serverar-raddad-mat.aspx
[3] For more details visit: UN-Zero Hunger Challenge (http://www.un.org/en/zerohunger/#&panel1-1); UN -Millennium Development Goals (https://www.un.org/millenniumgoals/

Food Industry and Greenhouse Gas Emissions

Modernised food systems are particularly extended and complex, extensively resource demanding and rather polluting (Vermeulen et al. 2012). Besides the social influences, the loss of valuable resources (water, land, energy) and the environmental load (acidification, eutrophication, chemical pollution, etc.) (FAO 2013; Vermeulen et al. 2012), the current food production systems and food consumption patterns have a high impact on the global climate, contributing to climate change through greenhouse gas (GHG) emissions.

It is estimated that 19-29% of global anthropogenic emissions are related to food production & consumption (Vermeulen et al. 2012). In the EU this has been estimated to be 31% (Garnett 2011), while in Sweden "eating" comprises a bit over 25% of private consumption emissions (SEPA 2010). Thus, food sector is a key contributor to human-induced GHG emissions.

In parallel, the availability of food supplies (food security) is threatened by climate change, as production is directly affected by its consequences: sea level rise, inland floods, or extensive droughts (Azar 2009; CCAFS - CGIAR 2013).

Aim and Research Objectives

The issue of food waste is ranked as a medium to high priority field of action to lower food-embedded GHG emissions (Garnett 2011; Berners-Lee et al. 2012). The aim of this thesis is to investigate the impacts of food waste and emissions occurring from food consumption in Sweden, by estimating the potential to decrease both of them, if avoidable food waste is reduced or eliminated. In other words the possibility to achieve a decrease in waste and emissions is investigated, by assuming that the food bought by consumers is used in a way that produces zero or significantly less avoidable waste. Further to this, the feasibility of substantially cutting down food waste and emissions through behavioural changes is studied. The main research points addressed in this thesis are to:

- Estimate the quantities of wasted food at consumption phase in Sweden; determine the proportion of waste that could be avoided ("avoidable waste"),
- Estimate the greenhouse gas emissions related to wasted food,
- Calculate the theoretical (maximum) potential to reduce such emissions, if all avoidable food waste was eliminated,
- Propose an action plan to achieve a practical reduction of both avoidable food waste and related emissions,
- Estimate the potential of waste and emissions savings that may be achieved through the action plan.

The concept here is that by reducing avoidable food waste, a "chain reaction" is expected to take place starting from consumers towards food production systems (also recommended by Garnett, 2011): consumers will only buy what they consume and the production will be adjusted accordingly to cover the new demand. This may imply lower food production and therefore lower use of resources and lower environmental impacts.

This thesis consists of the following chapters: introduction to the context of the project including the aim and research questions, literature review on the topics of food waste and food embodied GHG emissions, description of the methodology used to answer the research questions, presentation of results, discussion of results, points of improvement, and conclusions.

2. FOOD WASTE

This chapter presents a literature review on "Food Waste", aiming to provide a deeper understanding of how this topic is being dealt by scientists and other interested parties. Various studies and analyses have been carried out on, yet the outcomes are usually difficult to compare, mainly because of the variable definitions of food waste and the different methodologies of determining it (Parfitt et al. 2010; Koivupuro et al. 2012). The following part presents an overview of frequently used definitions and distinction between food losses and waste, classifications of food waste, followed by the main three methods of quantifying food waste at consumption level. Finally, an attempt to juxtapose published results of food waste studies and analyse the various implications related to this project, takes place.

Food Losses vs. Waste: Definitions

Discarded food (i.e. feed for humans) may be referred to as "food losses" that occur at the production, post-harvest and processing stages of FSC and as "food waste" when it is thrown away by the final users at the retail and consumption levels (Parfitt et al. 2010; Gustavsson et al. 2011). This distinction applies only to edible amounts of food produced for human consumption(Gustavsson et al. 2011).

WRAP (Waste & Resources Action Programme, a not-for-profit organisation established in UK) (Quested & Johnson 2009) gives a definition of food waste adjusted from the general waste definition of the EU Waste Directive (EU 2008): "food and drink that has not been consumed by humans"; followed by an extensive and detailed analysis of what this includes (see section "Classifications of Food Waste").

Buzby & Hyman (2012) provide a different approach of what is perceived as food waste and loss in the US. In this case the terms "loss" and "waste" are not associated with different FSC stages, but food losses describe what in general has not been consumed by humans and waste refers specifically to losses that result from human-made decisions.

In this project the definition of Parfitt et al. (2010) and Gustavsson et al. (2011) of food waste and losses is adopted. As the research objectives focus to consumers' actions, "food waste" is one of the quantified variables. The following section presents what may be included in the term.

Classifications of Food Waste

Food waste (FW) may be classified in variable ways in order to cover the different needs of the studied elements: a new classification may be introduced or a pre-existing one may be modified to match the scope of research and the availability of data; as (Lebersorger & Schneider 2011) note "practically every study uses its own subcategories".

For example the terms "**avoidable**" and "**unavoidable**" are frequently met, but their definitions may differentiate in details. Avoidable food waste, as generally agreed, includes whole unused and partially consumed food, but fractions like post-preparation waste and leftovers may be differently defined. On the other hand the term unavoidable seems to be more vulnerable to various interpretations and result in mid-solutions like the category of "possibly avoidable" that was introduced by WRAP (Ventour 2008; Lebersorger & Schneider 2011). Classifications according to life cycle stage (Langley et al. 2010; Lebersorger & Schneider 2011), preparation state (Ventour 2008) and food category (Quested & Johnson 2009; Gustavsson et al. 2011) are other options, too.

WRAP Classification

One of the most popular classifications of food waste was introduced by WRAP, within the context of an extensive and detailed report on food waste in UK households (Ventour 2008). An "avoidability" rating was used, according to whether food (and drink) waste is avoidable, possibly avoidable, or unavoidable.

A following, more extensive report was published in 2009 (Quested & Johnson 2009), which combined previous results with other input data (e.g. from national databases) to make more accurate estimations of the wasted food and drink in UK. In this study almost all sources and waste streams of food used in households are included and the above classification is further explained and presented within the context of terms such as "kitchen waste" and "edible waste" – Figure 1 presents the associations among them.

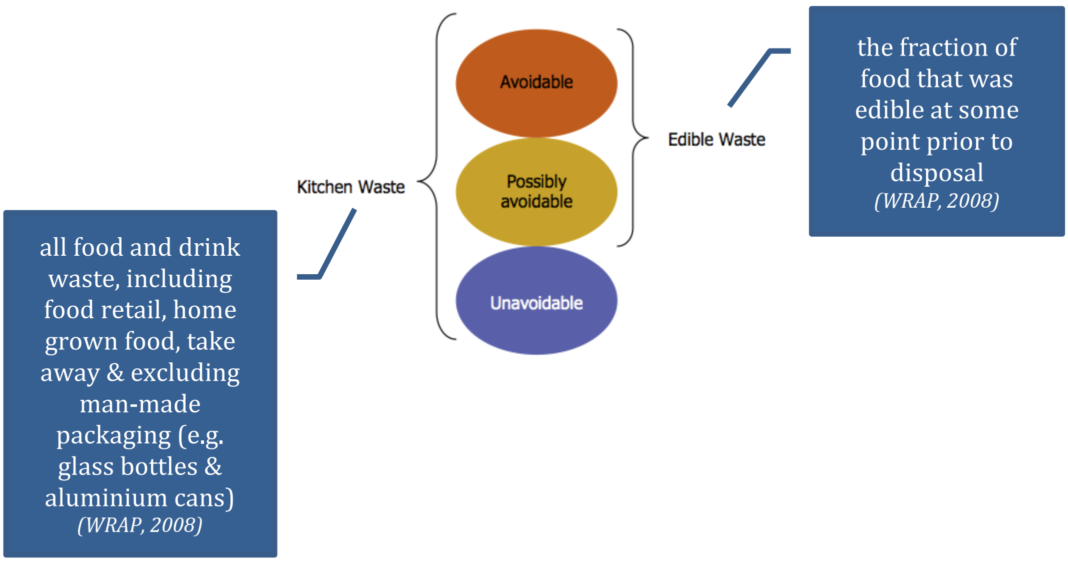

Figure 1: WRAP classification of food waste (Ventour 2008; Quested & Johnson 2009)

In detail, the updated classification system (illustrated in Figure 2) included the following:

- **Avoidable waste** – disposed food and drink "that is no longer wanted or has been allowed to go past its best". It includes food and drinks intended for human consumption (as accepted by the majority of people), which had been consumable prior to disposal. A further sorting is included based on the most important – for this report - disposal reasons:
  - *cooked, prepared or served too much* ("leftovers")
  - *not used in time* (after label date)
  - *other.*

- **Possibly avoidable waste** – also edible at some point prior to disposal, but includes food and drink "that some people eat and others do not" and that "can be eaten when prepared in a way and not in another" (e.g. potato skins).

- **Unavoidable waste** – food and drink waste that has never been edible prior to disposal (not edible "under normal circumstances"); it includes bones, tea bags, eggshells, etc.

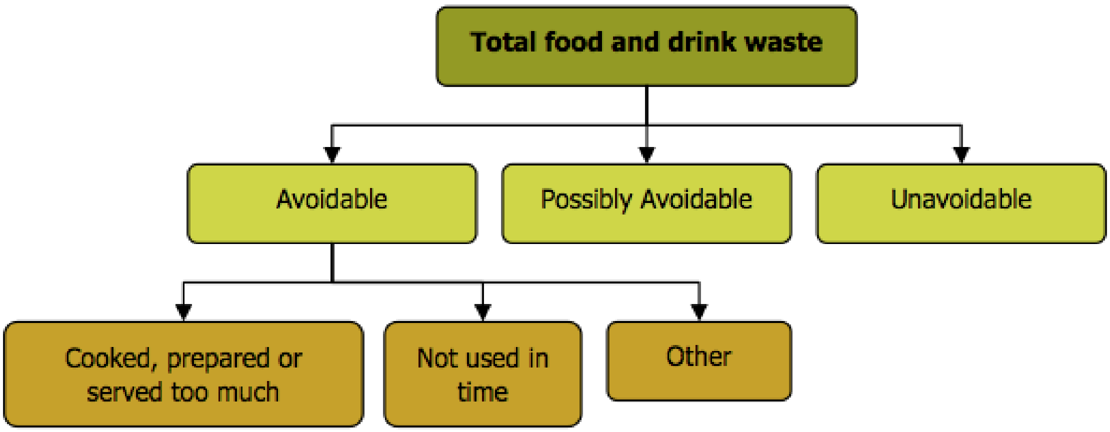

Figure 2: Food waste classification introduced in WRAP 2009 report (Quested & Johnson 2009).

Other FW Classifications

In 2010, Parfitt et al. published a thorough review of food loss/waste along the FSC, scrutinizing the potential for changing the current wastage until 2050 to meet the food needs of the global population at that time. In this review the wasted food at consumption level ("post-consumer food waste") is referred to as "food **wasted from activities and operations at the point at which food is consumed**". To determine the household food waste, Parfitt et al. use the approach of WRAP and add the food/drinks consumed "on-the-go", at work or in "catering establishments" that are left out from WRAP's focus.

A study conducted in Finland (Koivupuro et al. 2012), monitoring only a small number of Finnish households also used a rephrased version of WRAP's approach: "avoidability" is replaced by "**edibility**". The two wide categories of avoidable ("*all discarded food that has been **edible prior to disposal***") and unavoidable ("***inedible food parts**, such as vegetable peel, bones and coffee grounds*") food waste are used.

Lebersorger & Schneider (2011) developed a food waste classification scheme to fit the method of compositional food waste analysis for the determination of food waste (Figure 3). Their objective was to create a guiding tool, which would help limiting the subjective interpretation of findings in similar studies. They introduced four sub-categories, representing the various life cycle stages of the identified food items: preparation, post-preparation, consumption, partly consumed food and whole unused foods. These categories correspond to some "avoidability" rating, but "the differentiation between avoidable and non-avoidable food waste was made with regard to the theoretical prevention potential", as mentioned.

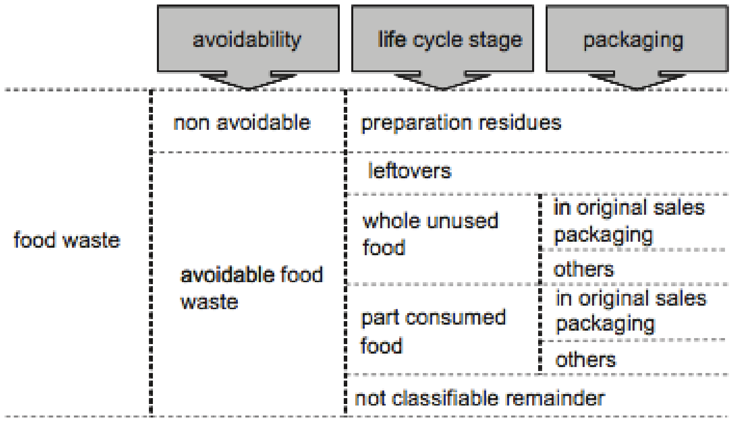

Fig. 2. Classification of food waste used in the study (see Section 3.3 for definition of terms).

Figure 3; Food waste classification system developed by Lebersorger & Schneider
(source: Lebersorger & Schneider 2011).

On the other hand, Langley et al. (2010) skipped any "avoidability" classification and collected data through consumer food waste diaries, focusing on the lifecycle stage (whole unused, part consumed, post preparation, preparation by-products non-edible elements, gunge) of wasted food items. Other data captured were the category of food, the waste routes, the packaging (loose, packaged re-sealable), consumer-estimation of the % of consumption (how much of the wasted food was consumed), etc.

Across the Atlantic, a different approach of classifying food waste is revealed. Buzby & Hyman (2012) talk about **qualitative** ("reduced nutrient value and undesirable changes to taste, texture, or colour") and **quantitative** ("decreased weight or volume") food losses. Buzby et al. (Buzby et al. 2011; Buzby & Hyman 2012) adopt the "loss assumptions" from LAFA (: Loss Adjusted Food Availability) Data Series (ERS/USDA 2013). At consumer level this includes **all food that is not available for consumption**, both at home or outside (e.g. in restaurants - a point that is avoided in most of the studies, as it is very hard to be determined). This broad category is divided in the **non-edible share** (according to the National Nutrient Database) and the **wasted edible share** (cooking losses and uneaten food, e.g. "extra tomato sauce poured down the drain", edible "plate waste" and spoiled fruits).

Estimation of Food Waste

Three main groups of methods for determining food waste are detected in literature (Parfitt et al. 2010; Koivupuro et al. 2012; Lebersorger & Schneider 2011):
- **Compositional food waste analysis**
- **Self-reported food wastage**
- **Models based on statistics**

The extent of each method depends on the study objectives and may vary from a little number of households (Langley et al. 2010) to large compilation of data and combination of the above methods (Quested & Johnson 2009). More details per method are described below.

