FOOD WASTE CARBON FOOTPRINT

A Case Study at Dansk Supermarked A/S

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Abstract

This project takes a point of departure in the food waste problems stated in recent FAO publications, and identify a specific hotspot to investigate applying knowledge gained during the programme. The aim is to use the consequential Life Cycle Assessment (LCA) approach to investigate the Dansk Supermarked A/S food wastage Carbon Footprint, on a national scale, in a one month period (February 2014). The food wastage alternatives assessed were the Dansk Supermarked 2013 waste scenario (incineration and bread for animal feed) as baseline, the Dansk Supermarked 2014 waste scenario (biogasification) and, as alternatives, 100% waste incineration, 100% waste composting and 100% waste for animal feed.

The main conclusions are that Dansk Supermarked Carbon Footprint depends of the food wastage treatment scenario, and the more relevant food categories are the Food preparations, the Dairy products and the Meat products pork. Furthermore, it was also concluded that reducing the food waste, in this case by 10%, by reducing the inputs and keeping the supermarket sales has a greater emissions reduction potential than changing the food wastage treatment.

Foreword and acknowledgements

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Contents

1 – Introduction

1.1 – Sustainability and Food Industry

Sustainability is one of the most important discussed topics nowadays, recurrently referred as a key for corporate success. It has been defined as "*development meeting current needs of society while ensuring that future generations' needs are met*" (UNEP 2006). When it comes to companies and their related products, processes and services sustainability, there are three dimensions to be accounted for, which are the social, environmental and economic dimensions.

The present food production industry is a worldwide sector that lacks sustainability, mostly because of its strong dependence on fossil fuels and natural resources for production and/or distribution activities (OHLSSON 2014) to meet the food consumption demands of the world population. That dependence on fossil fuels adds environmental impacts to the food value chain, especially on the first value chain stages. The main driver of increasing food demand is population growth, currently at 7.2 billion, which is expected to achieve 9.6 billion in 2050. Another important driver is diet and its changes over time (ALEXANDRATOS and BRUINSMA 2012), for example, an increased shift towards more processed food items.

The increase food production results in serious environmental pressures. It is estimated that nowadays global agricultural food production is responsible for 14% to 24% of the anthropogenic greenhouse gases emissions (VERMEULEN, CAMPBELL, and INGRAM 2012). If accounting for the entire value chain, with the related services and processes, food may be responsible for up to 29% of those emissions (VERMEULEN, CAMPBELL, and INGRAM 2012).

The previous scenario relates to what Garnett (2012) called as food 'problem', and can be seen as a base of the current concerns regarding the food industry sustainability. According to Garnett (2012), these concerns include the amount and type of food products under production, what are the production types and who are the producers, how transportation is done, how is food is handled regarding processing, packaging and distribution, what are the impacts of all the previous aspects, along with some social aspects including who has access to what type and amount of food, and how is this access granted.

1.2 – The problem of food waste

One of the major problems related to food production is the waste generated throughout the Food Value Chain (FVC). In 2011, the *Food and Agriculture Organization* of the United Nations (FAO) determined that one third of the global production of food for human consumption is lost or passed out as waste, corresponding to approximately 1.3 billion tons each year (Gustavsson et al. 2011; FAO 2013a; FAO 2013b). This may have several implications, namely the possibility of increased food prices. According to FAO (2013), in 2009 the food losses had an economical cost of 75 billion US dollars, a value which is higher than the gross domestic product of some European countries.

There are other problems associated with the current food production and its related food waste generation. FAO (2013) observed that in order to feed the ever growing human population, during the next thirty years the available food has to increase by 60% in comparison with the last decade (FAO 2013a). This growth will have an increased negative pressure over the global environment, since there is not much land available to increase the existent global arable soils and, currently, there are already 900 million people starving (FAO 2013b). Furthermore, there is also an environmental cost, because food waste and food losses may lead to a food production increase. This will increase the food production impacts, namely those associated to land use and quality, increased water scarcity, biodiversity and greenhouse gases emission.

1.3 – Environmental Impacts related to Food Waste

The previous paragraph introduced the reasons why food waste is a major sustainability issue. This section provides some details on the environmental impacts related to food waste generation.

Food waste generation requires more production activities than necessary to satisfy demand, which leads to a reduction in the available arable area (FAO, 2013).The 2007 global food loss corresponded to a production requiring 1.4 billion hectares of arable land, which is more the total area of Canada and India together (FAO, 2013). Thus, reducing food losses not only allows to increase food availability, especially to those already starving, but may also allow to reduce the required amount of arable land to feed the world's population. Since modern farming uses intensive and resource demanding production methods, reducing the amount of land required for food production would indirectly avoid soil nutrient depletion, erosion, and infertility.

Regarding human water consumption, 70% of all freshwater we use is already going to agriculture (FAO 2013b). According to FAO (2013b), in 2007 the third part of all food production that was lost or wasted accounted for a global water consumption of 250 km^3 of fresh water, especially for the production of meat, fruit and cereals, which is the same amount of the Volga river water discharge and three times more than the US water consumption that year (FAO 2013b). As so, accomplishing positive measures regarding food wastage could also be a sustainable measure to reduce the global water consumption. Furthermore, it could also be an important measure not only to increase the access to drinkable water, but to help maintaining our fresh water reserves, which have been affected by the human population growth and changes in climate.

Biodiversity is also affected by food wastage in the sense that the current amount of losses in the whole production and distribution chains has led to an increase of land conversion to arable land (FAO 2013b). This land use change is mainly done by deforestation. When looking to the global area which is deforested annually, the agricultural activities accounts for around 9.7 million hectares, which corresponds to between 70% and 80% of the global annual deforestation area (FOLEY et al. 2011; FAO 2013a; FAO 2013b). This affects ecosystems by reducing the numbers of plants and habitats (FAO 2013b). This can lead to consequent further losses in wildlife, namely insects and mammals (FAO 2013b).

Finally, food waste also contributes to climate change. Food production, whether there are food losses or not, uses fossil fuels across its supply chain, namely in mechanical planting/harvesting, transportation activities and cooling (FAO 2013b). Furthermore, the use of landfills in the disposal stage of food value chain for anaerobic decomposition emits methane (CH_4), which has 25 times the global warming potential of CO_2 (FAO 2013b).This food waste related climate change impact is the global emission of 3.3 Gtonnes of CO_2eq. which, on a global scale, is only surpassed by the national American and Chinese GHG emissions (FAO 2013b).

In summary, food losses lead to four main impacts: land use, depletion of water resources, biodiversity loss and climate change. One of the greatest aspects of the referred impacts in these categories is, according to FAO (2013b), the fact that food industry lacks on studies about food waste global environmental impacts. However, there are acknowledged externalities to those impacts, which may be associated to this industry, namely energy, natural greenhouse gas (GHG) emissions (FAO 2013a). Nevertheless, it is known that both food consumption and wastage is region- or country-specific and most of the impacts are majorly related to the agricultural production stage of the food products value chains (FAO 2013a).

1.4 – Food Waste Definitions and Related Problems

Throughout the food value chain, food is wasted in different stages, namely during production (by farmers), food processing, distribution (by retailers), and use (by caterers and consumers). Thus, food is wasted "*from farmer to fork*" (Gunders 2012). The causes for this wastage are various (European Commission 2014a) but are mainly attributed to:

- Production - overproduction, product and packaging damage from farmers and food processing;
- Retail - inefficient stock management, marketing strategies that lead to overbuying (e.g. 2 for 1, buy 1 get one for free), and aesthetic issues;
- Catering - the meal sizes and the difficulty to anticipate the number of clients;
- Households - lack of awareness towards food wastage, lack of shopping planning, misconception regarding the "best before" and "use by" date labels, and absence of knowledge/innovation to reuse and cook with the leftovers; and
- In general throughout the entire food value chain due to inappropriate storage and packaging methods.

Due to the different reasons for food waste it is possible to define and separate different definitions for food waste. According to Parfitt et al. (2010), cited in FAO's 2011 study "*Global food losses and food waste*", food losses are related to the decrease in mass (dry matter) or nutritional value (quality) throughout the supply chain of products that were specifically intended as edible food to human consumption. These food losses occur at the production, postharvest and processing stages of the food supply chain (PARFITT, BARTHEL, and MACNAUGHTON 2010). Ultimately, the losses taking place at the end of the food value chain (retail and consumption), can be rather called "food waste", which is related to the behaviour of retailers and consumers (PARFITT, BARTHEL, and MACNAUGHTON 2010). This study uses a pragmatic approach where the term "food wastage" will be used, meaning any food lost in production processes or wasted. Thus, the term "food wastage" encompasses both "food loss" and "food waste" (FAO 2013a).

In an ecological context, it is not sustainable to waste edible food instead of consuming it. Studies have shown that resource efficiency for the supply chain and consumption must be improved, along with a change in general diets (specifically in western countries), becoming a vital strategy to ensure future food supply for the 2050 estimations, for up to 9 billion people (Katajajajuuri et al., 2014). As common sense, this food wastage embodies a missed chance to improve global food security and to diminish environmental impacts created by agriculture (FAO, 2013).

According to its "*Roadmap to a resource-efficient Europe*", the European Commission pinpointed food as a fundamental sector in which resource efficiency must be amended. Furthermore, it announced the intentions to evaluate the procedures on how to reduce food waste along the food supply chain, and also to discover and promote ways to incentive the reduction of edible food waste by 2020 in the European Union (European Commission 2014b).

Facing the need for intervention, the EU was urged to designate 2014 as the European year to fight against Food Waste in the sense to provide information and increase awareness towards the European citizens, and to drive the national governments responsiveness on this imperative topic (European Commission 2012).

To consolidate information, the EU runs investigation programmes and studies on how to tackle the food waste problem, being one of them the application of life cycle thinking into the food value chain (European Commission 2014c). The life cycle thinking studies are developed by the European Platform on Life Cycle Assessment, which is a project of the European Commission, carried out by the Commission's Joint Research Centre (JRC). This platform exists due to the Integrated Product Policy (COM (2003)302) and recognition of Life Cycle Assessment as the best framework for assessing the potential environmental impacts of products (European Commission 2014d).

2 – Life Cycle Assessment as a tool for Environmental Management

This chapter serves as an introduction to Life Cycle Assessment, along with its structure, advantages and disadvantages and an introduction to Carbon Footprint. This is done to show the suitability of Life Cycle Assessment to address the problem of food wastage.

2.1 – Introduction to LCA

Life cycle assessment (LCA) is a technique to evaluate the environmental impacts of a product or service from a holistic perspective. It is defined as *"compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle"*, which can prove itself as a positive tool for decision making (ISO 14040, 2006). Thus, LCA is a tool used to bring Life Cycle Thinking (LCT) into Life Cycle Management (LCM.) A LCA study is usually translated into a report detailing potential environmental impacts in different impact categories, like climate change, water and soil emissions.
One of the most important aspects of LCA is that it does not account for economic and social aspects. These aspects can be evaluated through other assessments, namely by Life Cycle Cost analysis (LCC) (ISO 14040, 2006) and Social LCA (HEIJUNGS, HUPPES, and GUINÉE 2010).

LCA as a tool has gain strength since the 1990s, being reinforced by international standardization with the ISO 14040 series back in 1997. The standards' latest version was finalized in 2006, from which resulted the two core standards, the ISO 14040 and 14044. In ISO 14040, it is possible to find the principles and framework description for Life Cycle Assessment, and in ISO 14044 the requirements are specified, including the providence of guidelines for LCA (Wolf and others 2012).

2.2 – LCA Advantages

As any other tool or approach, LCA has a set of advantages. These are directly related to the LCA principles (Wolf and others 2012). There are six advantages that can be identified:

1. Its standardized methodology, its high degree of accuracy, and the fact that this internationally recognized assessment tool helps to inform decision makers regarding potential impacts of products;
2. LCA gathers an extensive variety of environmental problems to frame them into an integrated assessment workflow. This framework gives the possibility to avoid the unwanted shifting of burdens, namely when the reduction of an impact in one stage of a product leads to the increase of another impact in another stage.
3. LCA seizes these environmental problems in a scientific and quantitative approach. This is achieved by making an inventory with the quantity of related emissions and resource usage, allowing to conduct a relative and absolute analysis.
4. Environmental pressures and the impact potentiality can be related to any designated system in a LCA, namely a service, a technology strategy, a particular type of good, a company or a country.
5. LCA allows comparisons between different systems or options on an equal basis, and it facilitates their environmental performance assessment and unveil "hotspots" for improvement. This comparison between alternatives is achieved by looking into their functional unit. An example is the quantification of their technical performance/equivalence.

In overall, these advantages or principles help a LCA to be designed towards the question that it is intended to answer. This creates a "*smart approach*", that allows a scientific based and quantitative comparison of alternatives.

2.3 – Carbon footprint

The Carbon Footprint, as a result of the life cycle assessment, is a transversal tool that allows companies to analyse their performance towards sustainability, providing critical information about GHG emissions. These results identify cost-effectiveness measures to improve the environmental performance (emissions reduction) and economic (production or process cost reduction). When quantifying and communicating the GHG emissions to a group of interest (e.g. consumer), the carbon footprint (CF) of the entire life cycle of a product/service constitutes the most recent international trend (AGROGES 2012). By communicating the commitment and the performance to markets such as *business-to-business* (B2B) and *business-to-consumer* (B2C), it can help the company to boost their sales, identify cost savings, to gain a better image for the corporate brand and product-development opportunities (CARBON TRUST 2014).

In sum the CF provides the major advantages for companies (AGROGES 2012):

- **Customer Loyalty** – anticipating and providing answers to national/international costumers
- **Commercial stand**-out and new markets attraction – through product differentiation
- **Leadership and positioning**
- **Positive image/Notoriety** – through a recognized brand, that identifies modernity innovation and vision
- **Alignment** – towards a world market trend, using the best quantification methodology available
- **Efficiency and cost reduction**

3 – Literature review

This chapter presents the literature review that was done for this project, which helped to further investigate what is a food value chain and what has been done regarding LCAs in the food industry. This was done according to European Commission approach to deal with the food wastage problem through life cycle thinking. This literature review was done mainly to determine what the focus of this project could be according to recent studies on food value chains, namely the identification of a particular food wastage "hotspot".

3.1 – A Value chain Classification

In social sciences, the methodology used to analyse international trade is through the concept of a value chain. A value chain can be described as *"the full range of activities that firms and workers perform to bring a product from its conception to end use and beyond. This includes activities such as design, production, marketing, distribution and support to the final consumer". The activities that comprise a value chain can be contained within a single firm or divided among different firms"* (Global Value Chains 2006) . UNEP and SETAC (2009) provide two different levels of value chains to which one may choose to deal with, when they refer that "*A product value chain covers one product while a corporate value chain covers the product portfolio of a whole company*" (UNEP and SETAC 2009).

If the activities encompassed in the value chain definition are to be coordinated over different geographies, the term used in development literature is Global Value Chain (GVC), which provides a holistic view of global industries. This view is achieved by an analysis of the sequence of tangible and intangible value-adding activities, from design and production to use and end of life.
During the early stages of the GVC methodology the main focus has been primarily the economic and competitiveness issues (Gereffi and Fernandez-Stark 2011). Only recently the environmental and social dimensions have been integrated in the analysis (Gereffi and Fernandez-Stark 2011).
This recent phenomenon, referred by Irland (2007) as "greening the value chain", is the incorporation of the environmental dimension in the value chain analysis, which has gain emphasis in research over the years (Figure 1). This is particularly important, because the value chain activities are entrenched in the environment, being the most relevant the agricultural production of food and energy crops, which have a strong interrelation with consumption of environmental resources (Faße, Grote, and Winter 2009). Therefore, all the essential inputs and energy required for each specific activities is provided by the environment, also being the capacitor of emissions and waste disposal. In a sense, it can be called as the "environmental value chain" and, nowadays, it is in the public interest focus with the increased awareness of the consumers, and the environmental impact of the products or services has gain major relevance in environmental policy programs. More and more studies related to "carbon neutral" value chains, the sustainable use of natural resources, and the "eco-footprint" of products have been developed, providing information regarding input-output flows of products based on the value chain analysis results (Faße, Grote, and Winter 2009).