Compositional Food Waste Analysis (CFWA)

Household waste is collected from various disposal routes (e.g. containers of residual waste (Lebersorger & Schneider 2011)) and analysed to identify food traces. The results are usually expressed as percentage by mass or volume of the analysed stream.

It is considered to be the most objective and rather accurate way of getting waste information (Lebersorger & Schneider 2011; Parfitt et al. 2010; Koivupuro et al. 2012; Langley et al. 2010), as collection and analysis of data is conducted by a third, unbiased party ("third-party" method). The samples may include large number of households (Ventour 2008) and may be collected and analysed in a routine basis to provide a more complete picture of the food waste of an area (Lebersorger & Schneider 2011).

On the other hand, the results are pretty limited, as they include only the food discarded through the specific solid waste collection systems - other waste streams like sewer are excluded. Finally, it may be hard or impossible: i. to detect and weigh variable food items when these are cooked, rotten, mixed with other waste and ii. to identify the reasons of disposal or packaging details (Lebersorger & Schneider 2011; Koivupuro et al. 2012; Langley et al. 2010).

Self-reported food wastage

Food waste data may be collected right at the source of "production": within households. One or more members are engaged in capturing all information regarding the food they throw away (weighing, completing diaries and questionnaires, recording the reasons/routes of disposal, etc.). These studies may be carried out either at a small scale with a small (13 in (Langley et al. 2010)) to medium (380 in (Koivupuro et al. 2012)) number of participating households, or may extend to a much larger input like WRAP's work (Ventour 2008), which included more than 2000 households consenting to provide their data.

This method is detailed, accurate in terms of weight and includes all streams (waste collection, sewage, home composting, etc.) and reasons of disposal. It allows comparison of wastage rational among participants (vs. different kinds of food). Besides background demographic, socio-economic, etc., other data are collected, which may be correlated to specific behavioural patterns through statistical analysis (e.g. household economic status) (Parfitt et al. 2010; Koivupuro et al. 2012; Langley et al. 2010).

On the other hand related drawbacks may include the following:
- it may turn out to be rather demanding for the participants, beginning with enthusiasm and ending with avoidance of task completion (Langley et al. 2010);
- it embodies increased bias, as participants' behaviour is affected during the period of observation and they may avoid or forget to record some data (i.e. subjective and/or biased report of data), they may temporary decrease the amount of food they dispose (in this case anonymity may help) (Langley et al. 2010; Koivupuro et al. 2012). Langley et al. (2010) found that during that period the participants had also increased their recycling and composting activities, along with reducing the food waste.
- confusion and/or misinterpretation of the required tasks (Langley et al. 2010).

Models based on statistics

The third method of food waste estimation is that of building a mathematical model, based on data and statistics, like for example nutrition and food supplies (Lebersorger &

Schneider 2011), metabolism and body weight, e.g. food waste as a percentage of total consumed calories (Parfitt et al. 2010). The models may also provide calculations for other variables related to food waste, like GHG emissions (Ventour 2008; Quested & Johnson 2009).

In 2011 FAO and SIK[4] published "SAVE FOOD" (Gustavsson et al. 2011), a report on the global issue of food losses and waste; one of the objectives was to quantify food losses/waste throughout the FSC, through mass flow models, incorporating allocation and conversion factors. The detailed methodology was published in 2013 (Gustavsson et al. 2013) and revealed the inclusion of a wide range of input data from scientific literature, statistical databases, the Internet, national authorities and NGOs. All calculations were carried out for big geographical areas, by making assumptions and estimations to cover literature gaps (for example by using food waste levels in comparable regions, commodity groups and/or FSC stages). The results of waste/losses were expressed as percentages of waste per commodity group in each FSC stage.

US food availability and losses are estimated through corresponding datasets (e.g. LAFA: Loss-Adjusted Food Availability Data Series), occurring from numerical estimation methods and other calculations (Buzby et al. 2011; Buzby & Hyman 2012; ERS/USDA 2013).

The positive aspects of modelling are that they may incorporate a wide range of data and apply in broad geographical areas (Gustavsson et al. 2011). They may also be modified to fit case studies other than the one they were initially created for. Still, the produced estimates are based on numerous assumptions, which may make the results ambiguous and create cumulative effects on the final results (Buzby et al. 2011). Furthermore they may limit the results when total amounts of waste are requested, but various categories (e.g. raw commodities in Buzby et al. 2011) are not included (Buzby & Hyman 2012). Finally cumulative errors may occur when the wrong constants (e.g. food waste factors) are used in early stages of calculations (Buzby et al. 2011).

Table 1 includes a summary of the main food waste estimation methods and their main advantages and disadvantages.

Table 1: Main advantages and disadvantages of food waste measurement methods.

Method	Pros	Cons
Compositional Food Waste Analysis (CFWA)	1. objective 2. accurate (detectable details like product category, brand, packaging, life cycle stage, gross/net mass etc.) 3. examined in a regular basis	1. limited waste streams 2. classification of mixed, degraded foods 3. unidentifiable disposal reasons 4. results expressed only as % by mass or volume
Self-reported Waste	1. detailed and accurate (weight, commodity categories) 2. all disposal routes may be included	1. biased behaviour during observation period 2. demotivated participants
Models	1. may cover broad geographical areas 2. make use of available data 3. may be applicable in other case studies	1. sample size affects results 2. ambiguous results because of assumptions 3. cumulative effects of assumptions & incorrect factors

[4] FAO: Food and Agriculture Organisation of the United Nations
SIK: Swedish Institute for Food and Biotechnology

Comparability of FW estimation studies

Compilation of data

Table 2 presents a compilation of methodologies and results on household food waste quantification studies. The studies are selected to cover various food waste classifications and all quantification methods described above and are mainly European, including also the US approach.

Table 2: Studies on quantification of household food waste

Study	What is measured?	Definition/classification	Method	Result	Country
Koivupuro, et. al. (2012)	Amount of avoidable household food waste	WRAP definition (of avoidable waste)	Self-Reported	Only avoidable FW in - kg/household & - kg/person per time unit	Finland
Langley et al. 2010	Sorted and weighed food waste from consumers	Classified by: food categories & waste routes & LC stages	Self-Reported	- Total and landfilled (kg/person*day) - % by food category - % by LC stage	UK
Lebersorger & Schneider 2011	Urban and rural municipal waste from residual waste containers of households	"Food loss before, during or after meal preparation", including pet food and some food packaging. "Preparation residues" "Leftovers"	CFWA	Mean quantities (kg/cap*yr) & % by mass % of packaging % by LC stage	Austria
Williams et al. 2012	Weight/vol. of avoidable food waste Focus on packaging & behavioural aspect;	Avoidable waste in connection with meals (excluding inevitable waste), & food waste not in connection with meals (food waste from storage)	Self-reported	Fraction of waste from storage & meals kg/household*week % main reasons of disposal % of packaging	Sweden
Ventour 2008 "**The Food We Waste**"	Quantities & cost of food waste Causes of food waste	Avoidable Possibly avoidable Unavoidable	Self-reported + CFWA	Weight & cost of food waste (net values & %). All results available in UK total; by "avoidability"; by food commodity; by state of preparation; per person, per av. household; per year. Possible causes of food waste.	UK
Quested & Johnson 2009 "Household food and drink waste in the UK	Quantities & cost of food waste including drinks Estimations of environmental impacts (GHG emissions)	Avoidable, possibly avoidable and unavoidable. PLUS Further clarification of avoidable waste	Self-reported + CFWA + Model + other sources of data	Weight & cost of wasted food and drinks in net values and %. Results given per year/week; per household, etc. **GHG emissions**	UK
Buzby & Hyman 2012	Total & per capita value + value by food group	Food loss vs. food waste according to US approach (see Section 1.3.2) + ERS/LAFA definitions	Model	**Consumer level losses** in available, edible food supply. Weight and cost per person per year. % of total and per capita value of food loss.	US

As it becomes obvious the overall design (including definitions, tools, measurement units, sample size, area) of such studies may vary in a way that makes the process of interpreting the results pretty complex and rather limited when needed to detect comparable elements. Comparing absolute numbers would produce manifold outcomes, like for example the estimated average avoidable waste per person per year in three different countries (Table 3):

Table 3: Estimated average AW per cap per year in three European countries.

Country	AW	Specifications	Source
Finland	23kg/cap*yr	By extrapolation of originally estimated result	(Koivupuro et al. 2012)
Austria	17kg/cap*yr	Excluding packaging	(Lebersorger & Schneider 2011)
UK	70kg/cap*yr	Excluding drinks	(Ventour 2008)

While the results for Finland and Austria may be considered consistent, UK has a much higher net value, which may lead to a variety of conclusions, from behavioural ones (e.g. British waste more, while Finnish and Austrians have a much higher awareness of the issue) to methodological ones (e.g. WRAP's study captured more, as it included a bigger sample and country-wide input of data).

COMPARABILITY PATHS

However, in some cases valuable conclusions may be drawn through such comparisons. Here results with common and different interpretations are detected through comparability paths based on country/area, sample size, measured variables and methodological approaches.

Country level: UK

A lot of concern has been raised recently in UK about food waste and a lot of research has been carried out. The studies included here are: a pilot study (13 households) (Langley et al. 2010) and two big (country-representing) studies (>2000 households) (Ventour 2008; Quested & Johnson 2009). The methodologies also include an escalation of tools: from one-method (Langley et al. 2010) to combination of two or more (WRAP).
Apart from the significant difference in sample sizes, the results when expressed in net values (kg) cannot be compared, as they refer to different elements. Nevertheless the final results coincide when expressed as % of avoidable waste: ~60% of total waste is considered as "avoidable" by both Langley and WRAP. Still, WRAP (Ventour 2008) includes the extra category of "possibly avoidable", which is not included in Langley et al (2010).

Measured variables: top-list of wasted food categories

A common finding in literature is that the most perishable foods are the ones mostly discarded (Parfitt et al. 2010; Langley et al. 2010; Lebersorger & Schneider 2011; Ventour 2008; Williams et al. 2012). As WRAP (Ventour 2008) reported, 46% of all food thrown away in UK is fresh, raw or slightly processed. These include mainly fresh fruits (30%) and vegetables (23%) (Langley et al. 2010) and also dairy products (Williams et al. 2012). In Williams et al. (2012) the presence of dairy products at high level on the list of discarded food items is explained by the fact that the study focuses on packaging as a part of wastage.

This finding is confirmed by WRAP (Ventour 2008), which adds "bakery items" in the top-list. Similar is the finding in US. As (Buzby & Hyman 2012) found, the top-list categories of food waste are "meat, poultry & fish" (41%), "vegetables" (17%) and "dairy products" (14%). These three categories along with fruits (9%) comprise a bit more than 80% of total wasted food in US. Meat, poultry and fish are present in the top-wasted list, as they are included in one category, while usually results are split between meat and fish products.

Methodological approach: Life Cycle (LC) Stages

Lebersorger & Schneider (2011) and Langley et al. (2010) use the approach of life cycle stages to measure and analyse their results. Although the two studies differ in the methodology itself (CFWA vs. Self-reported), the sample size (137 containers vs. 13 households) and the area (Austria vs. UK), the analysis of data is based on the same concept. The stages refer in both cases to the "life cycle" of products (foods) during consumption phase, meaning food items that are whole, partially used and prepared/processed, when discarded by households. Through this approach, the investigators create certain LC groups, estimate how much food was found/reported in each group and present results as percentages.

Figure 4 illustrates the results of the two studies, which seem to coincide in certain groups.

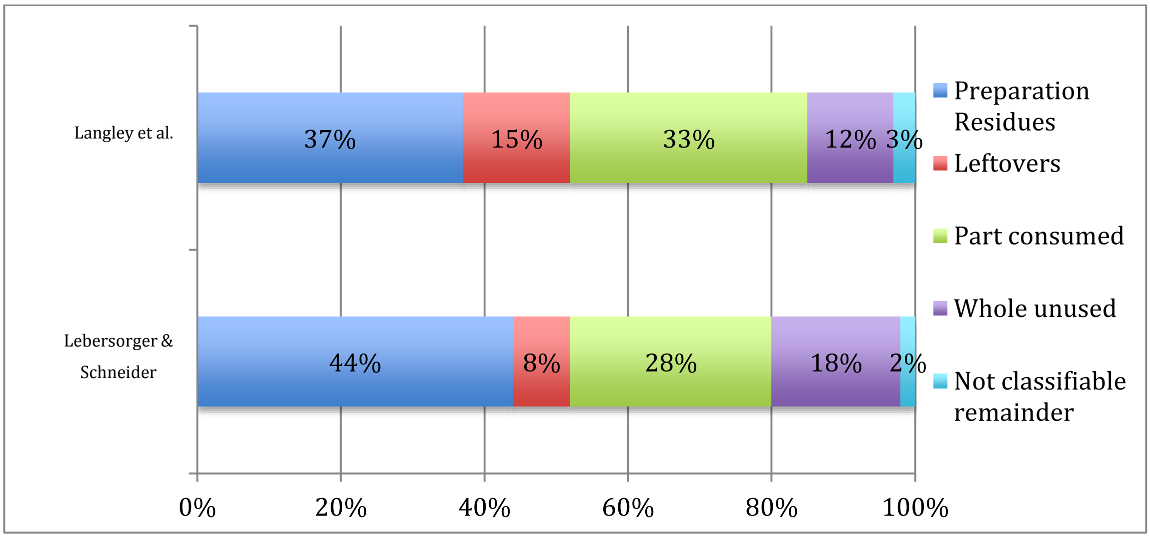

Figure 4: Juxtaposition of two studies' results on estimation of wasted foods per LC stage (the tags of LC stages are from Lebersorger & Schneider, but correspond to Langley's LC stages too).

Both studies consider the category of "preparation residues" as unavoidable waste and the remaining LC stages as avoidable (or mostly avoidable). There is an overall comparability of results:

- the sums of "part consumed" and "whole unused" categories are very close (45 vs. 46%) – during CFWA it is hard to tell if an item is either the one or the other, and
- the sums of "preparation residues" and "leftovers" are equal (52%) in both studies; these two groups of food items can also be mixed up when identified through waste analysis, depending on their degradation state or the definitions of both terms (as commented in both studies).

Lebersorger & Schneider (2011) underline these ambiguous interpretations of findings during CFWA and the need of an "international standard methodology and consistency in definitions" in order to have reproducible results and suggest corresponding solutions.

Large-scale studies

Large-scale studies - like UK (Quested & Johnson 2009; Ventour 2008) and US (Buzby & Hyman 2012) wide – may include combination of methodologies and/or input from various data sources. The results are considered as representing for wider geographical areas through assumptions and by taking into consideration the limitations of large-scale applications. For example, Buzby & Hyman (2012) note that the structure of their input data themselves does not allow them to determine the avoidable proportion of the total food waste. Consequently, they end up through a series of assumptions ("we suspect", they mention) to the conclusion that their estimations correspond mostly to avoidable waste and that unavoidable losses are "relatively small".

Packaging and other influencing factors

The influencing factors of determining food waste include, but are not limited to: packaging, settlement structure (rural/urban), house type, disposal routes; people's attitudes, age, gender, culture; household size, etc. These are common findings reported in various publications, but not always all or part of them play equally significant role.

Still, packaging does play a critical role in determining food waste. WRAP (Ventour 2008) reported that more than 25% of avoidable food waste is still packed (opened or unopened) when discarded. Additionally, other studies emphasize that packaging should be considered as a part of discarded food items and recommend to be classified with them (Lebersorger & Schneider 2011) and identify if packaging leads to disposal of an item (Williams et al. 2012). For example packaging with unclear end product date or packaging that does not allow the complete consumption of contained produce (e.g. yoghurt containers). An interesting point identified in the self-reported waste study of Williams et al. (2012) is that respondents were critical towards bad packaging practices, but no one commented on the importance of packaging, which in some cases protects and keeps the products fresh.

Koivuporo et al. (Koivupuro et al. 2012) found only few factors that affect the quantities of avoidable waste. For example they found that there is no correlation to household income, while the size and type of household, the gender of the responsible for groceries, etc. proved to be statistically significant. The influencing household size and purchase habits and non-influencing household income were also confirmed by Williams et al. (2012). On the other hand, the review of Parfitt et al. (2010) includes income (along with size & composition, demographics: younger vs. older and culture) to the main influencing factors.

As Langley et al. (2010) and Lebersorger & Schneider (2011) found (Figure 4) almost half (~45%) of the wasted food items are either whole unused or part consumed. The main reasons behind this phenomenon may be the poor shopping planning, the tempting grocery/super market offers, the large packaging of products, etc. that that lead consumers to buy more than they need.

Other – e.g. cultural perception or may cutting down food waste imply modifying cultural habits?

Lebersorger & Schneider (2011) use a cultural, country specific implication for waste that could be in some cases avoidable (see "possibly avoidable" category by WRAP). They avoid introducing such a category, as the amounts detected are not large enough to comprise one and they mainly reflect "common and individual eating behaviour, but do not result from too much buying". Instead, in cases of such findings, these were classified to either preparation residues or leftovers, according to "common Austrian eating tradition", as mentioned in the text.

Study Specifications

In this project the food waste definition, classification and estimations of WRAP are being used (Ventour 2008; Quested & Johnson 2009). The main input of consumption waste shares is derived from the report produced by FAO/SIK (Gustavsson et al. 2013), which assumes that the corresponding shares per food commodity applying in Europe are mainly the ones found by WRAP (Ventour 2008) for the UK (Gustavsson et al. 2013: Annex 1, p. 43, t. 33).

3. Embodying GHG Emissions on Food

Anthropogenic activities and the mechanisms that lead to climate change are widely researched and discussed within the scientific, policy-making and other communities (e.g. UN, IPCC). Briefly the phenomenon can be described as follows: the increasing concentration of greenhouse gases (GHG) in the atmosphere - intensified by human activities - affects its so-called "radiative balance"[5] and therefore increases the average temperature, resulting to phenomena like melting of glaciers, sea level rise and extreme weather conditions like drought or heavy precipitation, all comprising to the alteration of global climate or "climate change" (Azar 2009; UNFCC 2014). The main GHGs emitted by human activities are: carbon dioxide (CO_2), resulting from burning of fossil fuels (direct emissions), deforestation and land use change (indirect emissions); nitrous oxide (N_2O) and methane (CH_4) released mainly from agricultural activities (Carlsson-Kanyama & Gonzalez 2009; Azar 2009; Foley et al. 2011; Gerber et al. 2013).

This chapter presents the connection between Food Supply Chains (FSC) and climate change, as seen from the aspect of food systems, dietary choices & food waste.

GHG Emissions & Food Systems

GHG emissions derive from all stages of FSC (i.e. throughout the lifecycle of products), starting from agriculture (including livestock and fertiliser production), processing, storage, retail, consumption and disposal of waste, including the emissions from transportation in-between (Fig. 5). Principal factors that affect the level of the sector's emissions are the volume of food supply (determined by marketing practices), as well as personal, habitual choices of consumption (i.e. food demand) (Vermeulen et al. 2012), as well as the production and handling practices.

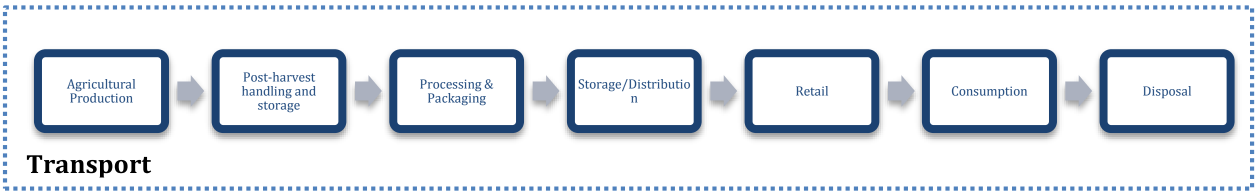

Figure 5: Food Supply Chain.

Still, each stage contributes to a different extent in the total LC emissions of a product. More precisely, the distribution of emission sources may be split into two major phases:

i. agricultural emissions[6], which comprise 80-86% of FSC emissions, 14-24% of global emissions (Vermeulen et al. 2012) and 56% of global non-CO_2 emissions (CCAFS - CGIAR 2013), and

[5] Radiative balance - for definition, visit: http://www.learner.org/courses/envsci/unit/text.php?unit=2&secNum=3

[6] N_2O from agricultural soils (crop production, use of fertilisers and other nitrogen sources, like crop residues); CH_4 from livestock, manure management, rice cultivation and other activities; CO_2 from energy consumption, production of fertilisers and biomass burning (CCAFS-CGIAR 2013; Garnett, 2011)

ii. post-farm emissions, which are mainly CO_2 emitted from fossil energy use (Garnett 2011).

Figure 6 illustrates the distribution of emissions in production and post-farm handling of livestock supply chains (Gerber et al. 2013). The magnitude of emissions per FSC stage is represented by the width of the arrows; in this way the main contributors to the sector's emissions can be easily distinguished:
- production stage within FSC and
- cattle (beef and dairy), from the aspect of products.

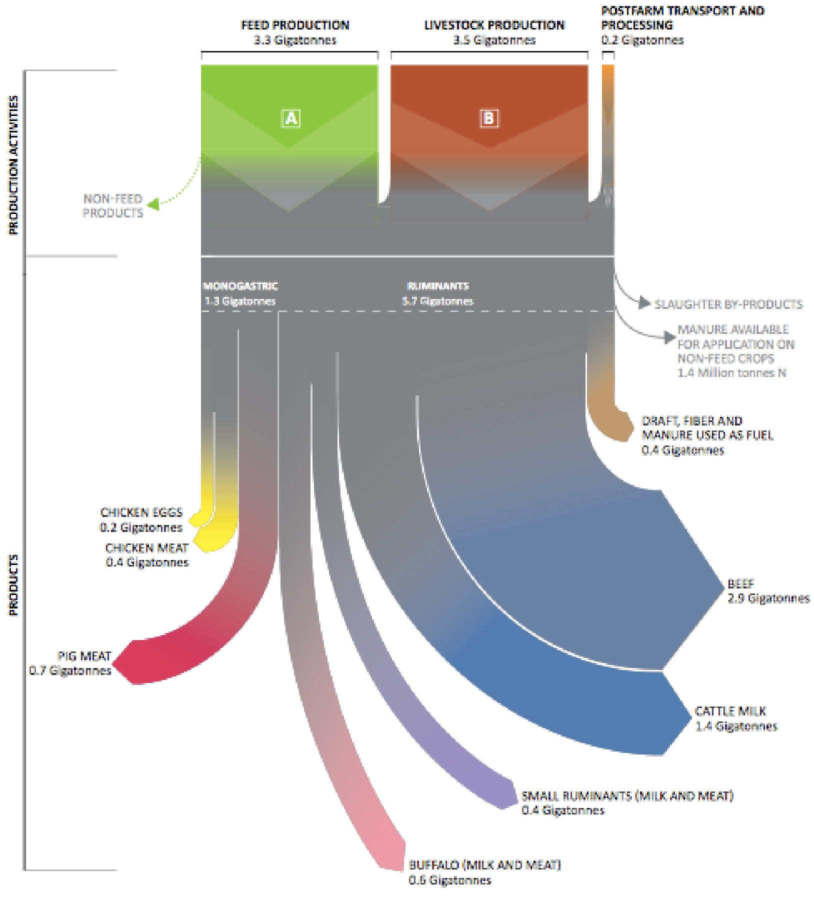

Figure 6: GHG Emissions from global livestock supply chains (Gerber et al. 2013)

The methods used to embody GHG emissions in food commodities depend on the production systems, as well as the objectives and boundaries of the studied system. Life Cycle Assessment (LCA) and Input /Output models (I/O) are principally used in such studies (Berners-Lee et al. 2012). LCA is a commonly applied method, used to estimate environmental impacts of products "from cradle to grave" and therefore it can provide an estimation of the carbon footprint of food items throughout their life cycle (e.g. Gerber et al. 2010). Input/output analysis (I/O) is based on economic parameters and the estimation of emissions is done on a basis of economic entities, like for example the emissions of a producing facility, instead of the product's itself (Carlsson-Kanyama 2004; OTL 2011). Besides, when quantifying food-related emissions, it makes sense to express the results as in accordance with a certain quantity of product at a given FSC stage, like for example quantity of emissions per litre of milk or kilo of potatoes at the "farm gate" (see "functional Unit" under "Emission Factors" in the "Methodology" chapter).

Careful selection of the studied system and the functional unit are important when calculating food consumption emissions, as the included items may affect significantly the result: the included FSC stages, the inclusion of indirect impacts (e.g. Land Use Change - LUC), the geographical region etc. For example, the electricity mix used to power activities in an area or the agricultural systems in practice may significantly affect the emissions, as Davis et al. (2010) detected in a study of the environmental impacts of four protein-based meals consumed in Spain and Sweden.

GHG Emissions & dietary choices

An approach of determining food-related emissions is to attribute them to certain consumption habits and dietary patterns. As Berners-Lee et al. (2012) mention in a brief historical review, the observation that there is a connection between dietary choices and emissions was first made in 1997 with the first calculations coming up the next years (e.g. Carlsson-Kanyama 1998). Some recent research works with interesting results on this field are presented in the following paragraphs.

At a country level, Berners-Lee et al. (2012) made estimates for the UK by using food supply data (top-down assessment), consumption data (bottom-up approach) and limiting their studied system from production to the point of sale for 61 categories of food. They estimated the GHG emissions (kg CO_{2eq} per kg of product) of the studied food categories for each one of the FSC stages up to retail, by using either LCA or I/O data.

The Swedish dietary trends have been identified and interrelated with cultural influences (Carlsson-Kanyama & Lindén 2001), energy use (Carlsson-Kanyama et al. 2003) and greenhouse gas emissions (Carlsson-Kanyama 1998; Wallén et al. 2004; Carlsson-Kanyama 2004; Carlsson-Kanyama & Gonzalez 2009). Additionally, the Swedish Institute for Food and Biotechnology (SIK) has published numerous reports on food related GHG emissions (Sonesson et al. 2010; Gerber et al. 2010; Wallman et al. 2011, etc.).

At a worldwide level, Pradhan et al. (2013 a & b) identified 16 global dietary patterns[7] and their trends from 1961 to 2007, based on FAOSTAT[8] country-level data of food consumption and composition (kcal/cap per day). The researchers determined the dietary trends in terms of food composition and energy content and connected them to both country development status and GHG emissions. Emissions were calculated by combining agricultural energy use (energy output/input ratios), non-CO2 emissions from agriculture and emission intensities of food products, and found that emissions increase in higher calorific diets.

Apart from the energy content, it is the qualitative aspect of food choices that has been connected to GHG emissions. For example, Davis et al. (2010) found that vegetarian meal of similar protein content to meat-based meals has overall a significantly lower environmental impact (incl. lower GHG emissions).

[7] Sweden is identified to be in pattern #15 (very high calorie diets) with average 3,300kcal/cap/day, which is characterized by "*the overall highest consumption of alcoholic beverages and exhibits the second highest amount of animal products and sugar- sweeteners.*" (Pradhan et al. 2013a).
[8] FAOSTAT: FAO, Statistics Division (http://faostat3.fao.org/home/E).

The majority of studies researching dietary emissions support this finding: animal products (meat and dairy) are top-contributors of food embedded GHG emissions (Carlsson-Kanyama & Gonzalez 2009; Berners-Lee et al. 2012; Pradhan et al. 2013b; Gerber et al. 2013). Livestock production emissions represent 14,5% of total human-induced emissions and are split into: 44% CH_4, 29% N_2O, 27%CO_2 (Gerber et al. 2013). Livestock emissions are produced in four main ways: i. CH_4 from enteric fermentation, ii. CH_4 and N_2O from manure management, iii. CO_2 and N_2O from feed production, processing and transport, iv. CO_2 from energy consumption (Garnett 2011; Gerber et al. 2013).

Most recommendations for emissions' reduction are made on dietary shifts form meat consumption to more environmentally friendly options (either meat-free diets or animal products with lower impacts, like pork and poultry) (Carlsson-Kanyama 2004; Carlsson-Kanyama & Gonzalez 2009; Garnett 2011; Berners-Lee et al. 2012; Hoolohan et al. 2013). Nevertheless, FAO (Gerber et al. 2013; FAO 2014) supports the use of animal products and presents ways to mitigate emissions in livestock production: adoption of lower emission intensity practices, improvement of production efficiency and upcoming technologies are claimed to result to significant emissions mitigation potential and at the same time to economic development.

GHG Emissions & Food Waste

One third of the food sector emissions (or 6-10% of global anthropogenic emissions) is attributed to wasted food (Vermeulen et al. 2012) and therefore they are unnecessarily released. Food waste emissions derive from two routes, as Vermeulen et al. (2012) outline:

- Direct emissions: CH_4 emitted from landfilled food waste; estimated to be 2-13MtCO_{2eq} in UK
- Indirect emissions: CO_{2eq} emissions from all previous FSC stages of the discarded food; estimated to be 20MtCO_{2eq} in UK.

Cutting down food waste to reduce FSC emissions is a recommended strategy in literature, considered as medium to high priority tactic (Garnett 2011; Dorward 2012; Berners-Lee et al. 2012; Hoolohan et al. 2013). Berners-Lee et al. (2012) estimated that by eliminating food wastage "pre- and post-purchase" would reduce UK's emissions by 0.94tnCO_{2eq} per cap per year, which corresponds to 35% of the emissions embodied in the national food supply.