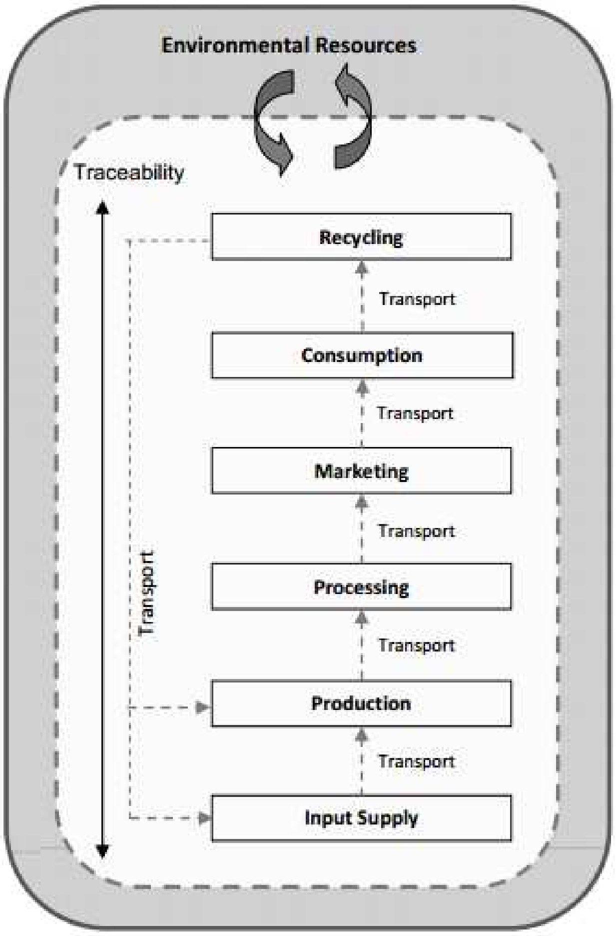

Figure 1- Greening the value chain

According to Eurostat (2008), food system as a whole (along with the pre-chain inputs) is considered the major industrial sector in Europe (SOUSSANA 2012). This sector brings several benefits, being vital for the human welfare by providing food, employment and increasing livelihood worldwide. Nevertheless, it is also associated to significant environmental impacts.

Nowadays, as elaborated in section 3.2, the environmental impacts are being fully recognised, which leads to an increasing pressure from stakeholders throughout the food value chain, in order to understand these environmental impacts. The extension of this recognition goes from the consumer, who wants to know what it is buying, passes through the retailer and food companies, that strive for competitive advantage by providing greener products, and all the way to the governments, who are pursuing the reduction of GHG emissions (DEIMLING, SHONFIELD, and BOS 2009).

The fully inevitable food wastage and its associated environmental impacts is an issue to be addressed, which could be included in the referred stakeholder's competitive advantage and in their principles to improve their environmental sustainability. In this context, the food wastage problem can be illustrative of triple wins for sustainability improvements, in a sense that wasted food represents not only a waste of entrenched GHG emissions and risk for food security but, frequently, an inefficiency at the financial level (GARNETT 2012).

Food wastage needs to be addressed as a dominant approach with efforts from all stakeholders. This means to include technological innovations and managerial changes as the answer to environmental impacts reduction and nutrition enhancement (GARNETT 2012).

3.2 – Specific literature focus in the recent years

Looking back to ten years ago, the LCAs regarding food industry did not consider the whole value chain, giving a higher focus to the production stage, and lesser or no attention to other stages such as the Retail, which was considered a part of the distribution stage. An example of this approach is described Salomone (2003), who considered the food industry value chain as being composed by the cultivation, processing, packaging, transport, consumption and disposal; and encompassed the retail as a part of distribution and only considered the transportation to and from the retail points. Other examples where the focus is on the production stage related inputs and impacts are: Basset-Mens and van der Werf (2003), Mungkung and Clift (2003), Papatryphon et al. (2003), Thrane (2003), Dalgaard et al. (2003) and Papatryphon et al. (2003).

This existing focus during this period on the production stages of food products and their related impacts, was based on four main reasons. The first reason for this focus is that agriculture guides the whole food industry (MUNGKUNG and CLIFT 2004). The second reason for the agricultural production stage was that agricultural production and fishing activities are the ones with the largest environmental impacts in the value chain(THRANE 2004; MUNGKUNG and CLIFT 2004), to which a considerable number of innovations have already been presented and applied, especially in cultivation(MUNGKUNG and CLIFT 2004). This reason can also be backed up by other studies which were done, namely, in Iceland and Sweden (THRANE 2004). The third for this focus was since the production stage was considered the stage with more impacts, there was a need to assure data quality, namely to allow comparisons (DALGAARD et al. 2004; PAPATRYPHON et al. 2004).

The literature review showed that, after 2003-04, there was deeper interest in different life cycle aspects, namely in three vectors. The first vector was to increase the focus in life cycles after the production (MILÀ I CANALS, FULLANA, and MANTOUX 2004; PFISTER et al. 2009; AUDSLEY and WILLIAMS 2009). This helped to deepen the knowledge about impacts, impact categories and also to propose differ alternative paths to *"reduce the environmental burdens of agricultural production"* (AUDSLEY and WILLIAMS 2009).

A second vector, argued by Achten, Mathijs, and Muys (2008) was towards methodologies, who stated that there was no consensus about them, namely to assess impacts in specific impact categories. Further examples of focusing on the impact categories assessment methodologies are the works of Jeanneret et al. (2008), Kowata et al. (2008) and Audsley and Williams (2008).

A third vector was towards an increased interest in LCA and Carbon Footprint (CF) in the food industry. A main reason for it was argued by Deimling, Shonfield and Bos (2003): "*As a consequence of the agriculture value chain environmental impacts, there was an interest change in the last decade about more sustainable products. This interest shift encompassed agricultural LCAs and carbon footprint, more specifically, from the biofuels carbon footprint to food chain carbon footprints*", which basis may be seen in Farine et al. (2003) argument, which is the importance of GHG emissions reduction, that was globally acknowledged when connected with energy security to reduce oil dependency.

Although there was this interest into LCA and CF after 2003, which was acknowledged namely by Deimling, Shonfield and Bos (2003), Basset-Mens (2003), Notarnicola et al. (2003), Figueirêdo et al. (2003), it was also acknowledged that there were some obstacles to apply those tools. Examples of these obstacles were absence of both data from different suppliers and different LC stages, and decent databases; the costs and difficult levels to collect data and create those databases, no common ground to characterize a "mean" dataset (DEIMLING, SHONFIELD, and BOS 2009).

In the last 4 years, the main focus regarding food industry and LCAs got widespread into topics like involving different stakeholders, challenges and innovations in the retail stage to reduce impacts, namely regarding animal products (Stehfest et al., 2009; Soussana 2012; Dron, 2012; Gheweala, 2012). It was the first time that a focus on retail was really seen, namely, in the works of Stehfest et al. (2009), Dron (2012), Soussana (2012) and Gheewala (2012).

As of the new focus on CF, Al Razi et al. (2013) argues that reducing GHG emissions has been also applied to waste management, as part of the international attention to reduce environmental impacts. Nevertheless, there is still work to be done regarding food wastage and waste management on the later stages of food products life cycle, although Venkat (2012) referred that Stenmark et al. (2011) accounted for general retail and/or wholesale waste numbers provided for some first world economies, namely the Nordic countries (40000-83000 tonnes per country), the United Kingdom and the United States of America.

Furthermore, during these recent years, the focus of LCA in the agro-food sector has not only evolved and became more holistic, but to *"identify opportunities where technology and management can improve production efficiency to reduce the relative 'footprint' of existing consumption patterns"* (SOUSSANA 2012) along with investigating *"alternatives to the status quo, should consumption patterns change"* (SOUSSANA 2012).

Summing up, the food production represents for 21st century a major challenge for global sustainability achievement. Retailers may hold a key position at the food supply chain to stimulate and enable sourcing and sale of sustainable food products, also the improvement of services and methods to reduce food wastage, and choose the best end of life alternative to deal with it. Nevertheless, efforts must be combined, to identify and work towards the reduction of the environmental impacts in a whole, along with the awareness promotion through the media or all stages of the product life cycle. Therefore considering the entire product life cycle for improvement efforts (Sarteel et al. 2012).

4 – Problem Formulation and Research Question

Chapter 1 presented the thematic framework of this project. From there, chapter 2 investigated the significant issues according to literature, and this chapter presents the selected issue under study, along with the research question.

4.1 – Problem Formulation

The consulted literature allowed to understand that food production and food wastage have global impacts, whether those impacts are environmental, social or economic, as described in Chapter 1. Furthermore, the more specific literature review on food wastage, food value chains and LCA showed in Chapter 3 what has been investigated regarding food sector LCAs, majorly in the 21st century, in order to determine an issue to be investigated.

During the whole referred literature review, it was discovered that food production represents, in the 21st century, a major challenge for global sustainability achievement, and that there is still a big load of research to be undertaken in the food sector, which was supported by (DRON 2012). The two main reasons for this are:

- Many LCAs still do not cover the whole food or food product value chain(s), focusing regularly in the production stage(s) and related inputs (BASSET-MENS and VAN DER WERF 2004; ERZINGER et al. 2004; PAPATRYPHON et al. 2004). This has been done mainly to characterize their environmental impacts, and contextualize these impacts in a global background and compare different production methods (PAPATRYPHON et al. 2004); along with generating accurate and illustrative data for inputs and emissions to product oriented analyses, like LCA (DALGAARD et al. 2004; PAPATRYPHON et al. 2004).
- LCAs may still need some incorporation in the food value chain. The lack of incorporation is related to the referred focus on production and its inputs, along with data unavailability regarding the later stages of the food value chain as well as the allocation of knowledge and resources to deal with that information (MILÀ I CANALS, FULLANA, and MANTOUX 2004; LAGERBERG-FOGELBERG et al. 2004). This issue is mainly related to upstream data availability, data collection huge costs, the mosaic of data flows, and scarcity of trustworthy databases (LAGERBERG-FOGELBERG et al. 2004; MILÀ I CANALS, FULLANA, and MANTOUX 2004).

Given that food wastage increases the potential impacts of food products, and the previously two presented reasons (focus on the production and lack of data mainly in the later LC stages of the food value chain(s)), it was asserted that it could be interesting to expand knowledge in these later LC stages, which include distribution and storage (namely by retailers), final consumers and end of life activities. This is why retailers may hold a key position at the food supply chain, to stimulate and enable sourcing and sale of sustainable food products, also the improvement of services and methods to reduce food wastage, and choose the best end of life alternative to deal with it. Nevertheless, efforts must be combined, to identify and work towards the reduction of the environmental impacts as a whole, along with the awareness promotion through the media or all stages of the product life cycle.

4.2 – Research Question

Recognising the need for further research in the retail stage of the food value chain, this report follows the guidance of the following research question:

"What is the food wastage Global Warming Potential of a Danish retail company on a national scale?"

The sub-questions associated with the research questions are:

1. What is the amount of food input, food sold and food wasted in the company?
2. Which food wastage treatment alternatives does the company use?
3. What other food wastage scenarios could be used?
4. If there is more than one waste treatment alternative on each scenario, what kind of food wastage and what is the volume of food wastage that goes to each alternative?
5. If there is more than one waste treatment scenario, what is/are the one(s) with more and least impacts?
6. Which food categories have more global warming potential regarding the food wastage treatment?

5 - Research Design

This chapter is divided into two parts. The first part regards the background theory used (systems theory), and the second part regards the methodological approach (mixed methods) and the two main methods used (semi-structured interviews and case study).

5.1 – Theory – System Theory

Chapter 2 has made a description of LCA as an environmental tool. According to Kohler et al. (2010), there is a scientific basis for life cycle analysis which is known as systems theory. The systems theory is an interdisciplinary cognitive model, developed by the biologist Ludwig von Bertalanffy back in the 1920s, in which a system is built to be possible to describe the variety of complex phenomena. This system describes the elements that are included and their interaction or relationship. Fundamentally, a system is described as the interaction of individual phenomena connected in a non-linear way (Kohler et al. 2010). Systems theory proposes a holistic vision, where phenomena are seen as part of a structured and complex whole instead of in isolation, (Boslaugh 2011). For example, the organization and interaction among different elements in a system (e.g. human body) instead of just a particular focus on the properties of a precise element (e.g.the human body cells).

Due to its general approach, systems theory has been used in various fields of study, such as mathematics, engineering, computing, industrial management, human relationships and ecology. Nevertheless, the description of any particular system is highly specific to that system. Furthermore, systems of theory has been highly influential in environmental studies over the years (Boslaugh 2011).

Apart of being a scientific principle of LCA, the reason for the use of system theory in this project is its methodology. This methodology allows to analyse the causes and effects of the inputs and outputs in food value chain systems, to understand behaviours that lead to food wastage production, and study possible better alternatives to reduce and to deal with the food wastage. Another reason is also based on the assumption that for the results determination, the system's structure and the system's components may be equally important. Regarding this study, this means that the whole food value chain may be as strong as one of is individual sectors, in this case the retail sector, to reduce the environmental impacts of food wastage.

5.2 – Methodology

5.2.1 - Mixed Methods Approach Definition

Mixed methods approach is a recent methodology which grabs different components of several approaches and methods (CRESWELL and CLARK 2011). According to Creswell and Clark (2011), one of the first definitions of mixed methods design was provided by Greene, Caracelli and Greyham (1989) which are designs "*that include at least one qualitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular inquiry apparently*". Nowadays, it has evolved to mix in all research phases (Tashakkori and Teddlie, 1998; Creswell and Clark, 2011). There are still several definitions, giving focus either on philosophy, methodology, research design, purpose and interpretation (CRESWELL and CLARK 2011). For the purpose of this report, the chosen one is the agreed by Creswell and Clark (2011): "*in mixed methods, the researcher:*

- *collects and analyses persuasively and rigorously both qualitative and quantitative data (based on research questions);*

- *mixes (or integrates, links) the two forms of data concurrently by combining them (or merging them), sequentially by having one built on the other, or embedding one with the other;*
- *uses these procedures in a single study or in multiple phases of program of study;*
- *frames these procedures within philosophical worldviews and theoretical lenses; and*
- *combines the procedures into specific research designs that direct the plan for conducting the study*" (CRESWELL and CLARK 2011).

The main reason to use mixed methods is to balance or minimize quantitative and qualitative methods' limitations (like understanding context limitations, or listening to participant voices at all, personal biases, generalization problems induced by sample size) (CRESWELL and CLARK 2011). In an LCA, this approach of including qualitative data allows to verify the accuracy of the overall data through a crossing of different data sources, or data triangulation, ensuring a higher degree of certainty (THRANE and SCHMIDT 2007).

5.2.2 – Semi-structured Interviewing

Semi-structured interviewing is a method defined by Ayres (2008) as "*a qualitative data collection strategy in which the researcher asks informants a series of predetermined but open-ended questions*" (SAGE Publications and Ayres 2008), to allow the interviewees to follow an interview guide and adjust it according to the volume and type of information the interviewee(s) can provide. It was used to set up the collaboration framework with Dansk Supermarked, to understand how the food wastage is separated in the supermarkets for waste treatment, to know if there are food reduction measures in the supermarkets, and how are they applied.

5.2.2 – Case Study Analysis

In this sub-section, Case Study as a research method is going to be presented, along with the reasons for choosing it for this project and some limitations and/or misunderstandings about this research method.

A case study is a method that has evolved in definition through time. Yin (2009) argues that case studies are able to supply knowledge for the understanding of individual, social, and political phenomena, including organizational phenomena. Furthermore, Yin (2009) also states that the case study method "*is preferred in examining contemporary events, but when the relevant behaviors cannot be manipulated".* As of advantage, case studying is strengthen by its capability of dealing with more different types of evidence or data (i.e. documentation, interviews, observation) than other methods (Yin 2009). These three case study aspects were the ones that lead to the use of this method, since it was intended to generate organizational knowledge from an institution regarding one phenomenon, without controlling behaviours and having to generate that knowledge from different types of sources within the institution.

Regarding case study typology, there are different ways to classify or systematize case studies. One simple way to distinguish different case studies is whether there is one or more experiments and/or phenomena under study. In this project, as there is only one phenomenon under study (food wastage) on only one institution under study (Dansk Supermarked A/S), this project is a Single Case Study.

The case study main advantages were presented before, and lead to the choosing of this method. Nevertheless, it has to be taken into account that case studying has potential drawbacks. These may lead to limitations to this method, however the limitations have to be considered hand in hand with Flyvbjerg (2006) five misunderstandings:

- **Misunderstanding 1:** "*General, theoretical (context-independent) knowledge is more valuable than concrete, practical (context-dependent) knowledge*" (FLYVBJERG 2006). The context independent theoretical knowledge was important namely in the choice between attributional vs consequential LCA and process vs Input-Output LCA. Regarding this project, concrete practical knowledge learned through the semester to gather and interpret data was equally important.