Study Specifications

The focus of this project is drawn towards the indirect emissions attributed to post-purchase food waste, rather than those occurring from dietary choices. Emissions occurring from waste disposal correspond to a rather low percentage of total FSC emissions (Garnett 2011; Vermeulen et al. 2012) and are not included in this work (i.e. impacts from handling after purchase and end-of-life are excluded). The GHG emitted from the food supply stages up to the point of sale (as described in the previous sections of this chapter) are ascribed to the food consumed and wasted from the end users; the proportion of emissions attributed to avoidable waste is referred to as "AW-emissions".

4. METHODOLOGY

The method of statistics-based modelling is employed to answer the research questions of this thesis. The source data used cover the following areas of interest:

i. Dietary Patterns (adult mean food & drink consumption at a given period of time)
ii. Food Waste (proportions of avoidable and total waste), and
iii. Life cycle GHG emissions of consumed food items ("emission factors" – $kgCO_{2eq}$ per kg of product).

The studied FSC-impacts are those of waste (variables: total -TW and avoidable - AW) and GHG emissions (variables: emissions connected to edible portions of food and principally "AW-emissions") attributed to food consumption.

The difference of the studied variables' values between the current state and a desired state with eliminated or reduced AW, provides multiple potentials to lessen the investigated FSC-impacts. This is examined through two scenarios:

a. the first scenario is that consumers produce zero AW; this will provide a theoretical maximum potential of savings in both AW and emissions, and
b. the second one is the case of putting into practice measures targeting the top wasting and emitting commodities AND their main reason of wastage. A more practical way to estimate the (maximum) savings is developed by assuming that the measures are so effective that no AW is produced due to the identified reason of disposal for these commodities.

Data processing and calculations are described in detail in the following sections, which comprise two parts: the first part includes the calculations made to estimate the studied variables by combining the input data (Fig. 7) and the second one includes the estimations of the "potentials" described in the above scenarios.

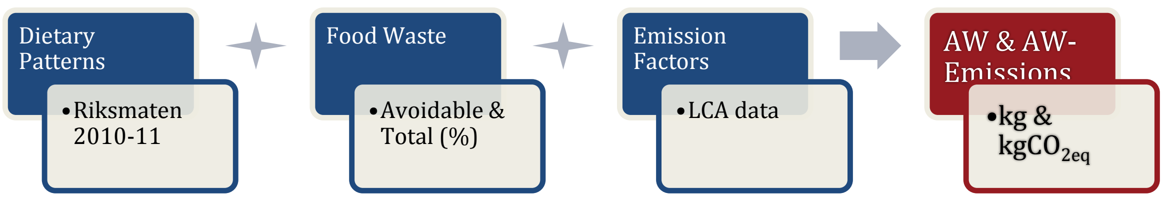

Figure 7: Methodology, part I

Part I: Dietary Waste & Emissions

Dietary Patterns

The results of the recent national Swedish nutrition survey (Riksmaten 2010-2011, by Amcoff et al. 2012) are used as the basic input that depicts the dietary habits in Sweden. The survey included 1797 adult participants: 792 men (44%) and 1005 women (56%)

(for detailed results see Annex I, Table I-1). To fit the objectives of this project the following adjustments were made:

- the results were converted from *mean daily per capita consumption* in gr/day to yearly consumption in kg/year and all calculations were carried out on an *average yearly per capita basis*.
- to facilitate the use and evaluation of the data, the reported food items were grouped in 8 broader food commodity groups (for items per group see Annex I, Table I-2):
    - i. cereals
    - ii. roots & tubers
    - iii. fruits & vegetables
    - iv. meat & meat products
    - v. dairy products
    - vi. fish & seafood
    - vii. others
    - viii. drinks (excl. water).

The English summary of Riksmaten 2010-11, the participants' profile and the reported quantities per food item (translated in English through "Google translate") were used in this work[9].

A series of assumptions had to be made to estimate the quantities of sub-groups for which no detailed data were given by the translated part of results (e.g. the rates of fresh and processed forms of commodities like fruits, potatoes, fish & shellfish); they are all included in Annex II.

For the group of fish & shellfish a separate calculation of quantities was carried out to estimate the amounts of fresh and processed forms of the various food items of the category (sea fish, freshwater fish, shellfish, etc.). For this purpose, consumption data of the fresh and processed forms available at the country, as provided in the 2009 Food Balance Sheets of Sweden (FAOSTAT 2014) and the corresponding market shares in the Swedish fish market in 2008 (Popescu 2010) were used. A detailed description of the estimation method along with calculation of waste and the allocation of emission factors is presented in Annex III.

Food Waste

The second group of data includes the proportions of wastage (total and avoidable) produced by consumers. The fractions of avoidable food waste (% per weight) are principally obtained from the FAO/SIK reports on Global Food Losses & Waste published in 2011 and 2013 (Gustavsson et al. 2011; Gustavsson et al. 2013). Eight major food commodity groups and the corresponding percentages of wastage at all FSC stages of eight major global geographic areas are presented in these reports; the facts that refer to consumption phase of Europe (Gustavsson et al. 2013, p. 43, t. 33) are applicable in this thesis.

The waste proportions of European consumption, that Gustavsson et al. (2013) use, are mainly estimations made by WRAP for UK[10]. It is therefore assumed that for most of the commodity groups these values correspond to the European trends. The cited WRAP

[9] The extended report –incl. detailed description and analysis of results- is available in Swedish.
[10] Gustavsson et al. 2013 - Table 33, p. 43, sources #5, 10, 15, 20, 25, 30, 35, and 40.

report (Ventour 2008) and a following, extended WRAP report (Quested & Johnson 2009) present them as "proportions of avoidable food waste in UK households". The same assumption is undertaken here for all commodity groups and items appearing in the Swedish dietary survey: wastage from Swedish consumption is similar to wastage in the UK. In other words, it is assumed that the waste percentages of avoidable and total waste of both FAO/SIK (Gustavsson et al. 2013) and WRAP (Quested & Johnson 2009) reports apply to Sweden too. The results of WRAP are used in cases where FAO/SIK outcomes are not sufficient for the calculation of AW, as well as for the estimation of total waste (Quested & Johnson 2009, p.89 t. 50,51,52).

A second reason for selecting the results of WRAP is the wide range of data included and analysed, as well as the **combination** of the three standard methodologies for estimating food waste, i.e. waste composition analysis, questionnaires/diaries (a survey and a physical analysis of the contents of bins) and statistical models. Additionally the WRAP report provides clear waste definitions and detailed descriptions of what they include, which are also adopted in this project (the proportion of "possibly avoidable" is incorporated to "avoidable" proportion of waste) – see chapter "Food Waste".

As waste percentages vary between fresh and processed forms of various commodities (e.g. vegetables, potatoes, etc.), rough assumptions have been made on the corresponding consumed proportions (listed in Annex II). For the diversification of "fish & seafood" (fresh/processed items; total/avoidable waste) a special breakdown was created (Annex III).

The avoidable and total waste quantities of all food items are estimated and expressed as kg per capita per year (see section "Quantifying Waste & Emissions"). GHG emissions are calculated for the edible part of each food item and correspond to the life cycle from production to retail (see "Study Boundaries"). The base-unit in this study is the purchased food and the wasted proportions are parts of it; as illustrated in Figure 8 the total of purchased food comprises 3 sub-elements: consumed food, avoidable and unavoidable waste. The edible portion is the sum of consumed food and avoidable waste.

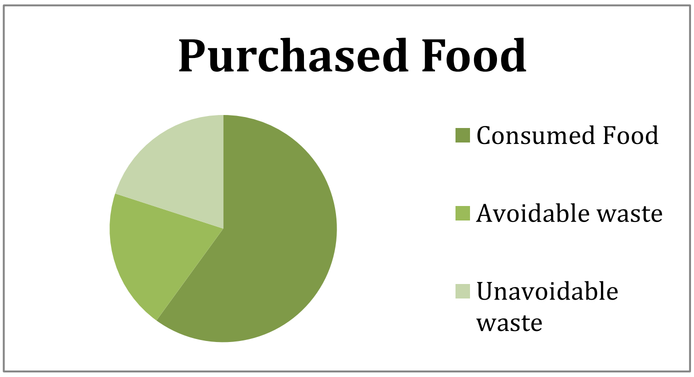

Figure 8: Purchased food items are divided into three parts: consumed food, avoidable and unavoidable waste.

Emission Factors

Emission Factors ("EF") incorporating the quantities of GHG emissions released throughout the life cycle (LC) of food items are used in this project. The selected EFs have been estimated through LCA methodology and correspond to the edible part of the food items at the point of purchase (*kg CO_{2eq} per kg of edible product*). The Swedish food market has also been taken into consideration, while it has been assumed that EFs apply to each item indifferently where the point of sale is located within Sweden.

The main EF sources are a recent master thesis on food GHG emissions in Sweden (Ekström 2012) and a frequently cited study also referring to the impacts of Swedish consumption habits (Wallén et al. 2004). The results of the second study were mainly used for food groups (like roots and tubers) the production methods of which are not supposed to have dramatically changed since the publication of the work. For items that were not covered sufficiently by these two sources other estimations were used (EFs applicable to Sweden detected in scientific literature, consulting reports and Internet).

Selected EFs correspond to the same LC stages and have consistent functional units (FU); when necessary, EFs have been recalculated to fit both study boundaries and FU. Emission Factors per food item, citation and the corresponding assumptions of all commodity groups are listed in Annex IV, except from all related information for "fish & seafood", which can be found in Annex III.

Study Boundaries

The boundaries of the studied system include all stages of product life cycle from cradle (agricultural production) to the point of sale (retail), as illustrated in Figure 9. This project investigates the GHG emissions of food products until purchase and excludes the impacts generated by the consumers' actions in terms of transporting, storing, cooking, etc. In spite of that, the estimated emissions are attributed to the quantities of food wasted by consumers (indirect emissions). Regarding the impact of transportation throughout FSC, it is not always included in the selected EFs, as it is estimated to be negligible compared to the total impact of the food item (e.g. Cederberg et al. 2009).

These study boundaries were selected in the first place to correlate the potential impact of consumer choices to the previous stages of FSC (i.e. less wastage at household is expected to lead to less purchased food and consequently to alterations in distribution and further to production). The second reason for limiting the boundaries up to the point of sale is the wide diversification of how consumers utilise the purchased food after buying it (transporting, storing, etc.); it would be pointless within this work frame to assume certain behaviours or to find data of "mean" patterns of household habits.

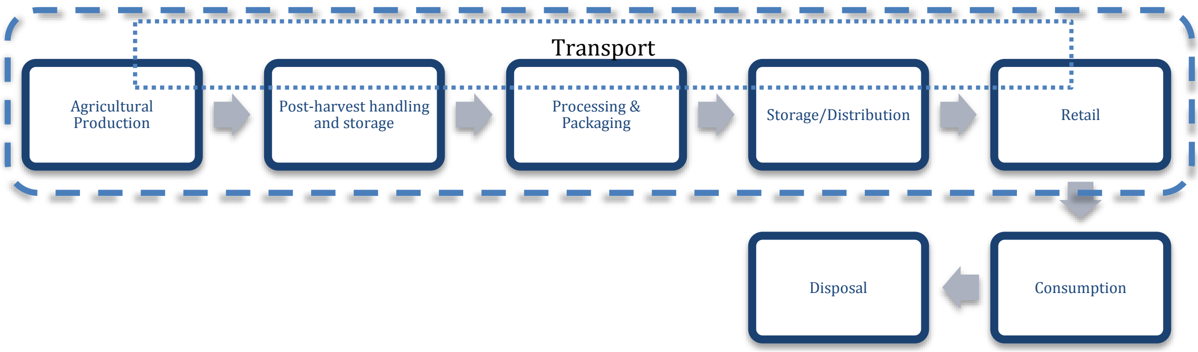

Figure 9: Food Supply Chain boundaries that correspond to required LCA data

Functional Unit (FU)

The functional unit selected in this project is *1kg of edible product*. Therefore the unit of EFs is *kg CO_{2eq} per kg of edible product* at the point of sale. In some cases it has been necessary to recalculate EFs, like for example in the case of canned fish, where the FU was kg CO_{2eq} per kg of the whole package of fish (see Annex III). The emission factors of meat are also re-estimated to exclude the inedible part of the carcass weight (edible part of beef is 70% of total carcass weight - (Cederberg et al. 2009)). Although inclusion of factors like packaging and total weights would give more realistic results, it is selected here not to do so, because the focus is on the influences of eating habits (i.e. dietary preferences as revealed through the survey) on avoidable (edible) food wastage.

Quantifying Waste & Emissions

Food Waste - Equations

All calculations were carried out in MS Excel. The variables used are on a per capita basis:

- PF: Purchased Food (kg/yr)
- CF: Consumed Food (kg/yr)
- TW: Total Waste (kg/yr)
- AW: Avoidable Waste (kg/yr)
- UW: Unavoidable Waste (kg/yr)
- EdF: Edible Food (kg/yr)
- a: Proportion of Avoidable Waste (% by weight) of purchased items
- t: Proportion of Total Waste (% by weight) of purchased items
- EF: Emission Factors (kgCO2eq/kg of edible product)
- EAW: Emissions attributed to AW – AW-emissions ($kgCO_{2eq}$/yr)

By considering that the following equations apply in general at household level for the above described variables:

$$\mathbf{PF = CF + TW} \qquad \mathbf{(1)}$$
$$\mathbf{TW = AW + UW} \qquad \mathbf{(2)}$$
$$\mathbf{t = TW / PF} \qquad \mathbf{(3)}$$
$$\mathbf{a = AW / PF} \qquad \mathbf{(4)}$$

and given the already known amounts of consumed food (CF - (Amcoff et al. 2012)), % by weight of avoidable waste (a) and total waste (t) (Gustavsson et al. 2013; Quested & Johnson 2009), the values of Purchased Food, Total and Avoidable Waste can be estimated:

$$(1), (3) \Rightarrow \quad \mathbf{PF = CF / (1-t)}$$
$$(3) \Rightarrow \quad \mathbf{TW = t*PF}$$
$$(4) \Rightarrow \quad \mathbf{AW = a*PF}$$

Flowingly, the amount of Edible Food (EdF) is estimated:

$$\mathbf{EdF = CF + AW} \qquad \mathbf{(5)}$$

Emissions - Calculations

The emissions attributed to avoidable waste (EAW), edible food (EdF) and consumed food (ECF) were given by multiplying the emission factor (EF) by the corresponding quantity of AW, EdF and CF, respectively. For example, the equation for the calculation of EAW is:

$$\mathbf{EAW = EF*AW} \qquad \mathbf{(6)}$$

Part II: Reduction Potentials For AW And AW-Emissions

Scenario A

In the first scenario a theoretical potential to reduce waste and GHG emissions is examined. The hypothesis here is that consumers buy only the quantities of food and drinks they consume and therefore produce zero avoidable waste. The quantities of AW and AW-emissions, expressed as portions of edible food, total waste and total "edible" GHG emissions give the maximum potential to decrease the studied impacts by eliminating avoidable food waste.