- **Misunderstanding 2:** "*One cannot generalize on the basis of an individual case; therefore, the case study cannot contribute to scientific development*" (FLYVBJERG 2006). It is true that there are limitations to generalize from this study to the whole Danish food retail sector, since it encompasses only one of the retailers in Denmark. Nevertheless, the knowledge generation statement may be false for this study for two possible reasons. On one side, it is generates knowledge to help fulfilling a knowledge gap referred in scientific publications as observed in Chapter 3 of this report. On the other side, the choice of the case study allows a fair generalization as Dansk Supermarket is the biggest retailer in DK, which probably sells over half of of all the food traded in DK yearly.
- **Misunderstanding 3:** "*The case study is most useful for generating hypotheses; that is, in the first stage of a total research process, whereas other methods are more suitable for hypotheses testing and theory building*" (FLYVBJERG 2006). This case study may allow generating the hypothesis whether changing the existing food wastage treatments may reduce or not the food wastage GHG emissions. Regarding this or other methods to test the hypothesis or test a theory, this case study will only not allow it the time frame given, but it can do it if its time span is widen to account for more data.
- **Misunderstanding 4:** "*The case study contains a bias toward verification, that is, a tendency to confirm the researcher's preconceived notions*" (FLYVBJERG 2006). It is true that case studying may allow the researcher(s) to be verification biased and subjective. Nevertheless, "*subjectivism and bias toward verification applies to all methods*" (FLYVBJERG 2006). Furthermore, there were no pre-conceived ideas about the results before they were generated, due to the studied system complexity.
- **Misunderstanding 5:** "*It is often difficult to summarize and develop general propositions and theories on the basis of specific case studies*" (FLYVBJERG 2006). Regarding this aspect, Flyvbjerg (2006) stated that "t*he problems in summarizing case studies, however, are due more often to the properties of the reality studied than to the case study as a research method*". Regarding the reality and its related properties studied in this project (Dansk Supermarked as a whole) may lead to some problems namely on the generalization level, and this may be related to the study reality properties: the supermarkets owned by Dansk Supermarked A/S have differences in typology, number, distribution and sales and waste generation numbers.

5.3 – Data collection

The data collection started with an online research. This showed that the Danish retail sector is dominated mainly by two retail consortiums (Dansk Supermarked A/S and Coop Danmark A/S) who own several chains of supermarkets. After this research, key people (administrators, responsible, etc.) within these two companies were contacted via mail to establish a collaboration. The positive feedback came from Dansk Supermarked, namely Hanne Neumann, head of the Corporate Social Responsibility department, who showed interest from the start to collaborate.

A first meeting was set up with Hanne Neumann (CSR) and Ulrik Lolk (Goods Not For Resale (GNFR) department), which served as an introduction from both parts, to assess the researcher's intentions, understand what could be done and establish a work frame. As a follow-up of the initial meeting with Dansk Supermarked, data on a national level was provided by email containing information on food wastage amongst the inherent food commodities, defining the item/product, the net weight, number of items wasted and the related wastage percentage.

After this data retrieval, the food commodities were sorted and re-categorized according to appropriate database of the used PC platform for life cycle assessment (Simapro 8.1). The remaining required data was calculated based on the data provided. Semi-structured interviews were also made at Bilka (Aalborg) and Føtex (Aalborg). At this time, there were contacts with ISS World and Dansk Supermaked to attempt a data collection regarding energy consumption and the average travel distance between the supermarkets and the waste treatment destination(s).

6 – LCA Framework – A Brief Introduction

As stated in the first two chapters, Life Cycle Assessment is the approach to assess the environmental impacts of a product's life from cradle to cradle (Figure 2), including raw material extraction, processing, manufacture, distribution, use and final disposal (ISO 14040 2006). Therefore, and also according to the European Commission's Joint Research Centre, LCA is chosen as the tool to assess the environmental impacts of food wastage and to answer the research question(s) of this report.

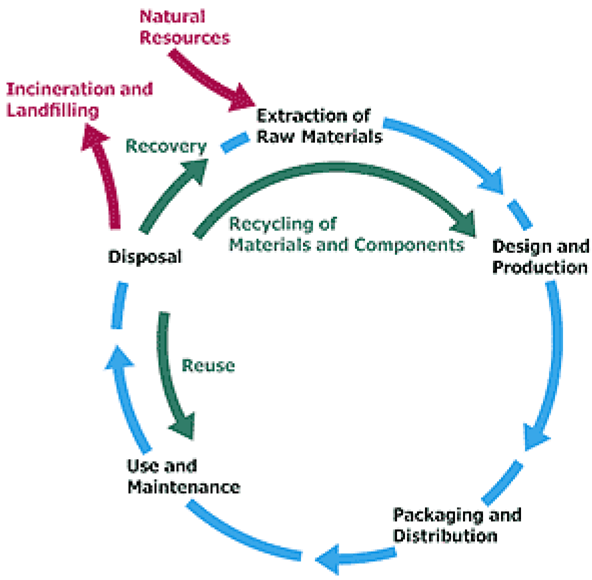

Figure 2- Product Life Cycle (Source: Life Cycle Initiative)

6.1 – Types of LCA

There are two basic kinds of LCA, as described below:

1. Process LCA – which is perceived as a bottom up approach, where data is collected for several specific processes, constituting a specific product system. It applies cut off criteria, entailing the decision of whether include aspects such as services, business travelling, capital goods or some less significant inputs from feedstock (THRANE and SCHMIDT 2007).
2. Input Output LCA (IO LCA) – which represents a top-down approach, where its databases are based on national economics and environmental statistics. Compared to the "process LCA", the advantage of IO LCA is that cut-off criteria are not needed, due to its whole economy coverage. The IO LCA expresses the environmental impact for a variety of product categories, for different countries or regions of the world (THRANE and SCHMIDT 2007).

Given the available data IO LCA was chosen as analytical tool instead of process LCA. Reasons for this are:

- In process LCAs the data collected are related to "*processes that compose a specific product system*" (THRANE and SCHMIDT 2007), which was not necessarily the focus on this project.
- The nationwide collected data relates more to the IO databases, and IO databases are based on environmental and national economic statistics (THRANE and SCHMIDT 2007),

- The nationwide collected data relates more to the Input-Output LCAs requirement for data collection to express product categories in countries or world regions as geographical delimitation (THRANE and SCHMIDT 2007).

6.2 – LCA structure and components

According to ISO 14040 (2006), a LCA consists of four phases as illustrated in Figure 3. The details of each phase is described in the following sub-sections.

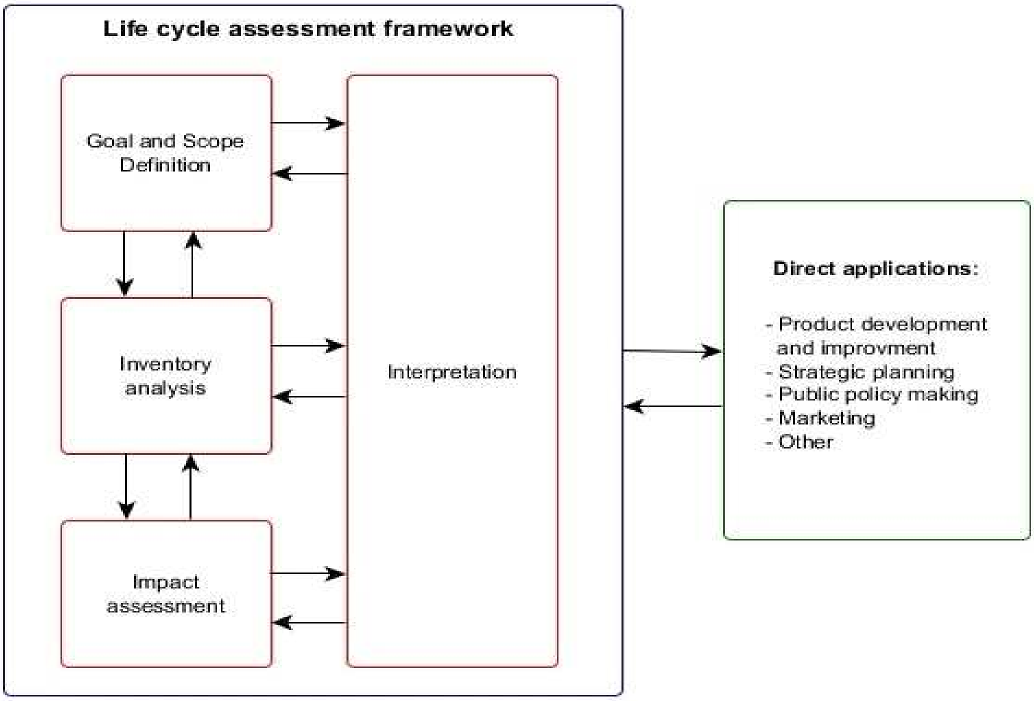

Figure 3 - The general methodological framework for LCA (Adapted from ISO 14040).

6.2.1 – Goal and scope definition

In the goal definition it is identified the decision context, the envisioned applications and also the target/addressed audience of the study. The scope of an LCA, containing the system boundary and the level of detail, rests on the subject and intended use of the study (ISO 14044, 2006). So in line with study goal, the scope definition includes the description of: the system to be assessed (e.g. a particular brand), the system functionalities, the covered life cycle stages, the investigated environmental impacts, the LCIA methodology to be implemented, the interpretation methods to be used, the data and methodology assumptions to the respective issues, value choices, limitations, the requirements for data quality and, if existent, the kind of critical review, and the report type and setup required for the study (Wolf and others 2012).

One of the most important points in this stage of an LCA is the functional unit. The functional unit (fu) can be defined as the quantified performance, translated in functional outputs of the product system. This provides a reference unit to which the inputs and outputs can be reflected (ISO 14040 2006; THRANE and SCHMIDT 2007).

6.2.2 – Life Cycle Inventory (LCI) analysis

The second phase of the LCA is the Life Cycle Inventory (LCI) analysis. This is an inventory of input/output data regarding the system being studied (ISO 14044, 2006). In simple words, it implies: (i) determining what products are exchanged between the activities included within the boundaries of the product system under analysis; and (ii) the collection of data on resource usage and emissions generated by these activities (Wolf and others 2012; ISO 14040 2006).

It has to be referred that a critical issue in LCI is the modelling of emissions of multi-functional processes, like activities that provide more than one product/service. Two approaches can be used for this purpose: consequential and attributional modelling. The main differences between both modelling approaches are described below in the Table 1.

Table 1 – Atrbutional and Consequential modelling comparison

Feature	Attributional modelling	Consequential modelling
Modelling approach	Describes how existing production is taking place	Attempts to predict to responses to a change in demand
Included processes/suppliers	Average of present suppliers	Marginal (actual affected supplier)
Co-product allocation	Co-product allocation is most often treated by using allocation factors, and in some cases system expansion may be applied	Co-product allocation is avoided by system expansion

(Source: Schmidt 2007, Weidema 2003)

The consequential approach implies that the system delimitation is based in a market oriented methodology, identifying the affected processes ((THRANE and SCHMIDT 2007). The opposite approach, called attributional modelling, has the system delimitation with a focus on the physical flows, while the market based system delimitation (consequential approach) has a starting point in the casual relations within the market (THRANE 2004). According to Weidema (2003), cited by Thrane (2006), an illustrative example of consequential approach is the determination of processes which are altered for electricity usage. In an attributional LCA, quantitative data regarding electricity is treated according to the average of the available electricity sources in a given geographical area (WEIDEMA 2003; THRANE and SCHMIDT 2007). On the other hand, in a consequential approach (market based), data related to quotas or similar kinds of restrictions can be excluded (WEIDEMA 2003), since they do not depend on market mechanisms. This market system based approach was used regarding the system expansion for co-product allocation avoidance purposes.

6.2.3 – The Life Cycle Impact Assessment (LCIA)

The third LCA phase is the Life Cycle Impact Assessment (LCIA), which has the purpose to provide additional information to ease the assessment of the products systems LCI results, allowing a better understanding of their environmental significance (ISO 14044, 2006). This is achieved by assigning the LCI results (emissions generated and resources used in the product system) to specific impact categories and by accounting the potential environmental impacts to each category. Examples of impact categories (midpoint) are: human toxicity, climate change, material resource depletion, acidification, land use, etc. (Wolf and others 2012).

6.2.4 – Life Cycle Interpretation

The final phase of the LCA procedure is the life cycle interpretation. This phase starts with the identification of significant issues (e.g. quantitatively, the main processes and resources/emissions that mostly contribute for the results), which is conducted having as basis the results of the LCI and LCIA phases. In this phase it is included a completeness, sensitivity and consistency checks, addressing the results uncertainty and accuracy. In accordance with the goal and scope definition, the results are summarized and discussed to be drawn into a conclusion, highlighting any limitations, and recommendations for decision making are derived (ISO 14044 2006; Wolf and others 2012).

6 – Dansk Supermarked as a Case Study

As referred in the previous sections, Dansk Supermarked A/S is the institution under study for the Food Waste Carbon Footprint conducted in this project. In this section, Dansk Supermarked A/S is briefly presented.

6.1 – The Company

Dansk Supermarked A/S is a Danish company, more specifically the largest retail group in Denmark, with international presence and a turnover of over 56 billion Danish Kroner (Dansk Supermarked A/S a; NCR 2013). It owns over 1200 stores, from department stores to hypermarkets in Denmark, Germany, Sweden and Poland, with over 42.000 employees and 2 million costumers (Dansk Supermarked A/S c; Retail Business Review 2010; Fish Info & Services Co. 2014). Dansk Supermarked A/S owns the supermarket chains Føtex, Netto, the hypermarket chain Bilka and the department stores chain Salling.

The 2012 overall numbers of Dansk Supermarked A/S can be seen in Table 2:

Table 2 - Dansk Supermarked A/S 2012 Overall Numbers (Adapted from:(Dansk Supermarked A/S b))

FINANCIAL RATIOS 2012		NUMBER OF STORES		NUMBER OF EMPLOYEES	
Turnover	55,6 Mill. DKK	**Netto**	1210 (DK: 441; DE: 345; PL: 276; SE: 148)	**Denmark**	32000
EBIT (Earnings Before Interest and Taxes)	1700 Mill. DKK	**Bilka**	18	**Sweden**	1700
		Føtex	89	**Germany**	4800
		Salling	2	**Poland**	4800
Profit after tax	1300 Mill. DKK	**Total**	1319	**Total**	42500
		Web shops	2		

Note: DKK – Danish Crowns; DK – Denmark; SE – Sweden; PL – Poland; DE - Germany

Dansk Supermarked A/S goes back to 1906, when Ferdinand Salling opened a retail store in Aarhus. This store was reconverted into a new department store in 1948 (Dansk Supermarked A/S c). In the 1960s, Jysk Supermarked was founded to operate supermarkets, Herman Salling (both in 1960) opened the first Føtex, and A.P. Møller-Mærsk stepped in as a partner in Jysk Supermarked, which subsequently changed its name to Dansk Supermarked (Dansk Supermarked A/S c).

The 1980s, 1990s and early 2000s corresponds to an expansion period, namely for Netto, which was inaugurated in Copenhagen in 1981, entered the United Kingdom (1990), Germany (1990), Poland (1995) and Sweden (2002) (Dansk Supermarked A/S c). In the last decade, Jess Søderberg (from A.P. Møller-Mærsk) was appointed chairman after Herman Salling passing; Føtex food has an expansion, namely to Skæring and

Hasseris; Netto surpasses the 1000 stores mark; the 193 British Netto stores are sold (2011) (Dansk Supermarked A/S c).

6.2 – Food numbers

In February 2014, Dansk Supermarked had 81.487.939,772 Kg of food for sale in Denmark, of which 98.519% was sold. It has to be referred that these are estimate values, since Dansk Supermarked was migrating it internal data to SAP during the data collection. Therefore, the numbers presented are the best approximation possible. Regarding the food wastage in 2013, Dansk Supermarked was sending the bread to farms as animal feed and the remaining food wastage was directed to waste incineration. As for 2014, Dansk Supermarked aims to send all its food wastage to biogasification. A mass flow diagram with the waste treatments can be shown in Figure 4.

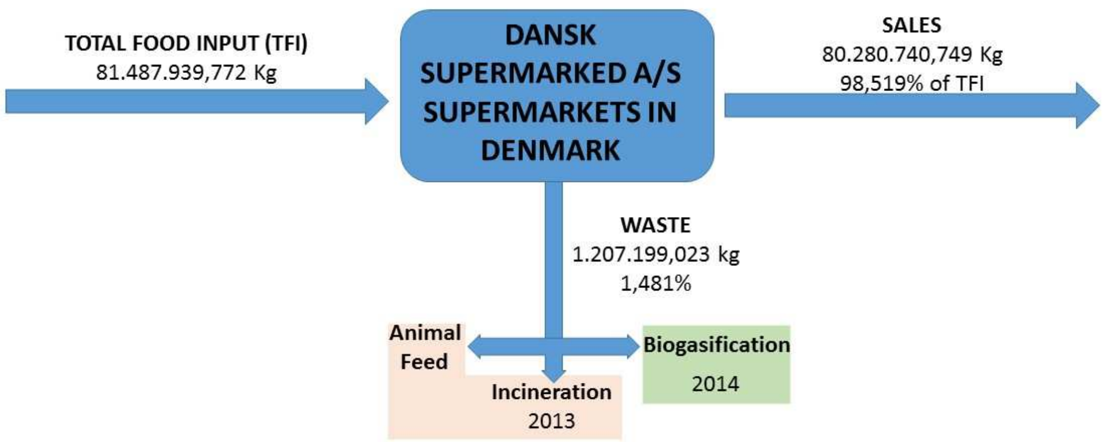

Figure 4 - Mass flow diagram for Dansk Supermarked (1 month values)

Dansk Supermarked acknowledged the need to address the food wastage issue and minimize it. Profit loss situations were being identified and, for some time, they were associated to different factors (e.g. stolen food items). In fact, the major contributor was the food wastage, with far larger numbers than stealing or other issues. It was also acknowledged that if there was a problem, it was most likely connected to other stages of the value chain as well. Therefore, the food wastage problem started to be addressed in a life cycle perspective (Føtex Eternitten 2014).

With the introduction of the new management software (SAP), it became possible to track the food inside the supermarket, which was pointed as "game changer". This allowed to account the food wastage produced and retrieve real numbers, along with the input and sales numbers. This allows to identify where more waste is being produced, and address the hotspots (e.g. fruits and vegetables). Another SAP feature is that it gives a warning when a specific food item is about to expire, so that the price can be reduced and more easily or faster sold (Bilka Skalborg 2014; Føtex Eternitten 2014) (see Figure 5). Regarding SAP, DS Supermarked has the goal to implement this new management software, for the entire chain until the end of 2017.

Figure 5 – Food promotions examples

For the time being, the food wastage is mainly directed for the following waste treatments: bread for animal feed, incineration and biogasification. Biogasification is still in the implementing phase with a few trial supermarkets. The goal is for 100% biogasification in 2014.

Regarding the food wastage storage, every department is responsible for their waste (Bilka Skalborg 2014), and it is separated into two individual containers, one for the bread and another for the rest of organic food, including food items still in package (Figure 6). From here the bread is expedited to two farms, namely Mortensen Agro and Nyrup, and the rest to incineration or biogasification, in a basis of two to three times a week. The company responsible for the entire chain waste expedition is ISS World (Føtex Eternitten 2014).

Figure 6 - Food wastage containers

07 – Carbon Footprint at Dansk Supermarked A/S

7.1 – Goal and scope of the study

This study goal and intention is to quantify the carbon footprint from the food wastage in the Dansk Supermarked A/S supermarkets in the Danish territory, on a one month period. It is also intended to compare the food wastage treatment measures applied by Dansk Supermarked A/S in 2013 and in 2014. Furthermore, Dansk Supermarked A/S may intend to use this study results as a proactive greenhouse marketing. This may be done by showing its costumers their efforts on reducing food wastage and reduction of GHG emissions, through the adoption of cleaner waste treatments and their environmental benefits.

This study involved three main stakeholders: the authors, their supervisors at Aalborg University, and Dansk Supermarked A/S. The target audience for this study is primarily the Dansk Supermarked A/S itself, who can use this study for further data completeness and further investigation on the study scope. Other audience can be included, in order to continue this study with Dansk Supermarked A/S permission. This study was not commissioned by Dansk Supermarked A/S. It was conducted as the authors Master's Thesis, in cooperation with Dansk Supermarked A/S. The results are to be communicated to the Corporate Social Responsibility department of Dansk Supermarked A/S, along with the study authors' supervisors at Aalborg University.

This study is a single product LCA, since it only investigates the food wastage at Dansk Supermarked. This allows conducting an environmental assessment which also identifies this single product hotspots (i.e. food commodities with more waste percentage and, eventually, more GHG emissions). Nevertheless, there are comparisons made between the impacts of different waste management alternatives. The main point for this comparison is to help Dansk Supermarked A/S to determine whether the change of incineration to biogas production as food wastage management alternative has provided actual reductions in their GHG emissions.

The functional unit for this study is 1 kg of food sold in the Supermarked A/S supermarkets in the Danish territory on a monthly basis. Associated to this unit are the total food input (TFI) on a monthly basis, and the waste generated, which is the unsold part of the TFI. For each kg of food sold, there is a food input of 1,01505 kg, from which 15,05 g are wasted. The product waste is considered from its input at the supermarkets until its storage for respective collection, and this includes wastage from damaged goods from transportation, handling in store, out of date products, processing (bakery, butcher) and products that costumers pick up and leave them abandoned somewhere in the store during the time they are still shopping in the supermarkets (Bilka Skalborg, 2014).

The life cycle stage covered in this study is the Retail sector in Denmark, in particular the Dansk Supermarked A/S, Hyper and Supermarket chains. A simplified scheme of the food products life cycle is shown in figure 7:

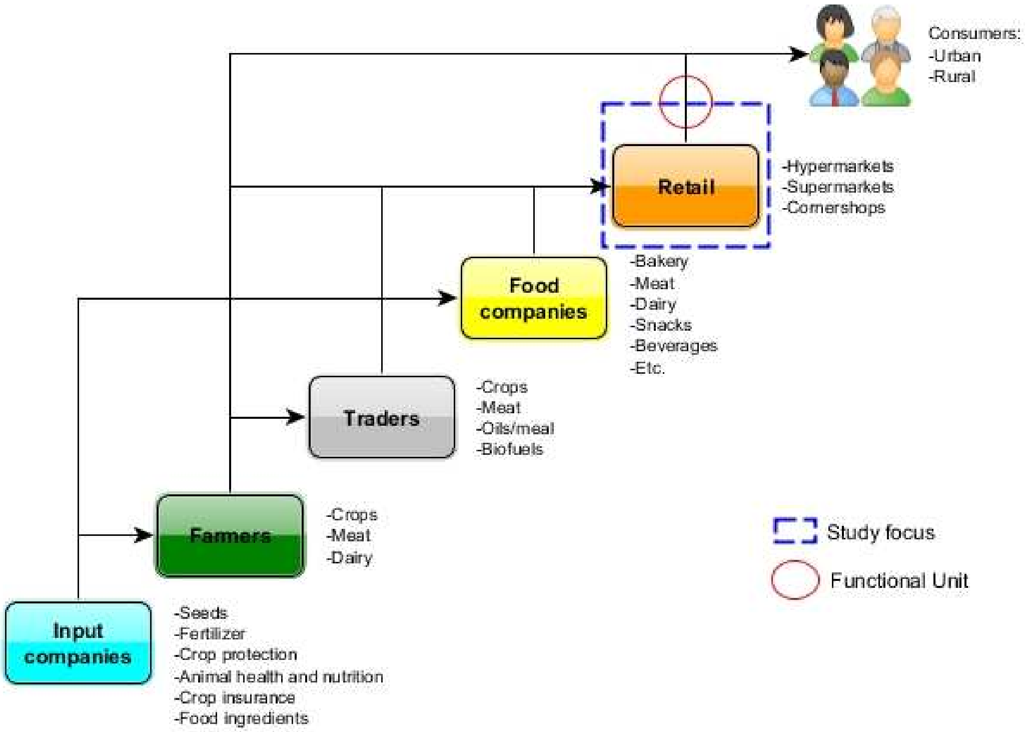

Figure 7- The agriculture and food value chain (adapted from: (KPMG 2013))

7.2 – Life Cycle Inventory (LCI) analysis

This stage encompassed three phases, which have already been elaborated in Section 5.3. The first phase was the data collection from Dansk Supermarked A/S regarding the Food commodities/items; net weight (kg); scrapping percentage and scrapping pieces.

After this contacts round, Simapro 8.1 was checked as PC platform, regarding the Input/Output (I/O) processes for food wastage management processes. As a result, the data provided by Dansk Supermaked was sorted according to the food categories of Simapro's EU27 and DK input-output (IO). The food categories used are shown in Table 3. This items/products sorting can be considered a subjective task, as sorting opinions may change between practitioners and/or readers. The reasoning used for this sorting was based on common sense and, when in case of doubt, it was assessed the level of processing involved in the respective item/product. As an example, when sorting the product bread there is no doubt that it is mainly constituted by flour but, at the same time, it also requires processing such as the baking process. In this case it was included in the food preparations not elsewhere classified category. The full range of products included in each food category can be seen in the CD attached to the report.

There is a remark that need to be done regarding the tobacco products and the chemicals not elsewhere classified. Although they may not be considered as food products, their related data was included in the inventory provided by Dansk Supermarked; the tobacco products organic content; and the chemicals are closely related to baking (e.g. baking soda) and are commonly found in several products contents.

Table 3- Simapro Input Categories

Grain crops	Fruits and vegetables, processed
Potatoes	Vegetable and animal oils and fats
Horticulture, orchards, etc.	Flour
Forest products	Sugar
Meat products, Pork	Food preparations n.e.c.
Meat products, Bovine	Beverages
Meat products, Poultry and meat n.e.c.	Tobacco products
Meat products, Fish	Chemicals n.e.c.
Dairy products	Water, fresh

After the sorting, the totals in kilograms for products inputs, sales and wastage were calculated for all the food items. Furthermore, as a requested procedure for Simapro, it was also quantified the Kilograms in dry matter for each product and total by category. The calculation procedures and the dry matter numbers according to Merciai and Schmidt (2012) are shown in the Annexes 1 and 2.

Two more interviews were also held, following the initial one. These where held to assess the type of measures or proceedings implemented at the Dansk Supermarked chains to reduce food wastage at the supermarket level ("in loco" assessment). They also served to assess the different food wastage treatment, such as incineration, animal feed and biogasification. These interviews were held with management representatives from Bilka and Føtex in Aalborg, and assuming that the procedures are the same at a national level. This round of interviews also lead to email exchanges with ESS Word, which is responsible for the waste transport management.

The overall data collection stage, as described here and in section 5.3 can be summarized in a process diagram shown in Figure 8.

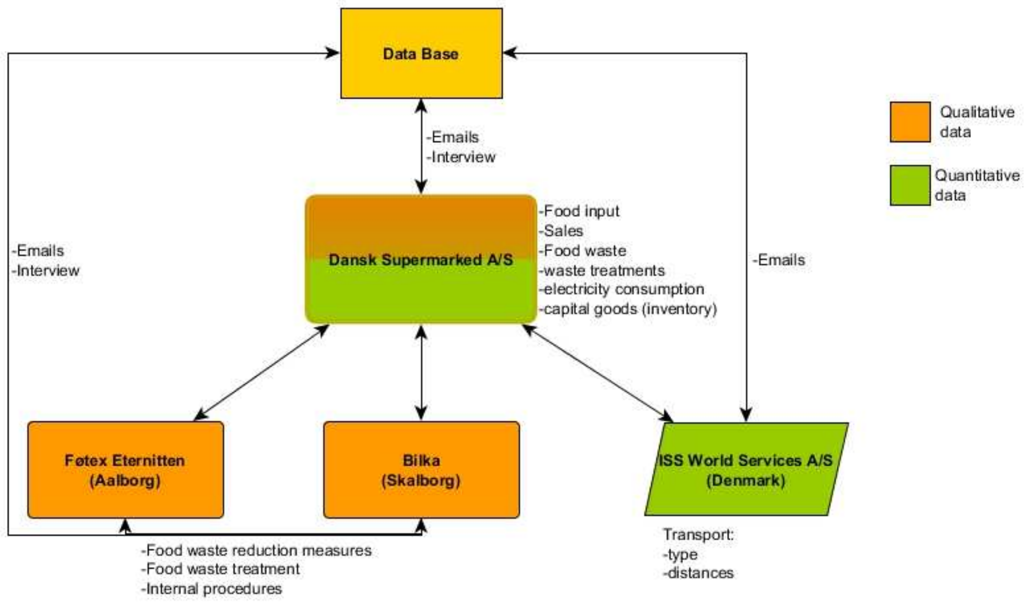

Figure 8 - Overall data collection process diagram

The Dansk Supermarket mass flows considered are from February 2014, and are shown in Table 4.

Table 4 - Mass flows by food category

Input Categories	Total food input dry matter (Kg)	Sales dry matter (Kg)	Waste dry matter (Kg)
Grain crops	769,500	767,961	1,539
Potatoes	84,933	84,679	0,255
Horticulture, orchards, etc	1.016,260	1.014,227	2,033
Forest products	46,265	48,408	0,278
Meat products, Pork	15.501,994	15.378,893	123,101
Meat products, Bovine	4.006,586	3.814,393	192,193
Meat products, Poultry and meat n.e.c.	1.672,286	1.582,061	90,225
Meat products, Fish	102,341	96,261	8,960
Dairy products	618,462	618,031	0,431
Fruits and vegetables, processed	85,440	81,168	4,272
Vegetable and animal oils and fats	1.309,000	1.305,400	3,600
Flour	124,560	121,446	3,114
Sugar	20.400,000	20.379,600	20,400
Food preparations n.e.c.	67.786,826	66.551,691	1.235,134
Beverages	2.619,250	2.588,331	30,919
Tobacco products	160,000	159,840	0,160
Chemicals n.e.c.	100,000	99,400	0,600
Water, fresh	800,000	798,400	1,600
TOTALS	**117.203,702**	**115.490,190**	**1.718,813**

The next step of the data treatment was the process building and assembly as shown in Figure 9.

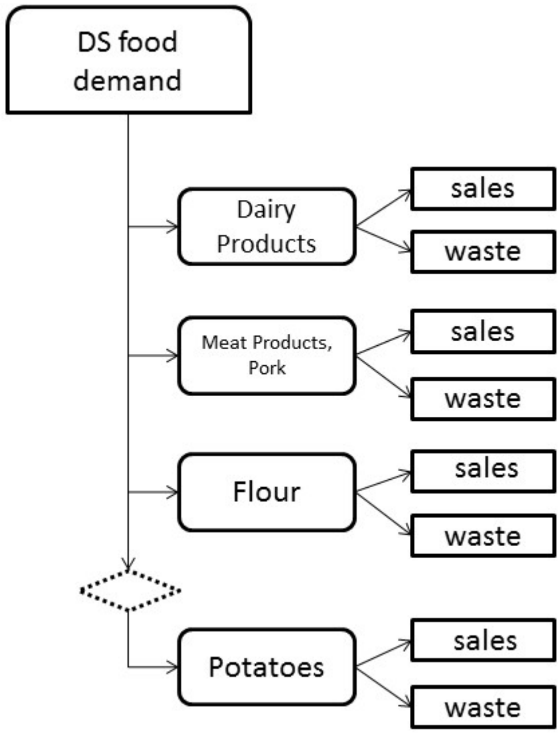

Figure 9 – Process building and Assembly Diagram

The approach applied in this LCA study is a consequential modelling. The reason for it was referred in the previous chapter, when it was stated that the consequential approach implies that the system delimitation is based in a market oriented methodology, identifying the affected processes (THRANE and SCHMIDT 2007, 205).

As stated in Chapter 6 and in Section 7.1, there are three types of waste treatment measures regarding the food wastage in the Dansk Supermarked supermarkets: animal feed, incineration and biogasification. In the three cases, there are determining co-products as outputs avoided by system expansion. These determining co-products can be defined as "*co-products for which a change in demand leads to a change in production*" (Weidema et al. 2008, Schmidt and Weidema 2008, Schmidt and Muñoz 2014). In the animal feed case, as referred during the data collection by Dansk Supermarked, the food commodities that go to animal feed are the bread products, which imply the substitution in the demand for soy beans as protein source, and barley as energy source. In the incineration waste treatment case, it is assumed that the combustion of food wastage generates heat and electricity as determining co-products, therefore, substitution is made for the respective market demand. In the biogasification case, it is assumed that the generated determining co-products are electricity and biogas (majorly methane), consequently, substituting their demand in the market.