Scenario B

Following the estimation of the maximum theoretical potential, a more practical solution is investigated. The savings in both waste and emissions are estimated under the assumption that measures are taken to beat the major reason of disposal of the food items with the highest emissions and wastage. The waste and emissions decrease estimated here corresponds to the maximum effectiveness of the measures.

The rationale behind this scenario is based on the fact that phasing out all avoidable food wastage in households cannot happen at once. It involves a complex process that will gradually lead to the behavioural change of consumers, engaging as well external actors like retail sector, dietary trends, etc. In order to achieve successful outcomes, such processes may be integrated in institutional or governmental strategies including policies for both consumers and food industry, which are further discussed in the next chapters.

Within the scope of this project an action plan is developed. The proposed plan includes the following steps:

1. identification of major contributors (commodity groups) to avoidable waste (AW) and emissions attributed to AW (AW-emissions); the "top-three" commodities in terms of net AW, net AW-emissions and AW-emissions intensity ($kgCO_{2eq}$ per kg of AW) are selected;
2. identification of the principal reasons for wastage and the extent of their occurrence, as derived from the results of WRAP report (Quested & Johnson 2009) on UK food and drink waste;
3. estimation of the waste and emissions savings, if all AW produced because of the identified reason(s) is eliminated; and
4. recommendations and measures aiming at the main reason(s) of wastage of the identified groups.

The hypothesis is that if the principal reasons of wastage are phased out, AW and AW-emissions will be significantly reduced. To achieve this, a set of possible actions aiming at these causes and involving principally consumers them are proposed (Fig. 10).

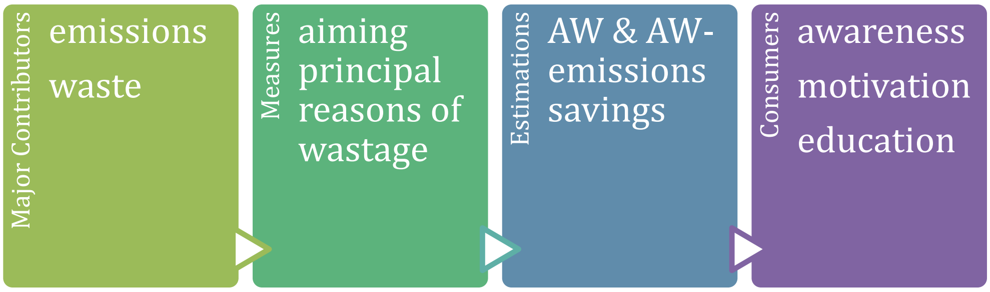

Figure 10: Action plan for r AW and AW-emissions reduction.

5. RESULTS

This chapter presents the results of calculated waste and emissions, the identified major contributors to both impacts and the estimation of the potentials to reduce emissions and food waste at consumption stage, according to scenarios A & B described in the previous chapter.

Waste & Emissions

Estimation of Food & Waste Variables

Figure 11 presents the estimated Food and Waste variables (in kg per cap per year) per commodity group. Detailed results per food item are listed in Annex V. The calculation of the variables is based on the quantities of consumption, as reported in the Swedish dietary survey of 2010-2011 (Amcoff et al. 2012), therefore the results correspond principally to that period and were scaled up from mean daily to yearly consumption.

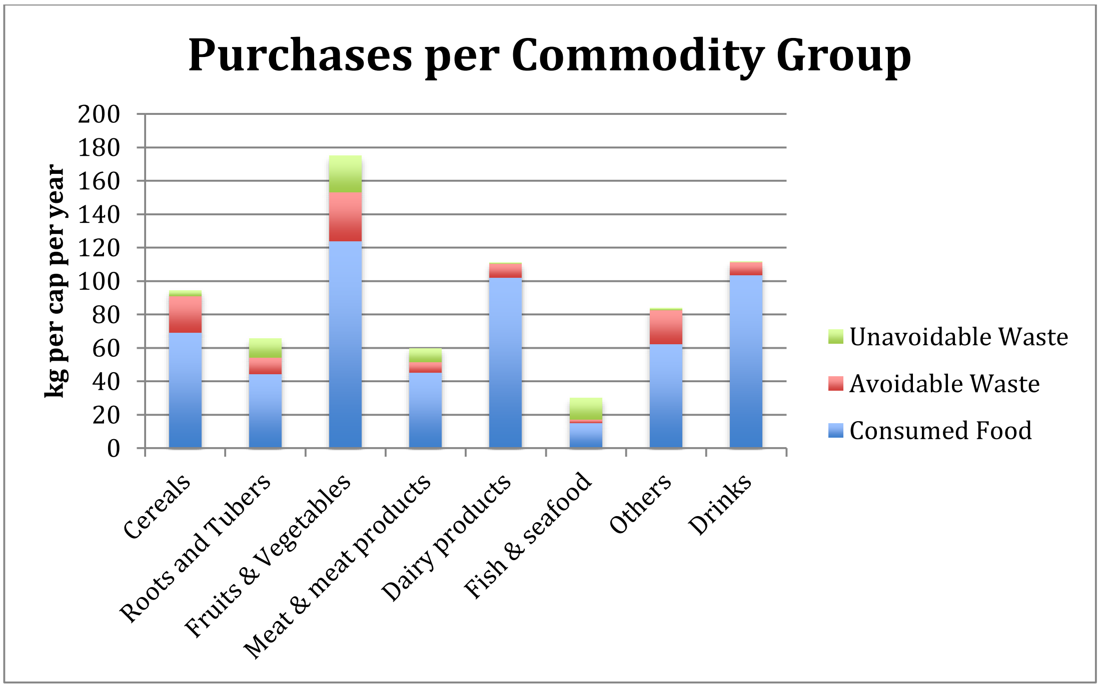

Figure 11: Quantities of purchases per commodity group.

Seen from the aspect of purchased food – which, as described in methodology, is the total of three sub-quantities: consumed food, avoidable and unavoidable waste – the estimations show that 165 kg out of the 731 kg (~23%) of purchased foods are thrown away, while the biggest part of this wastage (106kg or 14.5% of purchases) had been consumable prior to disposal (AW). In other words, in order to eat 566 kg of food, a consumer bought approximately 672kg of edible food and disposed of 106kg of it, within a year (Fig. 12).

Dietary GHG Emissions

The GHG emissions attributed to each commodity group represent the impact these foods have from their production to the point of sale and more specifically the impact of their edible part. The estimated GHG emissions (kgCO_{2eq} per cap per year) are presented in detail in Annex VI. In total it was found that the emissions of consumed food were 1,208kgCO_{2eq} per cap per year, while the total AW-emissions were 190kg per cap per year (Fig. 13). "Meat & meat products", followed by "dairy products" and "fruits & vegetables" make 67% of the total emissions of edible food.

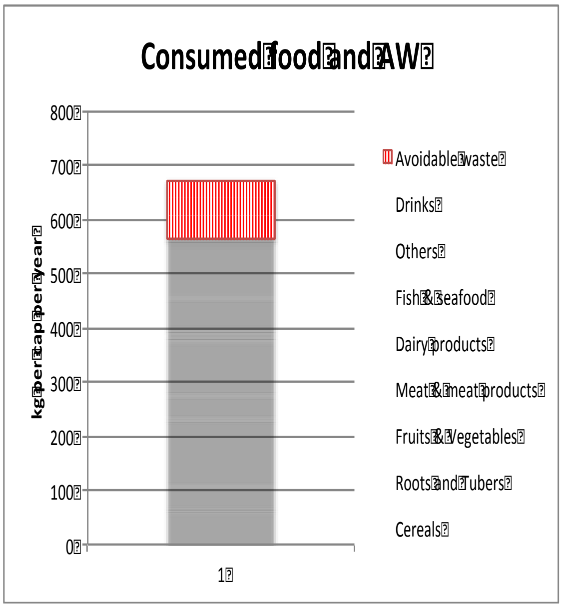

Figure 12: Net values of consumed food and AW.

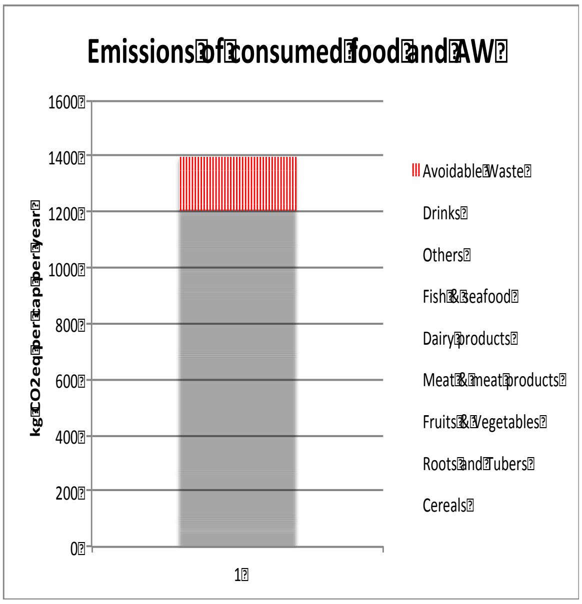

Figure 13: Net values of emissions corresponding to consumed food and AW.

Major Contributors

Based on the previous results, the top-three commodities in terms of AW, AW-emissions and AW-emissions intensity were identified.

Avoidable Waste (AW)

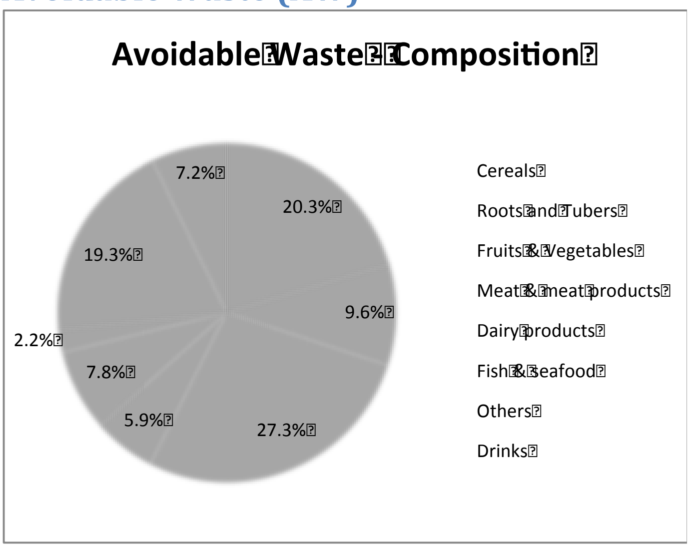

Figure 14: Contribution of commodity groups to total per cap avoidable waste.

In net values the top-three of avoidably wasted commodity groups are "fruits and vegetables" (29kg), "cereals" (22kg) and "others" (20kg). The three groups contribute over 65% in the total of avoidable waste, as illustrated in Figure 14.

Fruits and vegetables are expected to be the most wasted commodity group, because of the vulnerability of the items. Despite any protection packaging or processing techniques, fresh items are perishable and very often end up in the waste bin either whole or partly consumed (Parfitt et al. 2010).

More than half of avoidable waste of “others” is attributed to cereal-containing items like pizzas, pancakes and sweet bakery products, while the top-wasted item of “cereals” is bread (Annex IV). This finding implies a further loss of cereal grain produce, transformed in various edible forms (i.e. processed foods included in “others”), and makes “cereals” a high-priority commodity for intervention.

GHG emissions

The top-three contributors in net values of AW-emissions are: “meat & meat products” (60kgCO_{2eq}), “fruits & vegetables” (37kgCO_{2eq}) and “others” (26kgCO_{2eq}) which comprise 65% of the total AW-emissions (Fig. 15).

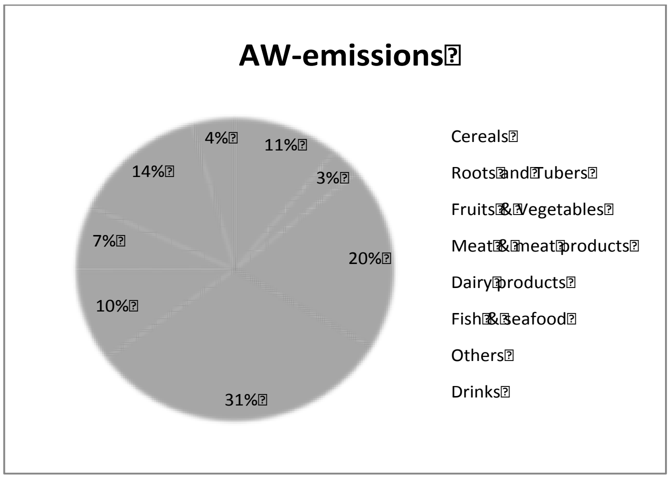

Figure 15: Shares of AW-emissions per commodity group.

The group of meat products has the most significant impact, as it includes beef and lamb (two of the highest emitting products). Fruits and vegetables are also expected to present high AW-emissions, mainly related to their high AW quantities, rather than to their lifecycle emissions.

AW Emissions Intensity

Another way to identify critical commodity groups is to estimate the AW-emissions per unit of avoidable waste (kgCO_{2eq} per kg of AW). The results are presented in Figure 16 and the top-three includes the following commodity groups:

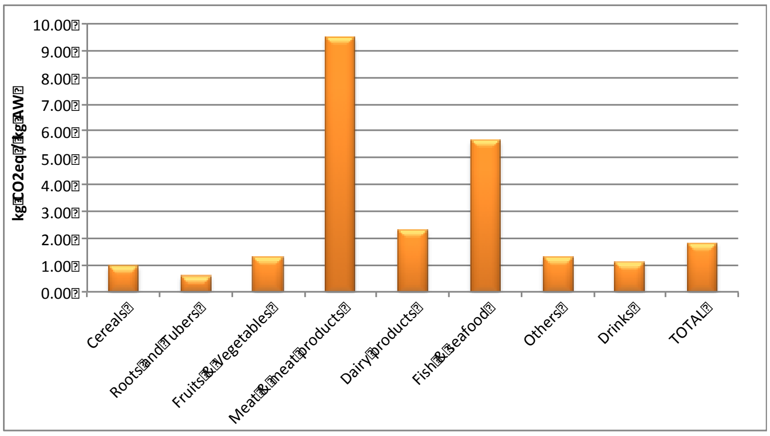

Figure 16: AW-Emissions per kg of Avoidable Waste.

i. “Meat and meat products” have the highest impact in terms of emissions intensity (9.5kgCO_{2eq} / kg of AW), which is explained by the high emissions attributed to this group and is also reflected in the estimated AW-emissions.

ii. The second most intense commodity group is “fish and seafood” (5.6kgCO_{2eq} / kg of AW). The emissions per unit of avoidably wasted fish products are higher compared to the remaining commodity groups (although almost half of that of meat) and therefore make this group a new point of attention and intervention, even though fish contributes just 7% to the total AW-emissions and has the lowest net weight of avoidable wastage (2% per weight).

iii. Third in line comes the "dairy products" group (2.3kgCO_{2eq} / kg of AW), which also has a relatively low net AW and AW-emissions contribution (~8% and ~10% respectively).