The system processes under study are the input of food to the Dansk Supermarked supermarkets in Denmark in a national scale on one month, the food sold and the food wasted in the same supermarkets in the same period of time, along with the energy used (i.e. lights, cooling and ovens) to prepare and/or maintain that food in optimal conditions while it is for sale, and the food wastage transportation until the farms and incineration/biogasification site's locations. There are two scenarios regarding the food waste managements, which are described below:

Scenario 1 (2013)

This scenario makes reference to the food waste treatments applied in 2013. Which consisted in incineration and animal feed. Although there were already testing points for biogasification treatment, this were excluded because of the small amount of waste that was being tested, and the lack of data to be provided by Dansk Supermarked. This data gap is due to the software transition process, to SAP. Figure 10 illustrates this scenario:

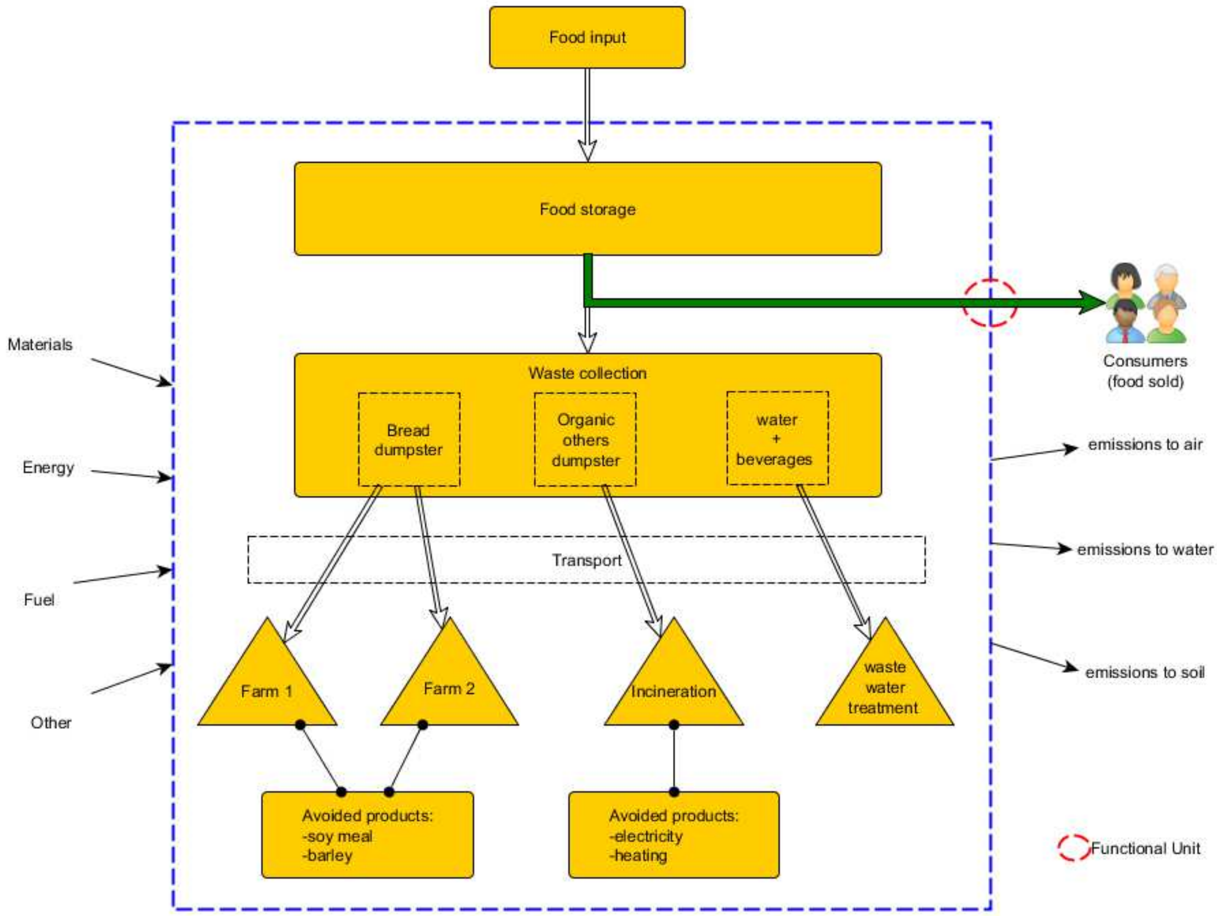

Figure 10- Scenario 1 (2013 waste treatments)

Scenario 2 (2014 goal)

This scenario makes reference to the 2014 goal set by Dansk Supermaked, in which all the food wastage will be sent to biogasification treatment. Figure 11 illustrates this scenario:

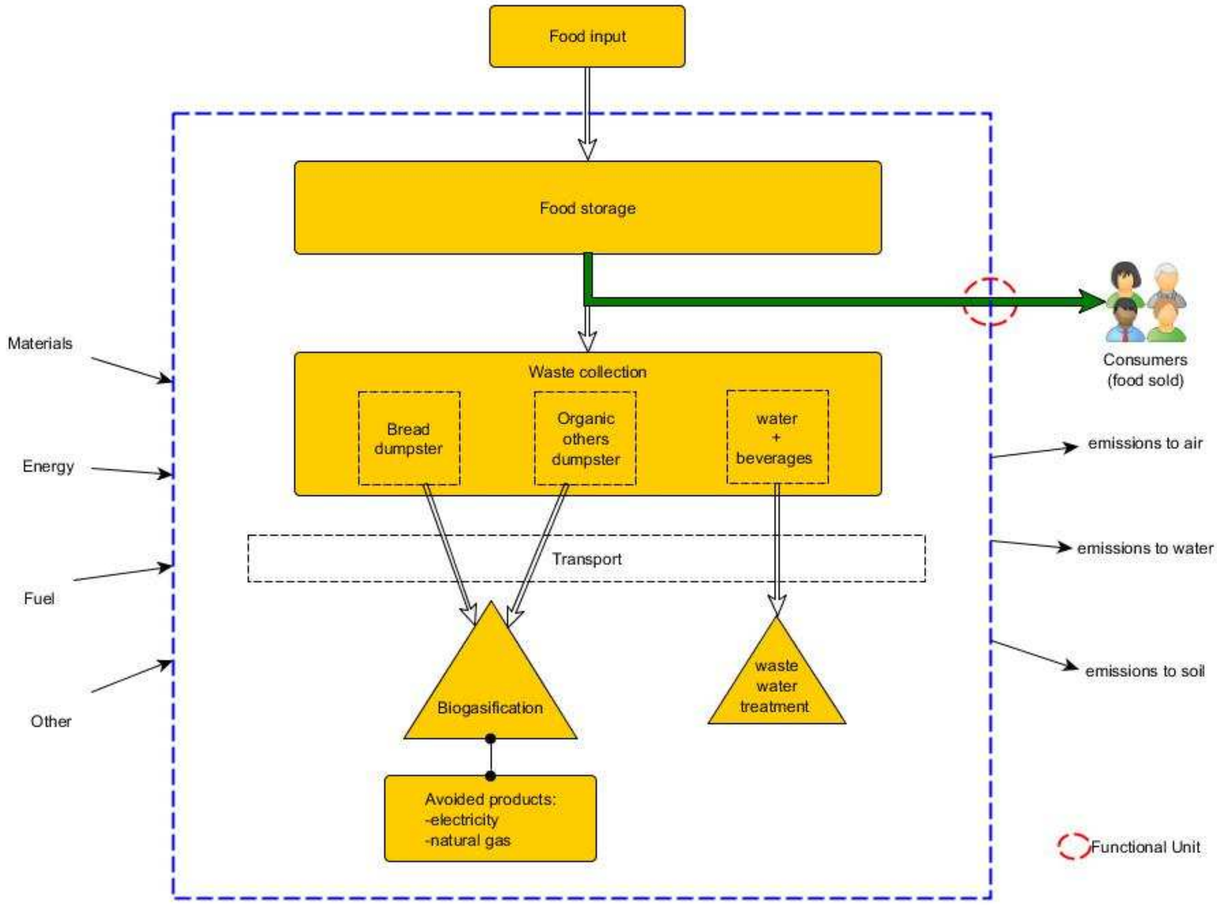

Figure 11 - Scenario 2 (2014 waste treatment goal)

7.3 – Life Cycle Impact Assessment (LCIA)

For the life cycle impact assessment, data has been collected in a qualitative and quantitative method, as described in Section 3.2. Furthermore, Simapro 8.1 has been used as a tool to determine the carbon footprint, using the EU & DK Input Output Database. For the processes not included in that database, Ecoinvent 3 consequential – unit database was used.

Since this study is a Carbon Footprint, it is a single issue analysis. The reasons for this:

- The only impact category under analysis for the LCI results is climate change.
- As characterization, the LCIA will provide results in carbon dioxide equivalents (CO_2-eq.), by applying the IPCC 100-years global warming potential (GWP100a) method.

For the impact assessments, the Simapro IPCC 2007 GWP 100a V1.02 was used. This method is the successor of the IPCC 2001 method, which was developed by the Intergovernmental Panel on Climate Change. It contains the climate change factors of IPCC with a timeframe of 100 years (SIMAPRO 2014).

7.4 – Life Cycle Interpretation

In this section, the results for a baseline scenario are going to be presented. This will start with the Dansk Supermarked food wastage treatments in 2013. After this, a comparison to this baseline is going to be made with the following scenarios:

- 2014 goal (100% biogasification)
- 100% Incineration
- 100% Composting
- 100% Animal Feed

Furthermore, it was acknowledged during the meeting with Føtex that water and beverages are sent to wastewater treatment. As so, the water and beverages wastes were always modelled for wastewater treatment in all scenarios.

For a better understanding of the following analysis, it is cleared out the following information:

- Supply to retail refers to all the stages and processes from the production stage until it is sold or wasted;
- Retail fraction to waste treatment corresponds only to a portion of the supply to retail, which is the food wastage that goes to waste treatment.

7.4.1 – 2013 Scenario – Bread for animal feed and Incineration for the remaining Food Wastage (baseline)

The results for this scenario are shown in table 5.

Table 5 - 2013 Scenario Results

Category	**Supply to retail**	**Retail fraction to waste treatment**	
	Total emissions (kg CO2 eq.)	Emissions (kg CO2 eq.)	% of total emissions
Dairy Products	271.329.286,26	-358.319,71	-0,132
Meat Products, Pork	114.983.027,45	-335.057,63	-0,291
Food preparations n.e.c.	86.584.319,14	-390.042,51	-0,45
Electricity consumption in Retail shops	85.249.015,17	n.a.	n.a.
Meat Products, Bovine	53.986.388,46	-51.855,73	-0,096
Meat Products, Poultry and meat n.e.c.	19.813.671,76	-81.187,85	-0,41
Vegetable and animal oils and fats	16.816.153,08	-56.506,84	-0,336
Beverages	6.844.646,92	21.169,83	0,309
Meat Products, Fish	2.676.088,29	-68.733,33	-2,568
Flour	1.660.695,09	-34.400,39	-2,071
Grain crops	1.299.980,99	-18.236,41	-1,403
Potatoes	1.022.200,80	-7.077,09	-0,692
Sugar	563.223,83	-7.085,80	-1,258
Water, fresh	295.632,99	2.367,66	0,801
Fruits and vegetables, Processed	170.543,32	-5.075,75	-2,976
Horticulture, orchards, etc	7.929,84	-48,62	-0,613
Tobacco products	3.807,77	-1,51	-0,04
Chemicals n.e.c.	3.031,17	-5,96	-0,197
Forest Products	-2.912,95	-2.981,43	102,351
Total	**663.306.729,4**	**-1.393.079,1**	**0.21%**

The most important information to be retrieved from Table 5 is:

1. The Cradle to retail Carbon Footprint is 663.306.729,4 kg of CO_2 eq.;
2. The Dansk Supermarked food wastage treatment Carbon Footprint is -1.393.079,1 kg CO2 eq.
3. The Dansk Supermarked food wastage treatment Carbon Footprint represents 0,21% of the value chain total GHG emissions.

It has to be noted that, in Table 5, the Retail waste has negative values. This means that the food wastage treatment saves more GHG emissions than those it emits. In this perspective, the food wastage from Dansk Supermarked has a positive impact. This is due to the electricity generated at the incineration waste treatment point(s), which substitutes the demand of electricity produced from fossil fuels and other sources. The exceptions towards the positive impacts are the beverages and fresh water food categories. These are directed to water waste treatment, which has a negative GWP impact. As for the animal feed, the bread substitutes the demand for barley and soy beans, which represents savings in production for these two items.

The categories with the greatest carbon footprint shares are shown in Figures 12 (supply to retail) and 13 (retail waste treatment).

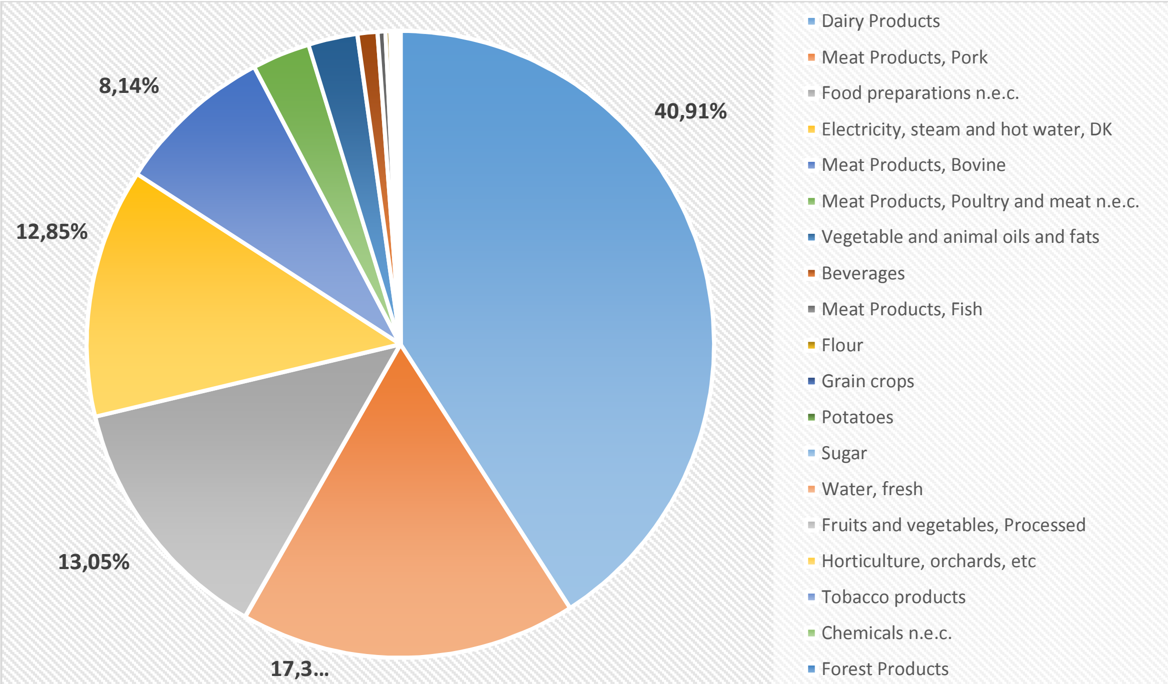

Figure 12 – Supply to retail GHG Emissions by food category

Figure 12 shows that the supply to waste major GHG contributors are the Dairy products (40.91%), the Meat products, pork (17.33%), the food preparations (13.05%), the electricity consumption on the retail shops (12.85%) and the meat products, bovine (8,14%).