Scenario A

For the estimation of the maximum reduction (theoretical potential) of food related waste and emissions in this case study, it is presumed that consumers manage their eating habits in such a way, that they produce zero avoidable waste. In such a case, if all avoidable food waste were eliminated, then the following "savings" would be achieved:

- 106kg of waste, or 16% of edible food or 64% of total food waste per cap, and
- 190kgCO_{2eq} of GHG emissions or 14% of yearly per cap emissions related to food consumption.

Scenario B

This section presents the second studied scenario, the proposed action plan incorporating solutions for the limitation of impacts and the estimation of its maximum effectiveness in AW and AW-emissions reduction. Following the steps described in methodology, the results are presented below.

Major Contributors

Six major contributors to AW and related emissions were identified as action-groups and are presented in Table 4.

Table 4: Commodity groups identified as major contributors to avoidable waste and GHG emissions.

	AW	AW Emissions	AW Em. Intensity
Fruits & vegetables	+	+	
Cereals	+		
Others	+	+	
Meat & products		+	+
Fish & seafood			+
Dairy Products			+

Principal reasons of wastage

The main reasons of disposal of each group and its AW-portion were detected through the results of WRAP (Quested & Johnson 2009). "Not used in time" appears to be the principal cause of disposing for all groups, with the exception of "meals" (sub-group of "others") and "other cereals" (sub-group of "cereals" including all items but bakery products), which lay in the category "cooked, prepared or served too much". As the dominant cause of wastage is "not used in time", this is the one considered in the design of the recommended action plan.
WRAP defines "not used in time" as "*food and drink that has been disposed of because it has passed a date label (e.g. use by or best before date), that has gone mouldy or rotten, looked, smelt or tasted bad*" (Quested & Johnson 2009).

AW & AW- Emissions savings

In order to estimate the AW and AW-emissions savings, it has been assumed that the measures to combat the main reason of AW production in these 6 commodity groups are expected to cease the wastage attributed to the targeted reasons. The results of savings in both AW and AW-emissions are presented in Table 5 and in detail in Annex VII.

Table 5: Estimation of avoidable waste and the corresponding emissions reduction, according to Scenario B.

Commodities	Main reason of disposal	% AW due to main reason of disposal	Net AW Savings (kg)	Net AW-Emissions Savings (kgCO2eq)	% Savings
Fruits & vegetables	**NOT USED IN TIME**	52%-66%	21	27	73%
Cereals		70%-82%	17	16	77%
Others		47%-80%	14	18	67%
Meat & products		66%	4	39	66%
Fish & seafood		66%	2	8	66%
Dairy Products		56-95%	6	15	75-80%
TOTAL			**63**	**123**	

Taking as an example 82% of bread-AW (in the group of "cereals) is disposed of because they are not eaten when they are considered proper for consumption (e.g. expired or foods with mould). Measures taken to battle exactly this consumption habit (e.g. training on the meaning of expiration dates, etc.) would save up to 12kg (maximum possible per person per year) of bread from being thrown away and emit 9kgCO_{2eq} less.

When this concept is applied to the top-six (as identified in this project) action groups, it will lead to:

- 63kg less avoidable waste or 9% less purchased edible food and savings of 38% of total food waste per cap and
- 123kg CO_{2eq} or 8% less food consumption emissions per capita per year.

When compared to the total AW and AW-emissions produced by the studied dietary pattern, then actions on 83% (88kg) of the total AW may result in 60% less AW and 65% less AW-emissions. This estimation presents the maximum effectiveness of an action plan aiming at AW and AW-emissions, as described in this scenario.

The AW and AW-emissions reduction potentials of both Scenarios are presented in Figure 17.

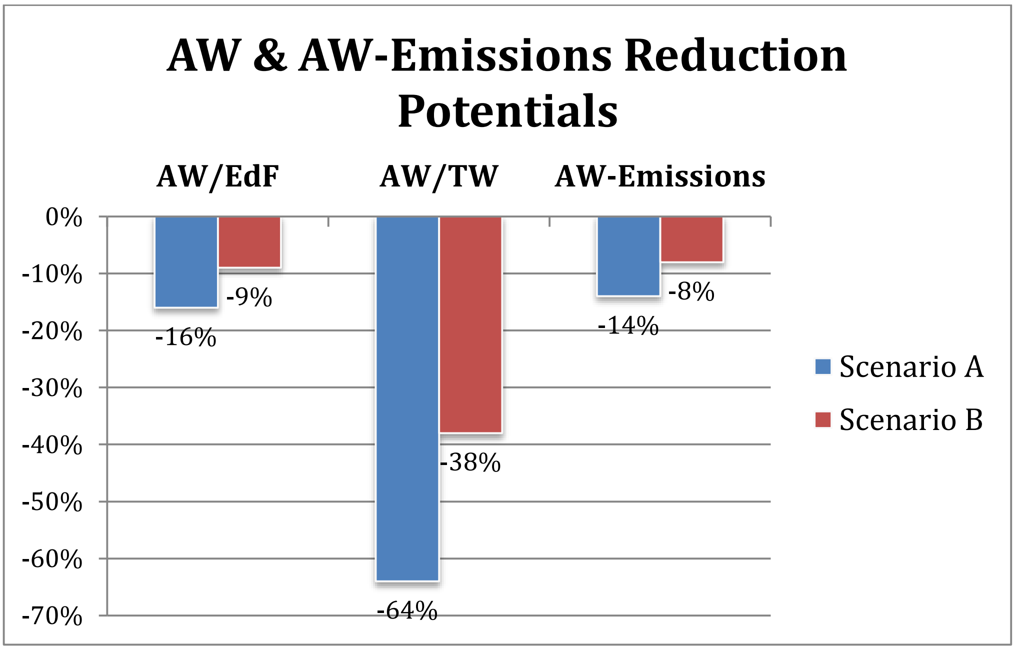

Figure 17: AW and AW reduction potentials according to Scenarios A & B.

Action Plan for Consumers

The estimated savings show that there is a potential to achieve significant results in impacts reduction. But the causes that lead consumers "not to use in time" the food have to be born in mind: product expiry, buying quantities over the needs, buying without plan. Actions that help consumers to reduce "not used in time" foods are commonly met in informative campaigns [11] and include but are not limited to:

i. planning of purchases (i.e. "smart" shopping, using a list, etc.),
ii. awareness of expiration dates (including knowing when to ignore them),
iii. knowing how to store and preserve the perishables (freezing, packaging, etc.),
iv. being cautious with supermarket "buy-one-get-one-free" offers.

Table 6 presents which actions apply in each of the identified commodity groups, according to their nature and special characteristics.

Table 6: Commodity groups and actions against "not used in time", based on the nature of the commodities.

<table>
<tr><th></th><th>PLANNING</th><th>EXP. DATES</th><th>STORAGE</th><th>PURCHASED QUANTITIES</th></tr>
<tr><td>Fruits & vegetables</td><td rowspan="6">+</td><td rowspan="6">+</td><td>+</td><td rowspan="6">+</td></tr>
<tr><td>Cereals</td><td></td></tr>
<tr><td>Others</td><td></td></tr>
<tr><td>Meat & products</td><td>+</td></tr>
<tr><td>Fish & seafood</td><td>+</td></tr>
<tr><td>Dairy Products</td><td>+</td></tr>
</table>

[11] Take Part – "5 easy ways to stop food waste": http://www.takepart.com/photos/5-easy-ways-stop-food-waste/trash-your-food-wasting-habits

Regarding labelled dates of expiry, there is a lot available in the Internet educating consumers to use properly the information[12] and – when applicable - even to "ignore" expiration dates[13]. Additionally, re-evaluation and prolongation of expiry dates – when applicable – could become official measures, imposed through relative policies. A further step, tackling the second in line reason of wastage ("cook, prepared or served too much") is the so called "smart/creative cooking" (i.e. preparing and serving the right quantities and using the leftovers).

Nevertheless, such campaigns alone cannot have a permanent effect, as affecting consumers' behaviour is a rather complex issue (Quested et al. 2013; Boström & Klintmann 2009). Informing/raising awareness on the FW issue and its impacts alone is not enough. Consumers need to be educated, receive training through practical, easy to understand tools (Wakeland et al. 2009), be motivated (e.g. saving money) and "nudged" (Ölander & Thøgersen 2014) to change habits and routine. Moreover, as Carlsson-Kanyama & Lindén (2001) pointed, information to consumers has low or no result if not accompanied by feedback; therefore they suggest the settlement of a feedback system that would help consumers to provide feedback about their performance (the publication refers to monitoring of energy intake, but in behavioural terms, such a closing loop would possibly help habitual adjustment in other fields, like reduction of waste). All these are summarised in BOX 1.

Still, not everything has to come from the side of the consumer. Marketing and selling practices have to change, to allow consumers to change within this context, by for example re-designing packaging, selling the right quantities and extending the shelf-lives of products, when possible (Quested et al. 2013).

BOX 1 – ACTION PLAN FOR CONSUMERS

How may all these be achieved? By educated and motivated consumers who will better manage and use their food purchases.
For this purpose the proposed action plan includes:

- Variable information sources:
    - audio-visual campaigns (printed, oral and visual advertising),
    - Internet (web pages, social media and other Internet applications),
- "Live", hand-on experience (lectures, markets and meetings/forums about food waste, public cooking using expired but edible foods),
- Literate people/trainers to provide the know-how and motivate consumers on the topic and its solutions,
- Creating feedback loops.

[12] Love Food – Hate Waste: http://england.lovefoodhatewaste.com/content/date-labels-infographic
[13] WebMed: http://www.webmd.com/a-to-z-guides/features/do-food-expiration-dates-matter?page=2
Take Part: http://www.takepart.com/photos/5-easy-ways-stop-food-waste/5-ignore-expiration-dates

6. DISCUSSION

This thesis focuses on two specific impacts of food consumption - avoidable waste (AW) and the AW-related GHG emissions - to identify any potential benefits deriving from consumers' behavioural adaptation towards more environmentally friendly habits. For this purpose the quantities of purchased and wasted food items and the corresponding GHG emissions were estimated, two scenarios for AW and AW-emissions reduction were investigated and an action plan was created. In this chapter a further analysis of results takes place, by introducing and discussing similar findings and points of improvement.

Commodity Groups

In accordance to most literature findings, bread and perishables like vegetables are mostly wasted (14kg per cap per year each), principally because they are left to decay, or have passed the "acceptable" date of use printed on the label, or even (as mentioned by Quested & Johnson 2009) because consumers considered that food looked or smelt inappropriately for consumption. Overall GHG emissions are elevated for the product groups with the highest emitting life cycles, like meat and dairy, but also for fruits and vegetables, due to the large purchased quantities, rather than because of their high EFs.

The bulk group of "others" contains all food items that could not be classified in one of the other groups or could not form a commodity group alone. As a result, processed foods like desserts, sweeteners and composite meals are included here, the impacts of which when accumulated make a significant contribution in both AW and AW-emissions. It is notable that "sweet bakery products", significant AW contributors, if studied along with "bread", could also formulate a group (i.e. "bakery" altogether) with high impacts on both AW (20kg of AW per cap per year) and AW-emissions (19kg CO_{2eq} per cap per year).

Packaging is not included here as a part of wastage, although it plays an important role in food waste, like for example in the case of dairy products which would appear having a higher impact in both AW and emissions if their packages were included in estimations. Packaging of wasted foods may also provide useful information about the reason of disposal (e.g. expiration dates) and additionally prolong the products' lifetime by protecting foods from degradation.

The Big Picture

The overall weight of per capita AW found here (106kg per cap per year) is rather high compared to the recently published result of the Swedish Environmental Protection Agency (SEPA 2014), not only in net values, but also as a share of the total food waste produced by consumers. Nevertheless, the results of the current work coincide with another, older SEPA study, which refers to similar findings in both waste and emissions (SEPA 2010) (Table 7).

Table 7: Comparison of results - current study, SEPA (2010), SEPA (2014).

	Current Study	SEPA 2010	SEPA 2014
TW	165 kg	n/a	102 kg
AW	106 kg	100kg	40 kg

%AW/TW	64%	n/a	39%
AW - emissions	190 kg CO_{2eq}	200 kg CO_{2eq}	n/a
Method	Model based on Statistics	n/a	CFWA and Statistics
Data sources	Global / European / UK studies	Swedish / UK studies	Swedish authorities
Definitions	WRAP	n/a	Own, similar to WRAP
Sewer Waste	✓	n/a	✗
Packaging	Not included	n/a	Not clear

It is interesting to look into possible reasons that explain such differences, between the results of the current study and SEPA (2014). Although the distinction between "avoidable" ("unnecessary" in SEPA) and unavoidable waste is similar, SEPA does not include sewer waste (incl. drinks and other liquids poured down the drain), which may only partially explain the lower quantities found (the AW of the current study, excluding liquids (drinks, juices, milk and yoghurt) is 88kg per cap per year). Although including limited waste streams is a disadvantage in the composition waste analysis (CFWA), on the other hand CFWA is usually more objective and accurate in terms of product category, mass, packaging, etc. Additionally, SEPA (2014) uses national, official data and statistics on waste, while in this study global, European and UK waste data is adopted (similar data are used in SEPA 2010). The method of the current study may have assets like broader applications, coverage of larger areas, etc., it produces however more ambiguous results because of the assumptions made.

Drivers of consumption habits

The action plan that aims to behavioural switch of consumers towards less AW includes apart from awareness, information and motivation, other elements, such as "nudging" and "closed loops" to create feedback reactions and lead to its improvement. However, these alone may not be enough, as societal and economical elements of the region have to be also considered in its design. As mentioned in the "Food Waste" chapter, the factors that lead to creation of waste are crucial and may differentiate from one region to another (or at least from one study to another). For example the income or age appear to play a significant role in some cases, while in others not. Other factors to be considered are the size and type of households, the educational level and cultural influences. The role of gender is also quite often discussed, with Boström & Klintmann (2009) making an interesting analysis of the fact that women appear to be more conscious in terms of "green" behaviour, than men.

Efficiency of Action Plan

The action plan is based on the concept of gradual, step-by-step evolution/transformation of consumers' habits (e.g. Hoolohan et al. 2013) by targeting the most crucial, high-impact commodity groups and the most common reason of wastage. The maximum effectiveness of the action plan against AW and AW-emissions corresponds to the maximum possible savings, which are not expected to be fully reached in practice.

It becomes evident, though, that not only the wasting habits, but also other things must change to move towards environment-friendly food consumption (i.e. with less waste & emissions). This includes additional actions from consumers (dietary shifts, conscious selection of food items, etc.), food industry (like the agriculture sector, which has the highest impact within FSCs) and other stakeholders, like state (country, county or municipality) through policies and guidelines. The development of measures, policies for industry and other stakeholders is proposed as a further point of research. The recommendation here is to incorporate all these elements in a broader, uniform Strategy, with clear objectives for the improvement on food consumption habits and the reduction of waste, as illustrated in Fig. 18.

Figure 18: Recommended strategic plan

Limitations and Points of Improvement

Carrying out this project involved the synthesis of data from variable sources - each of which includes its own uncertainties - and a series of assumptions to make possible the estimation of the investigated variables within the scope of a Master Thesis project.

The main limitations and points of improvement of this work include:

- Uncertainty in dietary consumption data: under-reporting – and in some cases over-reporting – of consumption data has been a repeatedly spotted in dietary surveys (Johansson & Solvoll 1998; Becker et al. 1999; Goris et al. 2007); Berners-Lee et al. (2012) adjusted the reported food intake by adding 20%. In this project, it was selected not to make such adjustments on the dietary data and therefore the net values of estimated food and waste variables might not be depicting reality. Nevertheless, the input data used are the official results of the latest national Swedish survey (Amcoff et al. 2012) and therefore these are officially considered to be the eating habits in the country.
- Application of WRAP results for UK wastage percentages on Swedish food consumption: as discussed in methodology, this assumption is based on the results of FAO report (Gustavsson et al. 2013) on global food waste trends, which used the percentages of WRAP to estimate waste from consumption phase in Europe. The use of waste percentages as identified by WRAP is expected to be valid, as apart from their use by FAO (2013), they were determined by the combination of the three available methods of estimating food waste (compositional waste analysis, self-reported, mathematic models).

- The reported food consumption does not correspond only to food prepared at home; it may also include food consumed in restaurants or take-away; additionally it is not clear whether reported meals are mainly cooked at home. Still, the WRAP results refer only to household waste and do not include waste from the service sector (restaurants, etc.), although the calculations in this work are done on food consumption, irrespectively where it took place. Therefore the estimation of avoidable waste may be higher compared to what is really produced in the houses.
- The breakdown of commodity groups was done according to external data like the national food supply as provided in the Food Balance Sheet for Sweden in 2009 (FAOSTAT 2014), when details were not provided by the dietary survey in English,
- LCA data are compiled from various sources: these were carefully selected, but still there is some point of uncertainty in the LCA process itself and details of the FSC are not always evident. For most of the food items, more than one LCA estimations were sought and compared, before making the final selection of the item's EF used in the project.

7. CONCLUSIONS

The theme of food incorporates a series of dimensions, starting from the fundamental need of nutrition and expands to health, pleasure, culture, social affairs, etc., which involve input from multiple disciplines like medicine, industry, politics, ethics, finance, society, etc. This project focuses on a partial aspect of this complex context: the impacts of food being misused and disposed of by the consumers themselves. Various opportunities appear for the reduction of food waste and GHG emissions in the stage of consumption, with "zero or less avoidable waste" being an option of medium to high priority to counteract the negative influences of this phenomenon appearing principally in developed, urbanised areas.

Within the scope of this work, the dietary habits of Sweden were used as a starting point to estimate the quantities and the potential to mitigate AW and AW-emissions. The European/UK wastage percentages were applied on the Swedish diet to estimate how much of the edible, purchased food ends up in the bin, and LCA data from farm to retail were used to calculate the GHG emitted throughout the FSC to make these goods available to consumers.

It was found that Swedish consumers have the potential to reduce their footprints by a maximum of 16% in terms of AW and 14% in terms of AW-emissions (shares of the edible part of food), by being precise with the quantities of their food purchases. As the complete elimination of AW is not feasible, at least not "at once", an action plan was developed that aims at more practical reductions of AW and AW-emissions, by fighting the main reason of disposal of the most wasted and emitting commodities. The detected major contributors were groups like fruits and vegetables in terms of waste and meat in terms of emissions, as expected from previous literature findings. A well organised action plan, targeting exactly this combination: commodity & major reason of disposal, may become a starting point to altering the consumers' behaviour. It is though important to be incorporated in a larger strategic plan against food waste (and losses) within the FSC, to tackle practices that create high-impact consumerism.

Concluding this project, it is obvious that actions to mitigate the studied issues are more important than just measuring them, as quantification may include substantial uncertainty. On the other hand, keeping track of the results and the desired potential improvement is equally important, to reinforce and improve the efforts. Consequently, continuous development of the methods of estimating food waste and GHG emissions is decisive to reach the goals of behavioural transformation in food consumption.

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9. ANNEXES

Annex I

Table I-1: Mean daily consumption of food items (g/day) as reported in Riksmaten 2010-2011[14].

[14] Source: Riksmaten 2010-2011
http://www.slv.se/upload/dokument/rapporter/mat_naring/2012/riksmaten_2010_2011.pdf

RIKSMATEN 2010-2011					
		men	women	TOTAL	
participants		792	1005	1797	
%		44%	56%	100%	
Food commodities		**g / day**			
Margarine, butter		13	10	11	
Cheese		25	25	25	
Milk, yoghurt		267	227	245	
Bread		102	75	87	
Potatoes		133	73	99	
Roots		20	23	22	
Vegetables		136	147	142	
Fruit and berries		105	147	129	
Juice		64	52	57	
Porridge, gruel		43	35	39	
Breakfast cereals, muesli		14	10	12	
Pancakes etc.		10	8	9	
Pizza, pie, pirog		46	27	35	
Rice, dishes		29	23	26	
Pasta		31	22	26	
Pulses		12	12	12	
Meat, poultry and dishes		103	70	85	
Eggs		14	14	14	
Fish, seafood		45	38	41	
Blood products		1	1	1	
Offal		3	2	2	
Sausages and dishes		28	15	21	
Nuts, snacks		8	8	8	
Sweet bakery products		33	30	31	
Ice cream, parfait		9	7	8	
Cream		7	9	8	
Sweet soups, desserts		16	18	17	
Marmalade, jam		11	9	10	
Soft-drinks, fruit syrups		132	95	111	
Chocolate and candy		10	13	12	
Sugar, syrup, honey		3	2	2	
Alcoholic beverages		217	97	150	
Coffee, tea, water		942	1099	1030	
Spices, salt, vinegar				0	
Sauces		29	26	27	
TOTAL (g/day)		**2661**	**2469**	**2553**	

Table I-2: Food Commodity Groups

COMMODITY GROUPS	FOOD ITEMS PER GROUP
Cereals	
	Bread
	Porridge, gruel
	Breakfast cereals, muesli
	Rice, dishes
	Pasta
Roots & Tubers	
	Potatoes: fresh and processed
	Other Roots
Fruits & Vegetables	
	Vegetables: fresh (tomatoes, onions, other) & processed
	Fruits and berries: fresh (orange & other citrus fruits, other fresh fruits) & processed (frozen, canned)
	Juices
	Pulses
Meat & meat products	
	Meat, poultry and dishes (beef, pork, lamb, poultry)
	Blood products
	Sausages and dishes
	Offal
	Eggs
Dairy products	
	Margarine
	Butter
	Cheese
	Milk
	Yoghurt
Fish & seafood	
	Fresh & processed
Others	
	Sweet bakery products
	Confectionary & snacks (nuts, snacks, chocolate and candy)
	Cakes & desserts (ice cream, parfait, cream, sweet soups, desserts)
	Condiments, herbs, spices (marmalade, jam, sugar, syrup, honey, sauces)
	Meals (pancakes, pizza, pie, pirog, etc.)
Drinks	
	Alcoholic beverages (wine, beer, other)
	Soft-drinks, fruit syrups
	Coffee
	Tea

ANNEX II

Assumptions on dietary data

As waste percentages vary between fresh and processed forms of various commodities (e.g. vegetables, potatoes, etc.), rough assumptions have been made on the corresponding proportions consumed (e.g. the shares between fresh and processed forms have been mostly considered to be 50-50). Below the affected commodity groups with the corresponding assumptions are listed.

Roots and tubers

Potatoes and other roots: 50% fresh & 50 % processed.

Fruits and vegetables

Vegetables: 50% fresh & 50 % processed.
The share of fresh vegetables was further split according to the food supply in the country in 2009 (2009-FBS for Sweden; (FAOSTAT 2014)).

Fruits: 50% fresh & 50 % processed.
The major categories in fruits are created according to the 2009-FBS for Sweden (FAOSTAT 2014): citrus fruits comprise 47% of all fruit supply, while apples and apple products are 15% and bananas 12%. Therefore the category of fresh fruits is split into "oranges and other citrus fruits" (47%) and "other fresh fruits" (53%).

For processed fruits a distinction between frozen and canned is made (assuming that the amount is again split into two halves).

Juices include the reported as "fruit and vegetable juices" and were included in this category - instead of drinks - and they are considered to be a direct product of this commodity group.

Meat and meat products

For the category of "meat, poultry and dishes" (subcategory of "meat & meat products") the allocation among the four main items (beef, pork, lamb and poultry) has been made according to the proportions of the national food supply as reported in 2009- FBS for Sweden.

Tea and coffee

Tea and coffee quantities have been converted from the weight of the consumed liquid to the weight of the products (leaves and grains) themselves. More specifically it has been assumed that densities of both coffee and tea drinks are 1gr/ml and that:
- a tea bag of 5gr is used to prepare 325ml of tea (WRAP, 2009, p.79)
- for a cup of coffee, one needs 177ml of water and 10.6gr of coffee (http://www.blackbearcoffee.com/resources/83).

ANNEX III

Fish and seafood exercise.

The amount of consumed fish and seafood provided by the results of the dietary survey included all items and their processed forms in a total quantity (mean value for men and women: 14,99kg/yr). In order to estimate the quantities of total and avoidable waste, as well as the related emissions, at a yearly per capita base, it was necessary to perform the following breakdown to estimate the contribution of the various food items (in fresh and processed forms) included in this category, making the necessary assumptions.

The input information was from two data groups:

a. the available forms of fish and seafood in Sweden in 2010, as provided in FBS (FAOSTAT 2014) (A), including their total available quantity at that year (B). Cephalopods and molluscs were merged into one item, as their wastage % and EFs are similar. The share (%) of each form was calculated (C). Based on this, it was assumed that the mean consumption of each item corresponds to the share of the available quantities (D).

A. Items	B. Total Supply (kg / cap) FBS Swe-2010	C. % of available fish items	D. CONSUMED Riksmaten 2010-11 (kg/cap)
Fish, Seafood	31,30	100%	14,99
Freshwater Fish	7,50	24%	3,59
Demersal Fish	7,40	24%	3,54
Pelagic Fish	6,90	22%	3,30
Marine Fish, Other	0,80	3%	0,38
Crustaceans	7,70	25%	3,69
Cephalopods & Molluscs, Other	1,00	3%	0,48

b. the shares of various forms of processing in which these products were consumed. The input of this information came from market data of 2008 (SOURCE: Popescu 2010), as more recent data could not be obtained.

FRESH	FROZEN	CANNED	SMOKED, ETC.
26%	35%	21%	18%
FRESH	**PROCESSED**		

The second assumption made here is that each one of the fish & seafood items was 26% freshly consumed and 74% consumed in a processed form (35% frozen, 21% canned, 18% smoked). Given all the above the corresponding amounts of each item and each form of processing were estimated:

Fish Items	CONSUMED Riksmaten 2010-11	FRESH 26%	FROZEN 35%	CANNED 21%	SMOKED, ETC. 18%
Fish, Seafood	**kg / cap**				
Freshwater Fish	3,59	0,93	1,26	0,75	0,65
Demersal Fish	3,54	0,92	1,24	0,74	0,64
Pelagic Fish	3,30	0,86	1,16	0,69	0,59
Marine Fish, Other	0,38	0,10	0,13	0,08	0,07
Crustaceans	3,69	0,96	1,29	0,77	0,66
Cephalopods & Molluscs, Other	0,48	0,12	0,17	0,10	0,09
TOTAL	**14,99**	**3,90**	**5,25**	**3,15**	**2,70**
	Fresh	**3,90**	**11,09**	Processed	

The next step was to estimate the avoidable and total food waste. The % of avoidable waste of fresh fish is 11% (a=0,11) and of processed 10% (a=0,10), while the total waste for both is 23% (t=0,23). The total waste of fresh crustaceans and molluscs is different as 62% of unpeeled shrimps (major item of crustaceans) and 71% of molluscs is unavoidable waste (Ekström 2012). Therefore the total waste is 73% and 82% of the fresh forms of product. Based on this the avoidable and total waste per item are:

Avoidable waste (kg)	FRESH	FROZEN	CANNED	SMOKED, ETC.	
Freshwater Fish	0,13	0,16	0,10	0,08	
Demersal Fish	0,13	0,16	0,10	0,08	
Pelagic Fish	0,12	0,15	0,09	0,08	
Marine Fish, Other	0,01	0,02	0,01	0,01	
Crustaceans	0,39	0,17	0,10	0,09	
Cephalopods & Molluscs, Other	0,08	0,02	0,01	0,01	
TOTAL AVOIDABLE	0,86	0,68	0,41	0,35	**2,31**

Total waste (kg)	FRESH	FROZEN	CANNED	SMOKED, ETC.	
Freshwater Fish	0,21	0,29	0,17	0,15	
Demersal Fish	0,21	0,29	0,17	0,15	
Pelagic Fish	0,20	0,27	0,16	0,14	
Marine Fish, Other	0,02	0,03	0,02	0,02	
Crustaceans	0,70	0,93	0,56	0,48	
Cephalopods & Molluscs, Other	0,10	0,14	0,08	0,07	
TOTAL	1,45	1,94	1,16	1,00	**5,54**

Following, the EFs of each item were identified in literature[15]:

EF ($kgCO_2$ / kg edible)	FRESH	FROZEN	CANNED	SMOKED, ETC.
Freshwater Fish	2,05	4,47	4,09	3,91
Demersal Fish	3,83	7,80	7,40	7,40
Pelagic Fish	1,36	3,20	2,80	1,49
Marine Fish, Other	0,72	1,80	2,60	1,49
Crustaceans	7,89	10,50	10,50	10,50
Cephalopods & Molluscs, Other	0,31	4,02	5,92	2,30

and the corresponding emissions of consumed food and avoidable waste were estimated:

Emissions of consumed (kg CO_2)	FRESH	FROZEN	CANNED	SMOKED, ETC.	
Freshwater Fish	1,91	5,62	3,09	2,53	
Demersal Fish	3,53	9,68	5,51	4,72	
Pelagic Fish	1,17	3,70	1,94	0,89	
Marine Fish, Other	0,07	0,24	0,21	0,10	
Crustaceans	7,57	13,55	8,13	6,97	
Cephalopods & Molluscs, Other	0,04	0,67	0,60	0,20	
TOTAL EMISSIONS	14,29	33,46	19,47	15,41	**82,63**

Emissions of avoidable waste (kg CO_2)	FRESH	FROZEN	CANNED	SMOKED, ETC.	
Freshwater Fish	0,27	0,73	0,40	0,33	
Demersal Fish	0,49	1,26	0,72	0,61	
Pelagic Fish	0,16	0,48	0,25	0,12	
Marine Fish, Other	0,01	0,03	0,03	0,01	
Crustaceans	3,10	1,76	1,06	0,91	
Cephalopods & Molluscs, Other	0,02	0,09	0,08	0,03	
TOTAL EMISSIONS AVOIDABLE	4,06	4,35	2,53	2,00	**12,95**

[15] The main sources of EFs have been the "LCA Food Database" www.lcafood.dk (Nielsen PH, et al. 2003) and Ekström 2012; all listed in Annex IV.