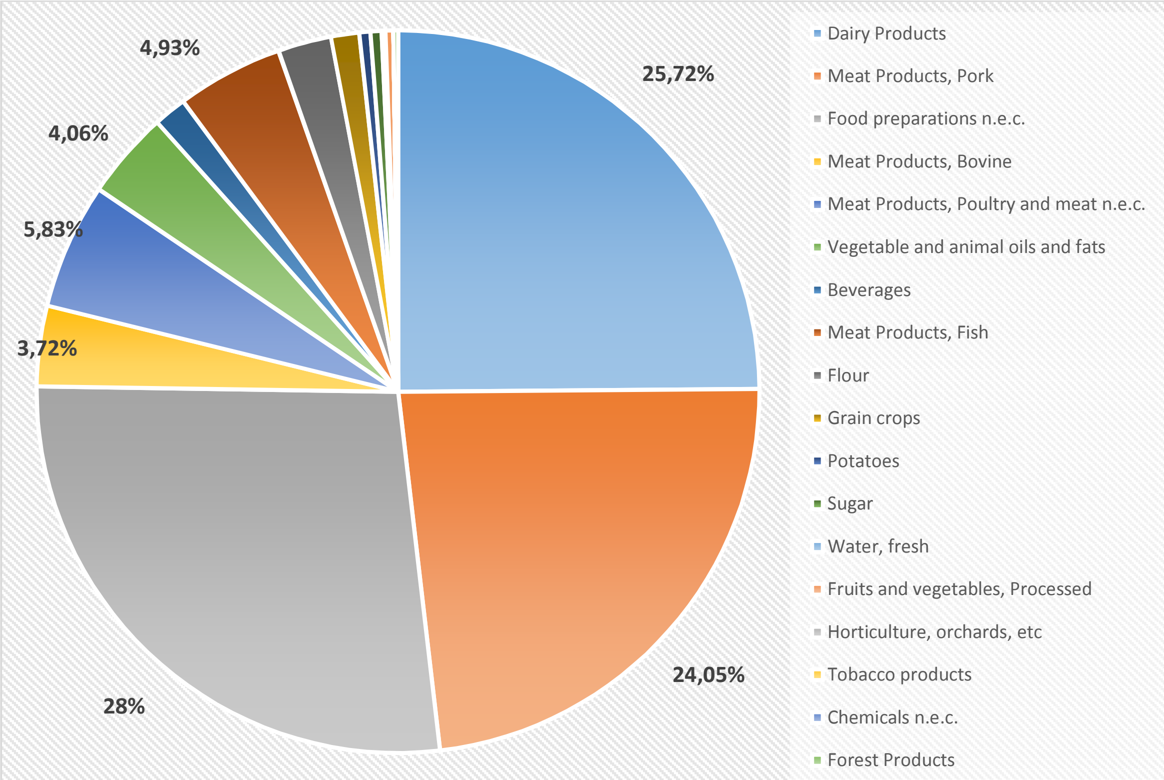

Figure 13- Waste treatment GHG Emissions by food category

The food categories with the greatest waste emissions contributions are Food Preparations n.e.c. (28%) Dairy Products (25,72%), Meat Products, Pork (24,05%), Meat Products, Poultry and meat n.e.c. (5.83%), Vegetable and animal oils and fats (4,93%) and Meat Products, Fish (4,6%).

7.4.2 – Scenarios Comparison

Given that the emission changes in the Supply to Retail have small variation in percentage, the emissions from the baseline scenario are going to be kept for comparative purposes. Nevertheless, the remaining Supply to Retail totals of each alternative scenario are presented in Table 6.

Table 6 – Different Scenarios Supply to Retail Emissions

	Supply to retail				
Scenarios	**2013 Scenario**	**2014 Scenario**	**Incineration Scenario**	**Composting Scenario**	**Animal Feed Scenario**
Total emissions (kg CO2 eq)	663.306.729,4	663.573.124,3	663.257.094,26	664.867.404,5	664.554.734,83

From Table 6, it is possible to see that there are changes from 266.000 kg CO2 eq. to 1.610.310 kg CO2 eq. As this represents changes inferior to 0,1%, the baseline emissions are going to be kept for comparison.

Table 7 shows the totals of the Retail Fraction to Waste Treatment for each scenario. This values correspond to the actual impact of each food wastage treatment.

Table 7 – Totals of the retail fraction to waste treatment

Category	Supply to retail	Retail Fraction to Waste Treatment				
	2013 Scenario total emissions (kg CO2 eq.)	2013 Scenario (kg CO2 eq.)	2014 Scenario (kg CO2 eq.)	Incineration Scenario (kg CO2 eq.)	Composting Scenario (kg CO2 eq.)	Animal Feed Scenario (kg CO2 eq.)
Dairy Products	271.329.286,26	-358.319,71	-281.089	-358.319,71	35.204,30	-55.666,37
Meat Products, Pork	114.983.027,45	-335.057,63	-262.840,73	-335.057,63	32.918,84	-52.052,51
Food preparations n.e.c.	86.584.319,14	-390.042,51	-344.912,69	-439.679,30	43.197,74	-9.129,59
Electricity consumption in Retail shops	85.249.015,17	0	0	0	0	0
Meat Products, Bovine	53.986.388,46	-51.855,73	-40.678,97	-51.855,73	5.094,74	-8.055,99
Meat Products, Poultry and meat n.e.c.	19.813.671,76	-81.187,85	-63.688,96	-81.187,85	7.976,57	-63.688,96
Vegetable and animal oils and fats	16.816.153,08	-56.506,84	-44.327,60	-56.506,84	5.551,70	-8.778,56
Beverages	6.844.646,92	21.169,83	21.169,83	21.169,83	21.169,83	21.169,83
Meat Products, Fish	2.676.088,29	-68.733,33	-53.918,84	-68.733,33	6.752,93	-10.677,99
Flour	1.660.695,09	-34.400,39	-26.985,88	-34.400,39	3.379,78	-5.344,24
Grain crops	1.299.980,99	-18.236,41	-14.305,81	-18.236,41	1.791,70	-2.833,10
Potatoes	1.022.200,80	-7.077,09	-5.551,72	-7.077,09	695,312	-5.551,72
Sugar	563.223,83	-7.085,80	-5.558,56	-7.085,80	696,168	-1.100,81
Water, fresh	295.632,99	2.367,66	2.367,66	2.367,66	2.367,66	2.367,66
Fruits and vegetables, Processed	170.543,32	-5.075,75	-3.981,75	-5.075,75	498,684	-788,54
Horticulture, orchards, etc	7.929,84	-48,62	-38,14	-48,62	4,776	-7,55
Tobacco products	3.807,77	-1,51	-1,19	-1,51	0,149	-0,24
Chemicals n.e.c.	3.031,17	-5,96	-4,68	-5,96	0,586	-0,93
Forest Products	-2.912,95	-2.981,43	-2.338,82	-2.981,43	292,92	-463,18
Total	**663.306.729,40**	**-1.393.079,1**	**-1.126.685,84**	**-1.442.715,9**	**167.594,39**	**-200.602,8**

From Table 7 it is possible to observe differences in terms of GHG emissions. The categories are ranked from the biggest to the lesser emitter in the following diagram:

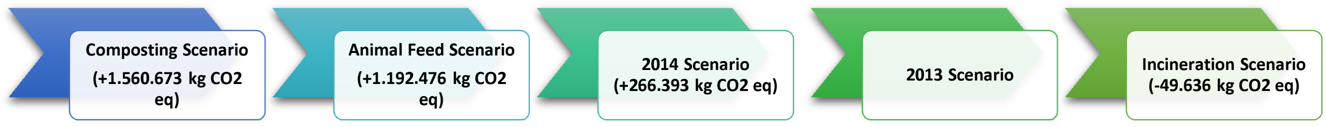

Figure 14 - Scenarios ranking by emission

Looking down to the waste emissions contribution of each food category, a comparison can be seen in Figure 15:

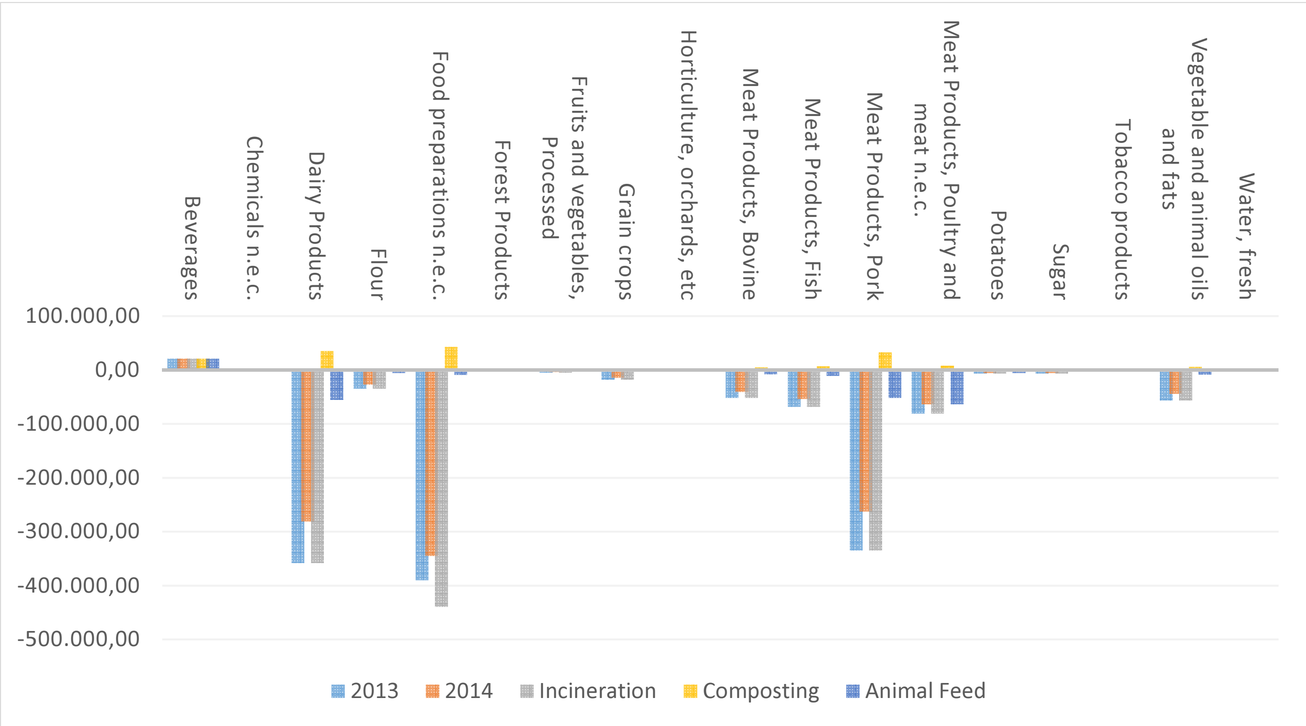

Figure 15 – Food Categories emissions by Scenario

From Figure 15, it can be seen that the beverages waste treatment (wastewater), always emits greenhouse gases. Regarding the remaining categories, it is possible to observe that the most important categories are the dairy products, the food preparations, and the Bovine, Poultry and Pork Meat product categories.

To better understand the relative share of each food category, these are going to be presented in the following figures, where each one corresponds to each of the four alternative scenarios.

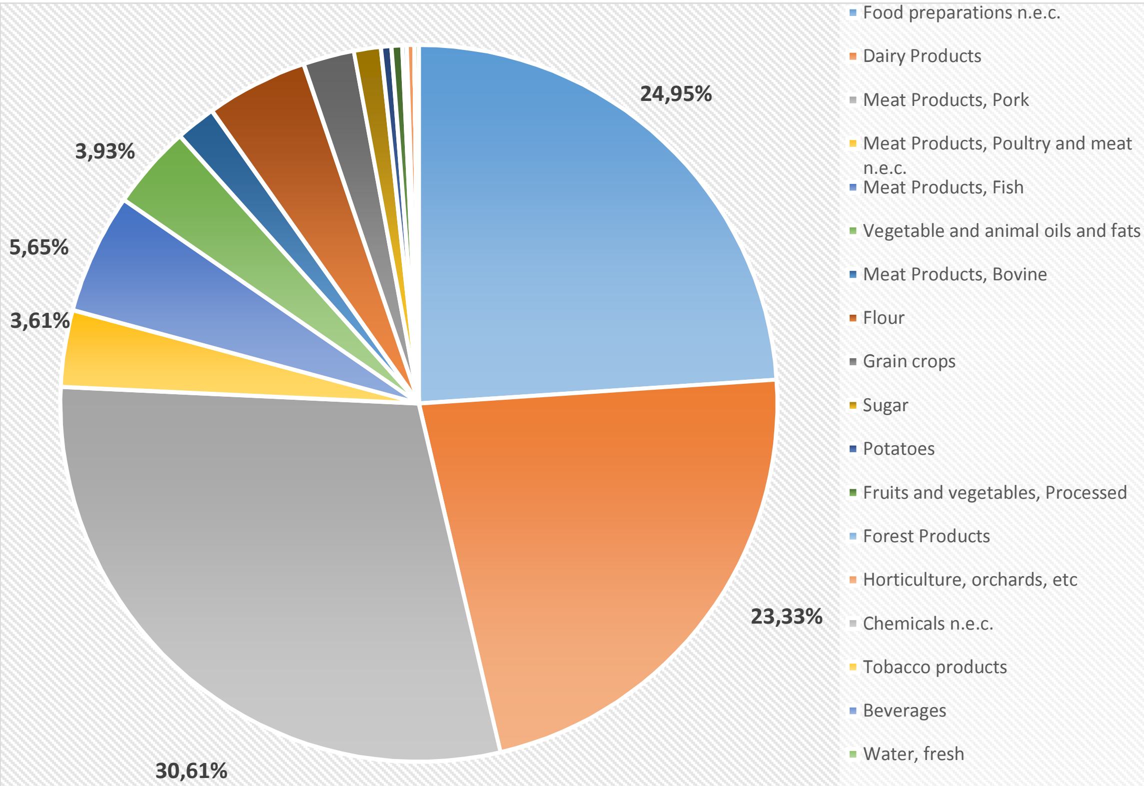

Figure 16 - Biogas waste treatment emissions share by food category

In Figure 16, the categories with the greatest emissions contribution shares are Food Preparations n.e.c. (30,61%) Dairy Products (24,95%), Meat Products, Pork (23,33%), Meat Products, Poultry and meat n.e.c. (5,65%), Meat Products, Fish (3,93%) and vegetable and animal oils and fats (3,61%).

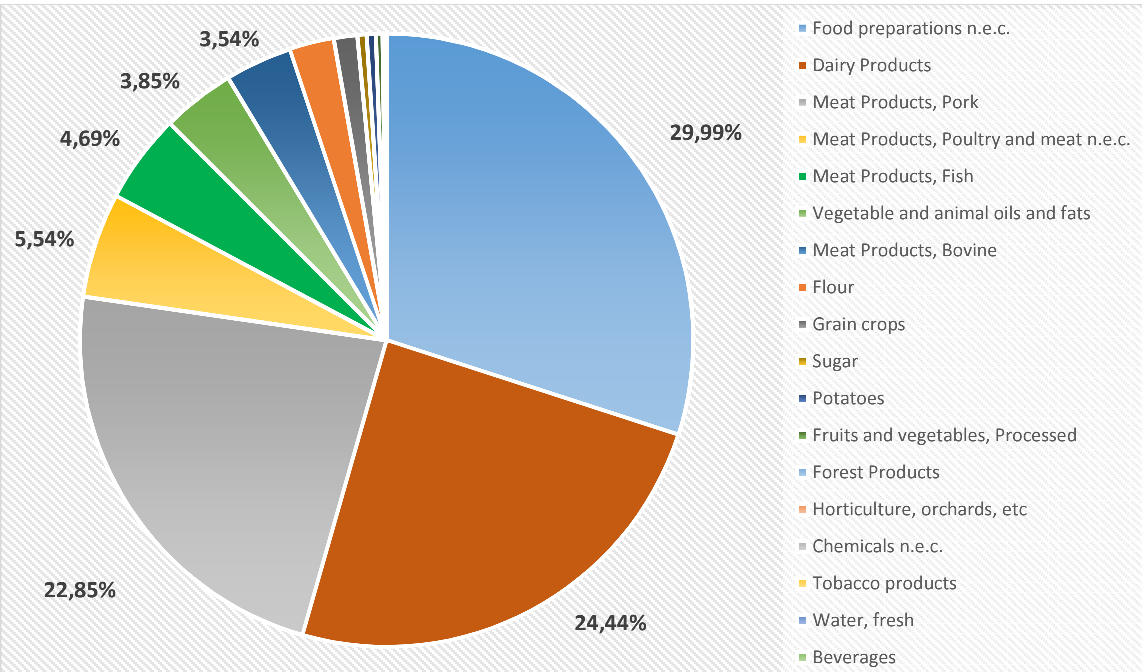

Figure 17 – Incineration waste treatment emissions share by food category

In Figure 17, the categories with the greatest emissions contribution shares are Food Preparations n.e.c. (29.99%) Dairy Products (24,84%), Meat Products, Pork (22,85%), Meat Products, Poultry and meat n.e.c. (5,54%), Meat Products, Fish (4,69%) and vegetable and animal oils and fats (3,85%).

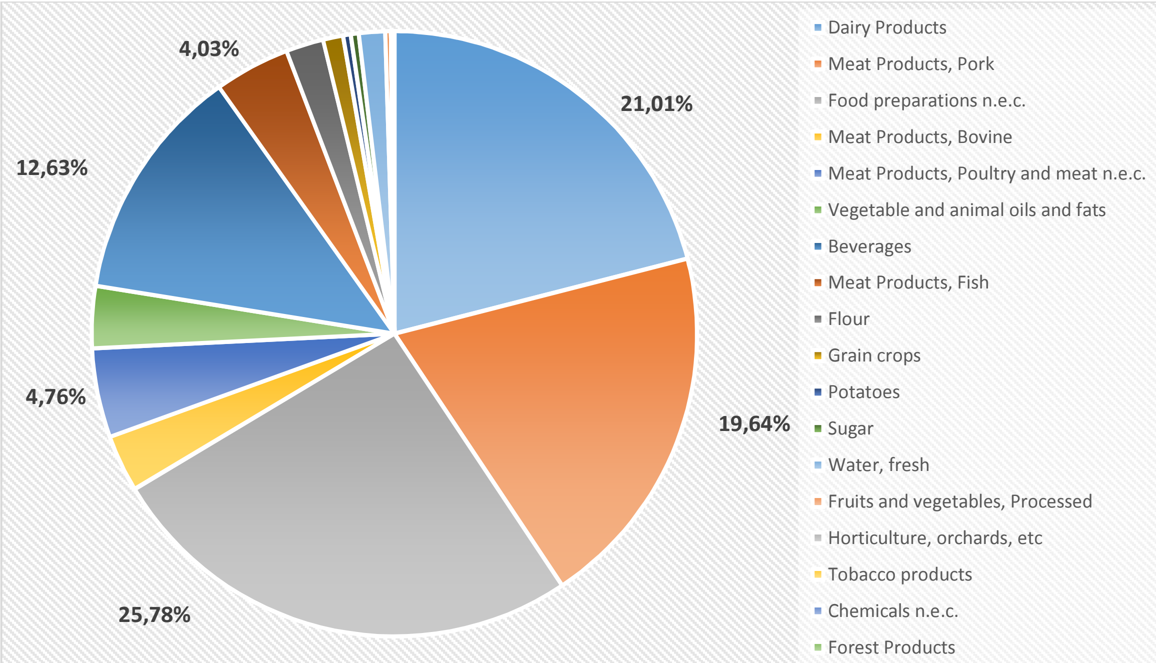

Figure 18 – Composting waste treatment emissions share by food category

As it can be seen from Figure 18, the categories with the greatest emissions contribution shares are Food Preparations n.e.c. (25,78%) Dairy Products (21,01%), Meat Products, Pork (19.64%), Beverages (12.63%) Meat Products, Poultry and meat n.e.c. (4.76%), and Meat Products, Fish (4,03%).

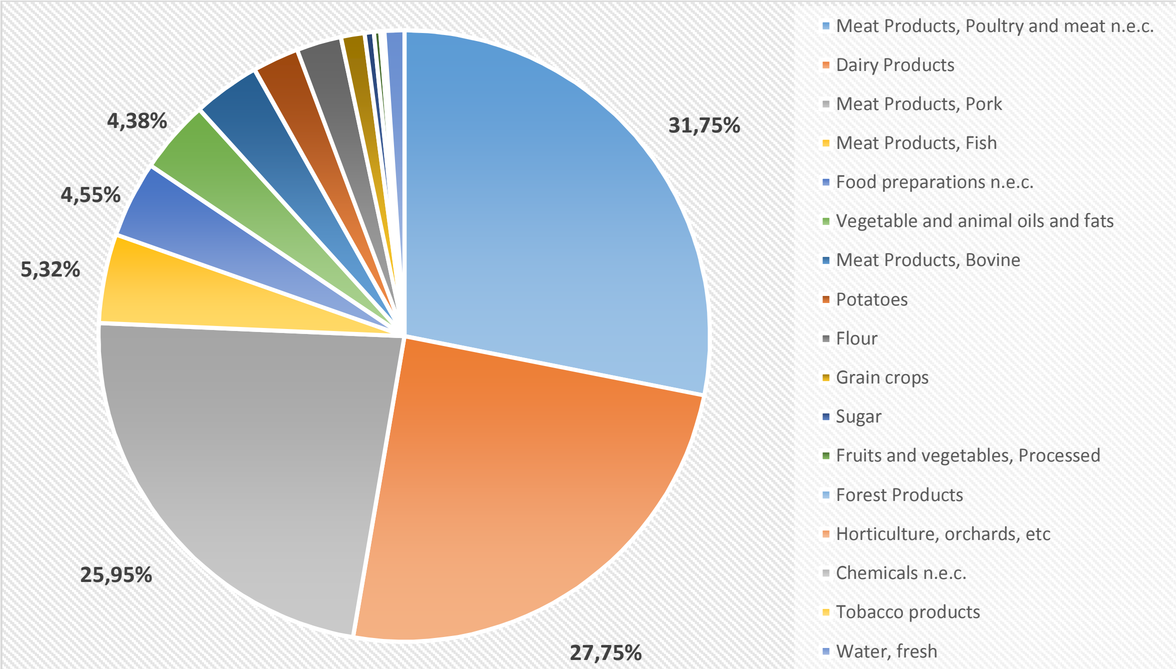

Figure 19 – Animal Feed waste treatment emissions share by food category

As it can be seen from Figure 19, the categories with the greatest emissions shares are the Meat Products, Poultry and meat n.e.c.(31.75%), Dairy Products (27,75%), Meat Products, Pork (25.95%), Meat Products, Fish (5.32%). Food Preparations n.e.c. (4.55%), and the Vegetable and animal oils and fats (4,38%).

Summing up, the weight of each food category waste treatment emissions changes with the waste treatment type. Nevertheless, it can be seen that the major contributors are the Food preparations, the Dairy products and the Meat products pork, since they always represent over 20% each on every scenario.

7.4.3 – Waste reduction scenario

In this scenario, it is assumed a reduction of 10% for the waste flow in each category, maintaining the sales flow constant. According to this model, this implies a reduction of 10% at the food input to each food category in the supermarkets. In this case, the 2014 scenario was adopted for comparison (100% biogasification), since it is the future scenario to be implemented.

The mass flow reduction is illustrated in Figure 20:

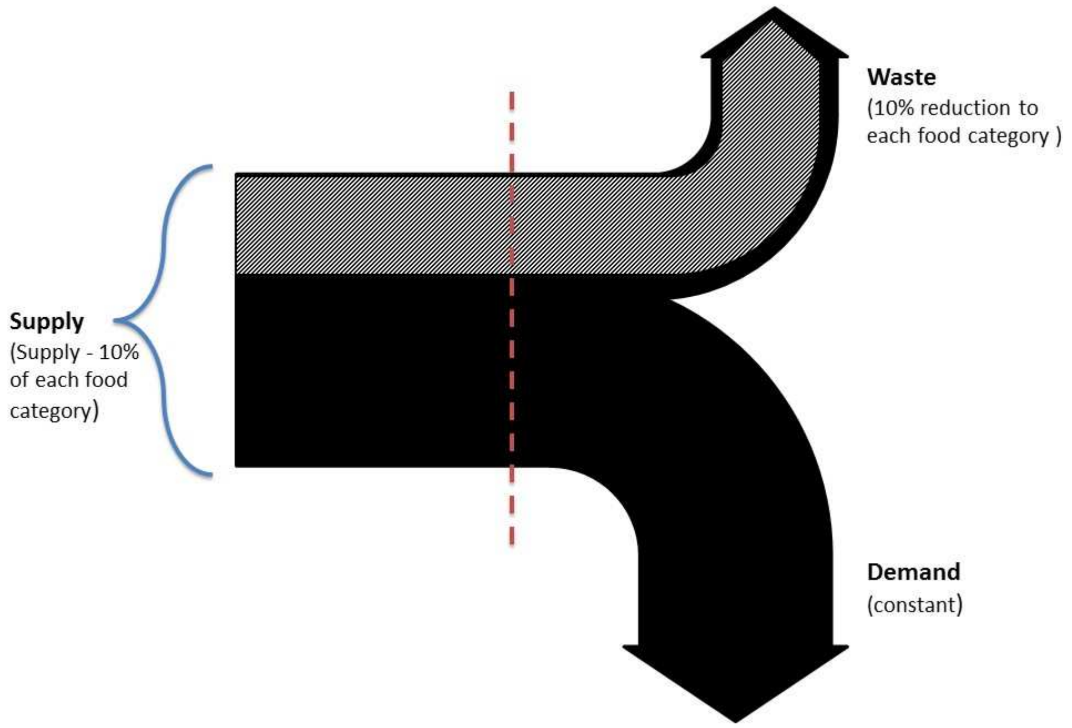

Figure 20 - 10% waste reduction mass flow model

The calculations to model this scenario, as shown in figure xx, are:

- **2014 Scenario:** $Demand(D) = Supply(S) - Waste(W)$
- **10% Waste reduction scenario:** $D = [S - (0.1W)] - 0.9W$

The results for this scenario are presented in Table 8:

Table 8 - 2014 and 10% waste reduction scenarios' emissions

2014 (100% biogasification)		2014 (10% waste reduction)	
Supply to retail emissions (kg CO2 eq.)	Waste treatment fraction emissions (kg CO2 eq.)	Supply to retail emissions (kg CO2 eq.)	Waste treatment fraction emissions (kg CO2 eq.)
663.573.124,28	**-1.126.685,841**	**662.411.317**	**-1.014.017,257**

Table 8 shows that, when reducing the waste by 10%, it can be observed that:

- The waste treatment emissions are increased by 112.668,6 kg CO_2 eq.
- The cradle to retail emissions are reduced in 1.161.807,2 kg CO_2 eq.

This means that a 10% food wastage reduction, by adjusting down the supermarkets supply, saves far more emissions than just treating the waste, as also shown in Figure 21.

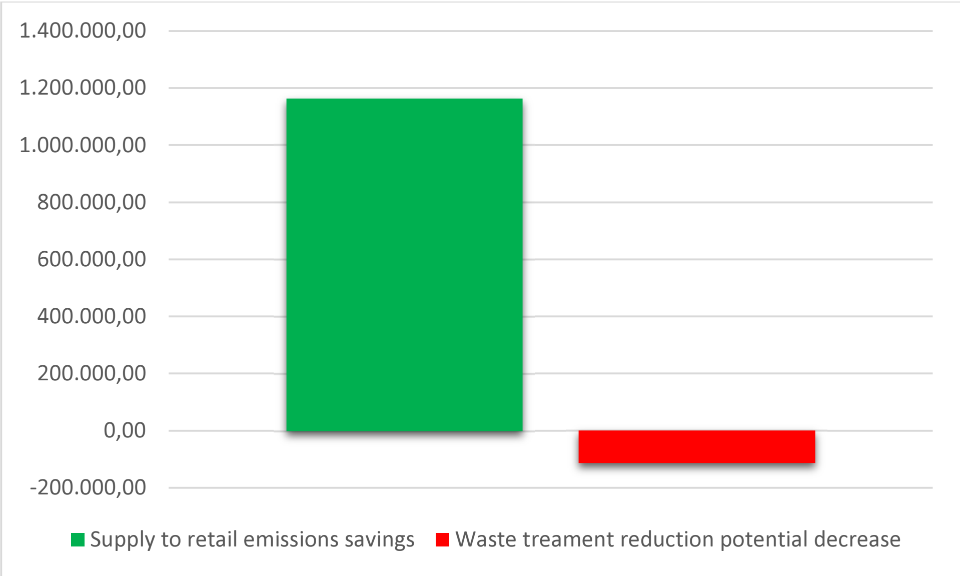

Figure 21 – Supply to retail and Waste treatment emissions differential

In Figure 21 the green bar shows an increase in the supply to retail emission reduction potential, and the red bar shows the decrease in retail waste treatment emission reduction potential.

8 – Discussion

8.1 – Results discussion

The Life Cycle Interpretation allowed to compile the supply to retail and the retail waste treatment emissions, for five different scenarios. These scenarios, except for the composting, showed waste negative emission values, which means they are saving GHG emissions. These can be seen in the Tables 9 and 10. Furthermore, it is also possible to rank the scenarios by emission in comparison to the 2013 baseline scenario, as shown in Figures 23 and 24.

Table 9 - Supply to retail emissions by scenario

	Supply to retail				
Scenarios	**2013 Scenario**	**2014 Scenario**	**Incineration Scenario**	**Composting Scenario**	**Animal Feed Scenario**
Total emissions (kg CO2 eq)	663.306.729,4	663.573.124,30	663.257.094,3	664.867.404,5	664.554.734,83

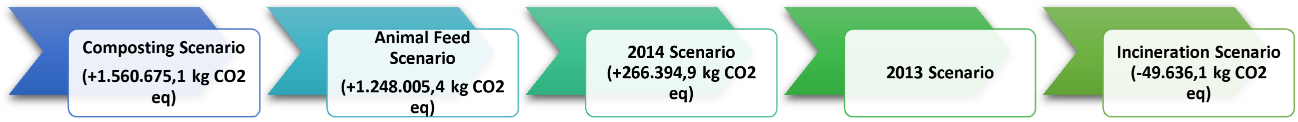

Figure 22 - Scenarios ranking by supply to retail emissions

Table 10 Retail emissions by scenario

	Retail Fraction to Waste Treatment				
Scenarios	**2013 Scenario**	**2014 Scenario**	**Incineration Scenario**	**Composting Scenario**	**Animal Feed Scenario**
Total emissions (kg CO2 eq)	**-1.393.079,10**	**-1.126.685,84**	**-1.442.715,90**	**167.594,39**	**-200.602,80**

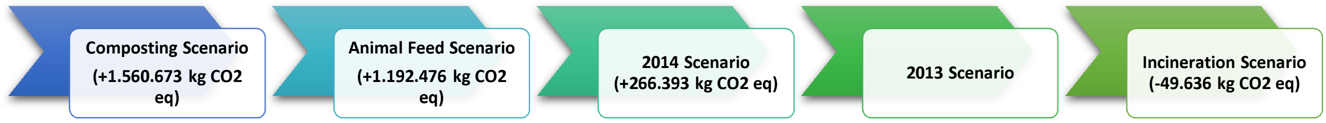

Figure 23 – Scenarios ranking by retail fraction emissions

Looking at the Dansk Supermarked waste scenario, which is being phased out (2013) and the one that has started to be adopted (2014), Figure 24 shows that the 2013 scenario is the best scenario in terms of GHG emissions (saves 266.393 kg CO2 eq.). Furthermore, it can also be seen that if the bread waste was sent to incineration, instead of animal feed (corresponding to the 100% incineration scenario), it would be possible to make savings of around 50.000 kg of CO2 eq. in one month, on a national scale.

Considering the possible alternative scenarios to incineration and biogasification, the composting and animal feed are considered the worst case scenarios. The reason for this is that they emit more GHG: +1.560.673 kg CO2 eq. (composting scenario), and +1.192.476 kg CO2 eq. (animal feed scenario) when compared to the 2013 scenario, in one month, on a national scale.

About the different food categories under analysis, the categories with the greatest share for the overall balances are:

- Food preparations,
- Dairy products,
- Meat products, pork
- Meat products, poultry and meat n.e.c. (not elsewhere classified).

The reasons for this are mostly related to the amounts wasted (sometimes over 1.000 tons/month) towards other categories, and the overall impacts the categories may have from the value chain's production stage. A good remark for this ranking is the absence of bovine meat products, since it is an important contributor for climate change. The reasons for not being highly ranked in the results may be related to the quantities accounted, and possibly to an information gap during the current management software transition.

Another point to discuss is the positive and negative emission values found in the different scenarios, regarding the retail waste treatment fractions. It has to be referred that a process with a certain amount of negative GHG emissions means that the process is saving that amount of emissions. Therefore, it has a positive environmental impact. On the other hand, a process with a positive amount of GHG emissions means that the process is emitting that amount. Therefore, it has a negative environmental impact.

From the results tables, it can be seen that the composting scenario is the only one with an actual positive emissions balance. To help understanding the reason why composting has a positive emissions balance, it was possible to observe in Simapro that this scenario leads to a substitution in the demand for fertilizers, other chemicals and minerals. This substitution occurs by incorporating the compost in the farmlands. However, this does not balance the overall impacts as it was observed especially in the incineration and biogasification scenarios. The main reason for this is that, unlike biogasification and incineration, composting does not produce energy back.

Regarding the other scenarios, the negative emission values may be based on two facts:

1. The animal feed in the 2013 and 100% animal feed scenarios reduce the impacts by substituting fertilizers, and also barley and soy meal used as feed for farm animals,
2. The incineration and biogasification waste treatments lead to energy production.

Regarding the energy produced from biogas and incineration, its importance relies on the fact that the energy produced is sent to the electricity and district heating grids, giving two positive aspects:

1. The energy produced may substitute energy production processes that emit more greenhouse gases (i.e. from fossil fuels);
2. It is possible that at least part of energy produced from the Dansk Supermarked food wastage is used back in the supermarkets (i.e. for cooling). If this is actually happening, the food wastage is partially substituting other energy sources (and its related energy production GHG emissions).