ANNEX IV

Emission Factors (kg CO2eq / kg edible product))

FOOD COMMODITIES	EF	Source	Notes / Assumptions
Cereals			
Bread	0.80	Ekström, 2012	
Porridge, gruel	1.00	Ekström, 2012	EF similar to "cereals"
Breakfast cereals, muesli	1.00	Ekström, 2012	EF similar to "cereals"
Rice, dishes	2.00	Ekström, 2012	
Pasta	1.00	Ekström, 2012	
Roots and Tubers			
Potatoes			
fresh	0.17	Wallén et al. 2004	
processed	1.35	Wallén et al. 2004	Mean value of 3 EFs for processed potatoes: mashed, frozen and other potato products.
Roots			
fresh	0.50	Wallén et al. 2004	
processed	1.35	Wallén et al. 2004	EF of processed roots same as EF of processed potatoes.
Fruits & Vegetables			
Vegetables			
fresh			
tomatoes	3.29	Wallén et al. 2004	
onions	0.50	Wallén et al. 2004	
other	0.70	Ekström, 2012	
processed	1.30	Ekström, 2012	Frozen vegetables
Fruits and berries			
fresh			
orange & other citrus fruits	0.90	Ekström, 2012	EF of "oranges"
other fresh fruits	0.50	Ekström, 2012	Mean value of EFs for apples, fresh fruit and berries from Nordic countries and imported fresh fruit and berries.
processed			
frozen	1.30	Ekström, 2012	Same as frozen vegetables
canned	1.00	Ekström, 2012	EF of "tinned food"
Juice	1.30	Ekström, 2012	
Pulses	0.70	Ekström, 2012	
Meat & meat products			
Meat, poultry and dishes			
Beef	29.00	Ekström, 2012; Cederberg et al. 2009	
Pork	5.10	Ekström, 2012; Cederberg et al. 2009	
Lamb	23.00	Ekström, 2012; Wallman et al. 2011	
Poultry	2.70	Cederberg et al. 2009	

Blood products	2.10	Ekström, 2012	Same as "sausages and dishes"
Sausages and dishes	2.10	Ekström, 2012	
Offal	2.10	Ekström, 2012	Same as "sausages and dishes"
Eggs	2.00	Ekström, 2012; Cederberg et al. 2009	
Dairy products			
Margarine	0.90	Ekström, 2012	
Butter	8.00	Ekström, 2012	
Cheese	9.30	Ekström, 2012	
Milk	1.50	Gerber et al. 2010	
Yoghurt	1.60	Gerber et al. 2010	
Fish & seafood			
Fresh		see Annex II	
Processed		see Annex II	
Others			
Sweet bakery products	1.30	Ekström, 2012	
Confectionary & snacks			
Nuts, snacks	1.90	Ekström, 2012	EF of "unspecified nuts"
Chocolate and candy	2.70	Ekström, 2012	EF of "milk chocolate"
Cakes & desserts			
Ice cream, parfait	2.00	Ekström, 2012	
Cream	0.41	Wallén et al. 2004	
Sweet soups, desserts	1.80	Wallén et al. 2004	EF of "sweats and desserts"
Condiments, herbs, spices			
Marmalade, jam	0.80	Ekström, 2012; Wallén et al. 2004	
Sugar, syrup, honey	1.00	Ekström, 2012	
Spices, salt, vinegar	0.30	Wallén et al. 2004	
Sauces	1.00	Ekström, 2012	
Meals			
Pancakes etc.	1.32	Berlin & Sund, 2010	EF of a "pasta meal", because of similar ingredients to a pizza
Pizza, pie, pirog	1.32	Berlin & Sund, 2010	EF of a "pasta meal", because of similar ingredients to a pizza
Drinks			
Alcoholic beverages			
Wine	1.80	Ekström, 2012	
Beer	0.40	Ekström, 2012	
Other	4.10	Ekström, 2012	
Soft-drinks, fruit syrups	0.33	Nilsson et al. 2011	EF for cola: 0,11kgCO2 per bottle of 33cl. Assumption: cola density = 1gr/ml EF per kg of product = 0,11/0,33
Coffee	5.45	PCF, 2009	
Tea	9.49	Doublet & Jungbluth, 2010	

List of LCA sources:

Berlin, J., & Sund, V. (2010). *Environmental Life Cycle Assessment (LCA) of ready meals*. SIK Report 804. Available at: http://www.sik.se/archive/pdf-filer-katalog/SR804.pdf, accessed May 2014.

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Wallman, M., Cederberg, C. & Sonesson, U., 2011. *Life Cycle Assessment of Swedish Lamb Production*. SIK Report 831. Available at: http://www.sik.se/archive/pdf-filer-katalog/SR831.pdf, accessed May 2014.

Annex V

Food and Waste Variables – detailed table of results per commodity item

COMMODITIES	FOOD			WASTE	
	Purchased	Edible	Consumed	Avoidable	Unavoidable
	kg per year per cap				
Cereals	94.4	90.9	69.4	21.5	3.5
Bread	49.6	46.1	31.8	14.4	3.5
Porridge, gruel	16.9	16.9	14.2	2.7	0.0
Breakfast cereals, muesli	5.2	5.2	4.4	0.8	0.0
Rice, dishes	11.3	11.3	9.5	1.8	0.0
Pasta	11.3	11.3	9.5	1.8	0.0
Roots and Tubers	65.5	54.4	44.2	10.2	11.1
Potatoes	53.4	44.2	36.1	8.0	9.2
Fresh	32.9	23.7	18.1	5.6	9.2
Processed	20.5	20.5	18.1	2.5	0.0
Other Roots	12.1	10.2	8.0	2.1	1.9
Fresh	7.4	5.5	4.0	1.5	1.9
Processed	4.7	4.7	4.0	0.7	0.0
Fruits & Vegetables	174.9	153.1	124.1	29.0	21.8
Vegetables	78.7	66.1	52.2	13.9	12.6
Fresh	48.3	35.8	26.1	9.7	12.6
Tomatoes	11.9	8.8	6.4	2.4	3.1
Onions	3.2	2.4	1.7	0.6	0.8
Other	33.2	24.6	17.9	6.6	8.6
Processed	30.3	30.3	26.1	4.2	0.0
Fruits and berries	66.7	58.2	46.7	11.5	8.6
Fresh	38.9	30.4	23.4	7.0	8.6
Orange & other citrus fruits	18.3	14.3	11.0	3.3	4.0
Other fresh fruits	20.6	16.1	12.4	3.7	4.5
Processed	27.8	27.8	23.4	4.4	0.0
Frozen	13.9	13.9	11.7	2.2	0.0
Canned	13.9	13.9	11.7	2.2	0.0
Juices	24.2	24.2	20.8	3.4	0.0
Pulses	5.3	4.6	4.4	0.2	0.7
Meat & meat products	59.7	51.6	45.3	6.3	8.1
Meat, poultry and dishes	42.2	35.6	31.0	4.5	6.7
Beef	12.9	11.4	9.9	1.4	1.5
Pork	18.7	16.4	14.4	2.1	2.2
Lamb	0.7	0.6	0.6	0.1	0.1
Poultry	9.9	7.1	6.1	1.0	2.8
Blood products	0.5	0.4	0.4	0.1	0.1
Sausages and dishes	10.0	8.8	7.7	1.1	1.2
Offal	1.4	1.3	1.1	0.2	0.2
Eggs	5.6	5.6	5.1	0.4	0.1
Dairy products	111.0	110.5	102.2	8.3	0.5
Margarine	4.0	4.0	3.7	0.3	0.0

Butter	0.4	0.4	0.4	0.0	0.0
Cheese	10.0	9.9	9.1	0.8	0.1
Milk	61.2	61.2	56.9	4.3	0.0
Yoghurt	35.3	34.9	32.1	2.8	0.4
Fish & seafood	29.9	17.3	15.0	2.3	12.6
Fresh	7.8	4.8	3.9	0.9	3.1
Processed	22.1	12.5	11.1	1.4	9.6
Others	83.8	82.7	62.2	20.5	1.2
Sweet bakery products	18.1	17.2	11.4	5.8	0.9
Confectionary & snacks	7.8	7.8	7.3	0.5	0.0
Nuts, snacks	3.1	3.1	2.9	0.2	0.0
Chocolate and candy	4.7	4.7	4.4	0.3	0.0
Cakes & desserts	14.0	14.0	12.0	2.0	0.0
Ice cream, parfait	3.4	3.4	2.9	0.5	0.0
Cream	3.4	3.4	2.9	0.5	0.0
Sweet soups, desserts	7.2	7.2	6.2	1.0	0.0
Condiments, herbs, spices	19.2	19.2	15.4	3.8	0.0
Marmalade, jam	4.6	4.6	3.7	0.9	0.0
Sugar, syrup, honey	0.9	0.9	0.7	0.2	0.0
Spices, salt, vinegar	1.4	1.4	1.1	0.3	0.0
Sauces	12.3	12.3	9.9	2.5	0.0
Meals	24.7	24.5	16.1	8.4	0.2
Pancakes etc.	5.1	5.0	3.3	1.7	0.1
Pizza, pie, pirog	19.7	19.5	12.8	6.7	0.2
Drinks	111.7	111.3	103.7	7.7	0.4
Alcoholic beverages	57.6	57.6	54.8	2.9	0.0
Wine	20.7	20.7	19.7	1.0	0.0
Beer	36.1	36.1	34.3	1.8	0.0
Other	0.8	0.8	0.7	0.0	0.0
Soft-drinks, fruit syrups	44.9	44.9	40.9	4.0	0.0
Coffee	8.3	8.0	7.3	0.7	0.3
Tea	0.8	0.8	0.7	0.1	0.0
TOTAL (kg/year)	**731**	**672**	**566**	**106**	**59**

Annex VI

GHG Emissions (kg CO_{2eq} per cap per year) – detailed table of results per commodity item

COMMODITIES	GHG EMISSIONS (kg CO_{2eq})		
	Edible Food	Consumed Food	Avoidable Waste
Cereals	93	72	20
Bread	37	25	12
Porridge, gruel	17	14	3
Breakfast cereals, muesli	5	4	1
Rice, dishes	23	19	4
Pasta	11	9	2
Roots and Tubers	41	35	6
Potatoes	32	27	4
Fresh	4	3	1
Processed	28	24	3
Other Roots	9	7	2
Fresh	3	2	1
Processed	6	5	1
Fruits & Vegetables	209	172	37
Vegetables	87	69	18
Fresh	47	35	13
Tomatoes	29	21	8
Onions	1	1	0
Other	17	13	5
Processed	39	34	6
Fruits and berries	88	73	14
Fresh	21	16	5
Orange & other citrus fruits	13	10	3
Other fresh fruits	8	6	2
Processed	32	27	5
Frozen	18	15	3
Canned	14	12	2
Juices	31	27	4
Pulses	3	3	0
Meat & meat products	480	420	60
Meat, poultry and dishes	447	391	56
Beef	330	288	41
Pork	84	73	10
Lamb	15	13	2
Poultry	19	17	3
Blood products	1	1	0
Sausages and dishes	18	16	2
Offal	3	2	0
Eggs	11	10	1

Dairy products	247	228	19
Margarine	4	3	0
Butter	3	3	0
Cheese	92	85	7
Milk	92	85	6
Yoghurt	56	51	5
Fish & seafood	96	83	13
fresh	18	14	4
processed	77	68	9
Others	112	85	26
Sweet bakery products	22	15	8
Confectionary & snacks	18	17	1
Nuts, snacks	6	6	0
Chocolate and candy	13	12	1
Cakes & desserts	21	18	3
Ice cream, parfait	7	6	1
Cream	1	1	0
Sweet soups, desserts	13	11	2
Condiments, herbs, spices	17	14	3
Marmalade, jam	4	3	1
Sugar, syrup, honey	1	1	0
Spices, salt, vinegar	0	0	0
Sauces	12	10	2
Meals	32	21	11
Pancakes etc.	7	4	2
Pizza, pie, pirog	26	17	9
Drinks	121	112	8
Alcoholic beverages	55	52	3
Wine	37	35	2
Beer	14	14	1
Other	3	3	0
Soft-drinks, fruit syrups	15	13	1
Coffee	43	40	4
Tea	8	7	1
TOTAL	**1,398**	**1,208**	**190**

Annex VII

Scenario B - detailed results

Commodities	Main reason of disposal	% AW due to main reason of disposal	Total AW (kg)	Savings AW (kg)	Total AW Emissions (kgCO2eq)	Savings AW Emissions (kgCO2eq)
Fruits & vegetables	**not used in time**	**52%-66%**	**29**	**21**	**37**	**27**
Fruits & juices	not used in time	83%	15	12	19	16
Vegetables & pulses	not used in time	52-66%	14	9	18	11
Fresh veg. & pulses	*not used in time*	*66%*	*10*	*7*	*13*	*9*
Processed veg.	*not used in time*	*52%*	*4*	*2*	*5*	*3*
Cereals	**not used in time**	**70%-82%**	**22**	**17**	**20**	**16**
Bread	not used in time	82%	14	12	12	9
Other	cooked, prepared or served too much	70%	7	5	9	6
Others	**not used in time**	**47%-80%**	**20**	**14**	**26**	**18**
Sweet bakery products	not used in time	80%	6	5	8	6
Confectionary & snacks	not used in time	72%	0	0	1	1
Cakes & desserts	not used in time	47%	2	1	3	1
Condiments, herbs, spices	not used in time	60%	4	2	3	2
Meals	cooked, prepared or served too much	65%	8	5	11	7
Meat & products	**not used in time**	**66%**	**6**	**4**	**60**	**39**
Fish & seafood	**not used in time**	**66%**	**2**	**2**	**13**	**8**
Dairy products	**not used in time**	**56-95%**	**8**	**6**	**19**	**15**
Margarine	not used in time	92%	0	0	0	0
Butter	not used in time	92%	0	0	0	0
Cheese	not used in time	95%	1	1	7	7
Milk	not used in time	56%	4	2	6	4
Yoghurt	not used in time	93%	3	3	5	4
TOTAL			88	**63**	176	**123**