To finalise this discussion, apart of the composting scenario, the overall results may provide a misconception that food wastage is good, in the sense that allows the substitution of energy sources and other natural resources (as it can be observed in the negative balance of all waste treatments). A good example of this misconception is the 100% incineration scenario generated in this report. As analysed before, it is the treatment with fewer emissions due to the heat and energy substitution. This may lead to the idea that the more waste for the energy substitution the better, since it may allow more GHG emissions savings. However, the 10% waste reduction scenario proved the opposite: in a 10% waste reduction by scaling the inputs can have ten times more value chain savings than retail waste treatment emission increases (see Figure 21).

This interpretation of the results may lead to a paradox, in the sense that more waste is good, less waste is bad. This outcome may be related to the way that the energy system of Denmark is mounted, in which the majority of waste (80%) is incinerated, retrieving considerable amounts of energy from it. Therefore, the results for the incineration carbon footprint show emissions savings. But as Denmark aims to become independent from fossil fuel by 2050, this also may imply to shut down the most polluting waste-to-energy incineration power plants. In this sense, the results from this report most likely balance to the biogasification scenario side, which is the 2014 goal of Dansk Supermarked.

However, the most important fact to retrieve is that food wastage needs to be avoided/reduced. The reason for this is it implies "*throwing away*" natural resources used in production, and there is where the biggest share of impacts occurs within the value chain. If the picture is understood in a holistic way, it is possible to understand that less food wastage implies less food input, therefore less natural resources use.

8.2 – Consistency and sensitivity discussion

As it has been discussed in Chapter 3 (literature review), there is a gap in this kind of studies in the retail sector. As so, it has not been possible to compare this study's results to check their consistency.

Furthermore, the data collection took place during a period where Dansk Supermarked was migrating its data into SAP. This may have led to a small data uncertainty, due to small data gaps or deviations. The possible data uncertainty was not possible to be measured, since the migration was still on course by the delivery date of this report.

There was also the attempt to collect data regarding the food wastage transportation, from the supermarkets to the ISS World collection points. Despite the efforts to include this data, it was not possible to retrieve it in time to be included in this report. The relevance of this data relates to the fact that transportation has direct associated emissions from the transportation lorries, and it is unknown the significance of the transportation emissions for this study.

Another point to refer is that each category relative impact may not be the same on each month of the year. This may happen due to possible consumption pattern changes along the year (i.e. product consumption changes in Easter or Christmas). As this study has data for only one month period (February), this study does not account for the referred consumption changes.

It was also provided a detailed list with the typical capital goods which can be found at a Dansk Supermarked supermarket. However, due to the workload and time constraints, it was not possible to sort the ones directly connected to food storage, and model that information into this project's database.

Furthermore, there were two Simapro libraries used (Ecoinvent 3.0 consequential unit and DK and EU I/O database). From the beginning of this project, the intention was to solely use the input-output library, in order to have the maximum process consistency possible. However, it was not possible to do so when creating the "utilization of bread for animal feed" process. Therefore, this process building also involved the Ecoinvent 3.0 consequential unit library. The use of these two libraries may bring some inconsistencies, but these may be small in scale due to the relevance of the bread for animal feed in the whole analysis.

09 – Conclusions

The conclusions are presented as direct answers to the research question and sub-questions. As so, these questions will be presented and followed by the conclusions that were drawn to answer them.

Research Question - What is the food wastage Global Warming Potential of a Danish retail company on a national scale?

The Dansk Supermarked Carbon Footprint depends of the food wastage treatment scenario. To provide an answer for a one month period on a national scale, the two scenarios used by Dansk Supermarked have to be separated:

- 2013 Scenario: -1.393.079,1 kg CO2 eq. (while for supply to retail is 663.306.729,4 kg CO2 eq.)
- 2014 Scenario: -1.126.685,84 kg CO2 eq. (while for supply to retail is 663.573.124,3 kg CO2 eq.)

Sub-questions

What is the amount of food input, food sold and food wasted in the company?

The total net weights retrieved for a one month period (February 2014) are 81.487.939,772 kg of food inputs to the supermarkets, 80.280.740,749 kg of food sales and 1.207.199.203 kg of food sales (1,48% of the food input).

Which food wastage treatment alternatives does the company use?

In 2013, the waste treatment methods used By Dansk Supermarked were Incineration and Animal Feed (bread). By the end of 2013, Dansk Supermarked started to implement trials for biogasification food waste treatment, going towards their goal of 100% food wastage biogasification by the end of 2014. However, water and beverages are always directed to waste water treatment in every scenario.

What other food wastage scenarios could be used?

The other possible alternatives are 100% incineration, 100% composting and 100% for animal feed.

If there is more than one waste treatment scenario, what is/are the one(s) with more and least impacts?

From the waste treatment analysis, it was possible to rank them in following way (from fewer to more impacts):

1. 100 % incineration
2. Incineration plus animal feed
3. 100 % biogasification
4. 100 % animal feed
5. 100 % composting

Which food categories have more global warming potential regarding the food wastage treatment?

The major contributors are the Food preparations, the Dairy products and the Meat products pork. However, in a life cycle perspective, bovine meat is one of the major climate change contributors in the whole value chain.

10 – Reflections and Perspectives

10.1 – Reflections

Regarding the data collection, it was known from the kick-off meeting with Dansk Supermarked that the data regarding the transport and electricity would be necessary for data completeness. However, due to the workload the request for transport data information was sent in a late stage of the time frame available. Nevertheless, that data has not been provided by the project submission deadline.

Regarding the collected data about the food items, there is an upside and a downside. The upside is that, even with the data migration into SAP, all the food items sold in the supermarkets were practically covered Dansk Supermarked owns in Denmark, if not all of the food items. The downside is the amount of food items included (over 8.000) led to an extremely high amount of time to categorize them according to the Simapro I-O database. This time consumption, led by the data volume, was aggravated by the fact that our Danish language skills are currently limited. Therefore, additional time had to be invested for some product names translation into English.

Although this project's possible limitations, the project's objectives, the opportunity to collaborate with Dansk Supermarked and the inputs from our supervisors made this thesis an intensive learning process for the report authors. An example of this is that it was learned not only how to start working with a life cycle assessment framework, but also with a sustainability tool such as Simapro.

Finally, it is true that the provided results have some inherent uncertainties, and it is true that this project was done by two Master's Degree students who are starting to do this kind of projects. Nevertheless, it is hoped that this project may help to reduce the lack of data and studies for the food retail sector, as referred in the literature review.

10.2 – Perspectives

Regarding Dansk Supermarked and the work done in this project, there is a small set of future perspectives that can be presented:

1. After the full data migration into SAP, it would be interesting to update the collected data and include the capital goods and transportation related data, to mitigate uncertainty associated effects.
2. It would also be interesting to make a food wastage monthly account. This means to get the results retrieved in this report for every month of the year, in order to know the GHG emissions evolution along the year.
3. Regardless of the monthly carbon footprint stated in point 2, it would also be interesting to do an annual Dansk Supermarked Carbon Footprint (annual mass flows instead of just February 2014).

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12 – Annexes

Annex 1 – Calculations

For each food item

$$Waste\ (kg) = Netweight \times Scrapping\_Pcs$$

$$Total\ Food\ Input\ (kg) = \frac{Waste\ (kg) \times 100}{Scrapping\_Percentage}$$

$$Sales\ (kg) = Total\ Food\ Input - Waste\ (kg)$$

$$Sales\ Share\ (\%) = \begin{cases} 1 - Waste\ share\ (\%) \\ or \\ 100 - Waste\ share\ (\%) \end{cases}$$

For each category totals

$$category\ Waste\ (kg) = sum\ of\ the\ waste\ of\ all\ the\ products\ on\ that\ category$$

$$Waste\ share\ (\%) = \left(\frac{category\ waste\ (kg)}{category\ \ Total\ Food\ Input\ (kg)}\right) \times 100$$

$$category\ Total\ Food\ Input\ (kg) = sum\ of\ the\ Total\ Food\ Input\ of\ all\ the\ products\ on\ that\ category$$

$$category\ Sales\ (Kg) = \ category\ Total\ Food\ Input - \ category\ Waste\ (kg)$$

$$category\ Sales\ Share\ (\%) = \left(\frac{category\ Sales\ (Kg)}{category\ \ Total\ Food\ Input\ (kg)}\right) \times 100$$

Annex 2 – Dry Matter content

The dry matter values used in this project are presented in the following table. The food items without source in the table are based on Merciai and Schmidt (2012).

Input Categories	% of dry matter
Poultry and animals n.e.c.	Poultry (30%) Eggs (26%) http://urbanext.illinois.edu/eggs/res16-egg.html Meat animal's n.e.c. (43%)
Grain crops, DK	Paddy rice (85%) Wheat (86%) Cereal grains n.e.c. (85.5%) Oil seeds (91.5%) Processed rice (0.85%)
Potatoes, DK	Raw Potatoes (20,2%) http://wholefoodcatalog.info/food/potatoe(tuber,_raw)/ Fried potatoes (47.1%) http://wholefoodcatalog.info/food/potatoe(fried_potato)/ Chip potatoes (98%) http://wholefoodcatalog.info/food/potato_chip(regular)/
Horticulture, orchards, etc, DK	Vegetables, fruit, nuts (18%) Plant-based fibres (92.5%) Crops n.e.c. (21.1%) Mushrooms raw (6.1%) http://wholefoodcatalog.info/food/common_mushroom(raw)/
Forest products	Products of forestry, logging and related services (48.7%)
Meat products, Pork	Products of meat, pigs (58.9%)
Meat products, Bovine	Products of meat, cattle (39.4%)
Meat products, Poultry and meat n.e.c.	Animal products n.e.c. (73.7%) Products of meat poultry (25%)
Meat products, Fish	Meat products n.e.c. (65%) Fish products (20%)
Dairy products	Dairy products (54.3%) Butter (84%) http://www.webexhibits.org/butter/composition.html
Fruits and vegetables, processed	Vegetables, fruit, nuts (18%) Mushrooms canned (8%) http://wholefoodcatalog.info/food/common_mushroom(canned_in_brine,_solids)/
Vegetable and animal oils and fats	Products of animals, oils and fats (100%) Products of Vegetable oils and fats (100%)
Flour	Flour "wheat" (86.5%) http://wholefoodcatalog.info/food/buckwheat_flour(straight)/
Sugar	Sugar cane, sugar beet (25%) Sugar (99%) Honey (75%) http://www.beesource.com/resources/usda/honey-composition-and-properties/
Food preparations n.e.c.,	Food products n.e.c (67%) Bread "white table" (62%) http://wholefoodcatalog.info/food/white_table_bread/
Beverages	Beverages (100%)
Tobacco products	Tobacco products (80%)
Chemicals n.e.c.,	Chemicals n.e.c. (100%)

Annex 3 – Process Networks

2013 Baseline Scenario – Incineration and Bread for Animal feed

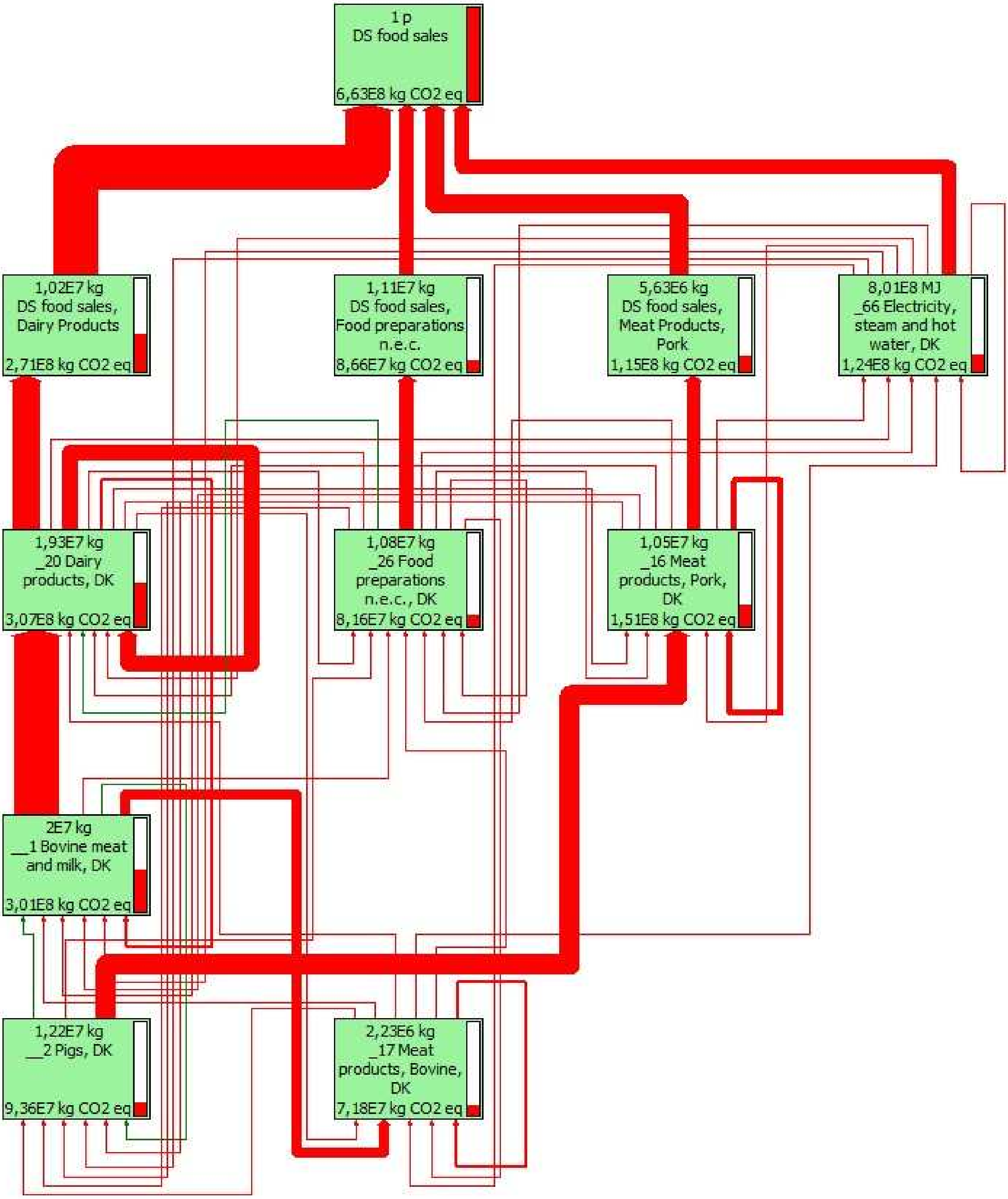

Figure 1 – Supply to Retail Process Network

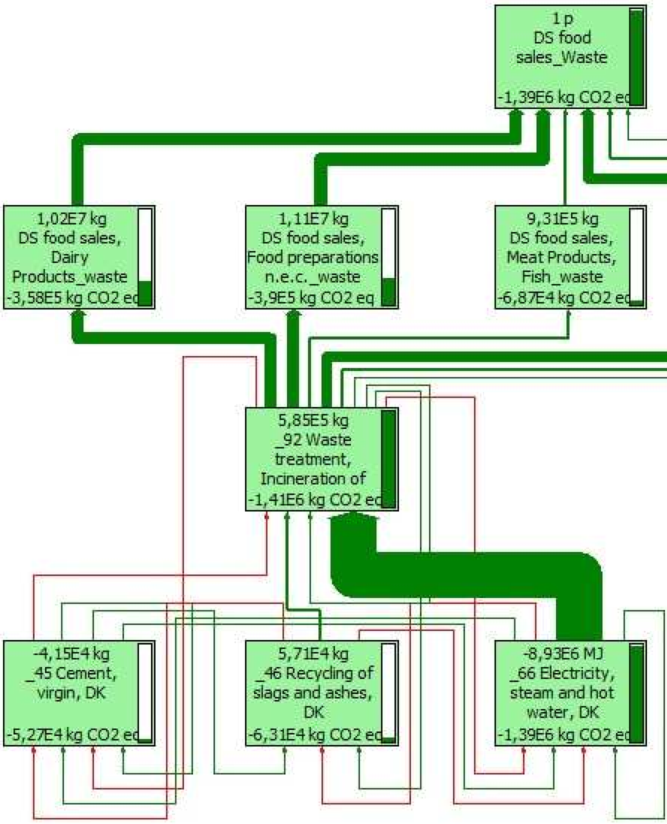

Figure 2 – Retail Waste Treatment Fraction Process Network

2014 Scenario – 100% Biogasification

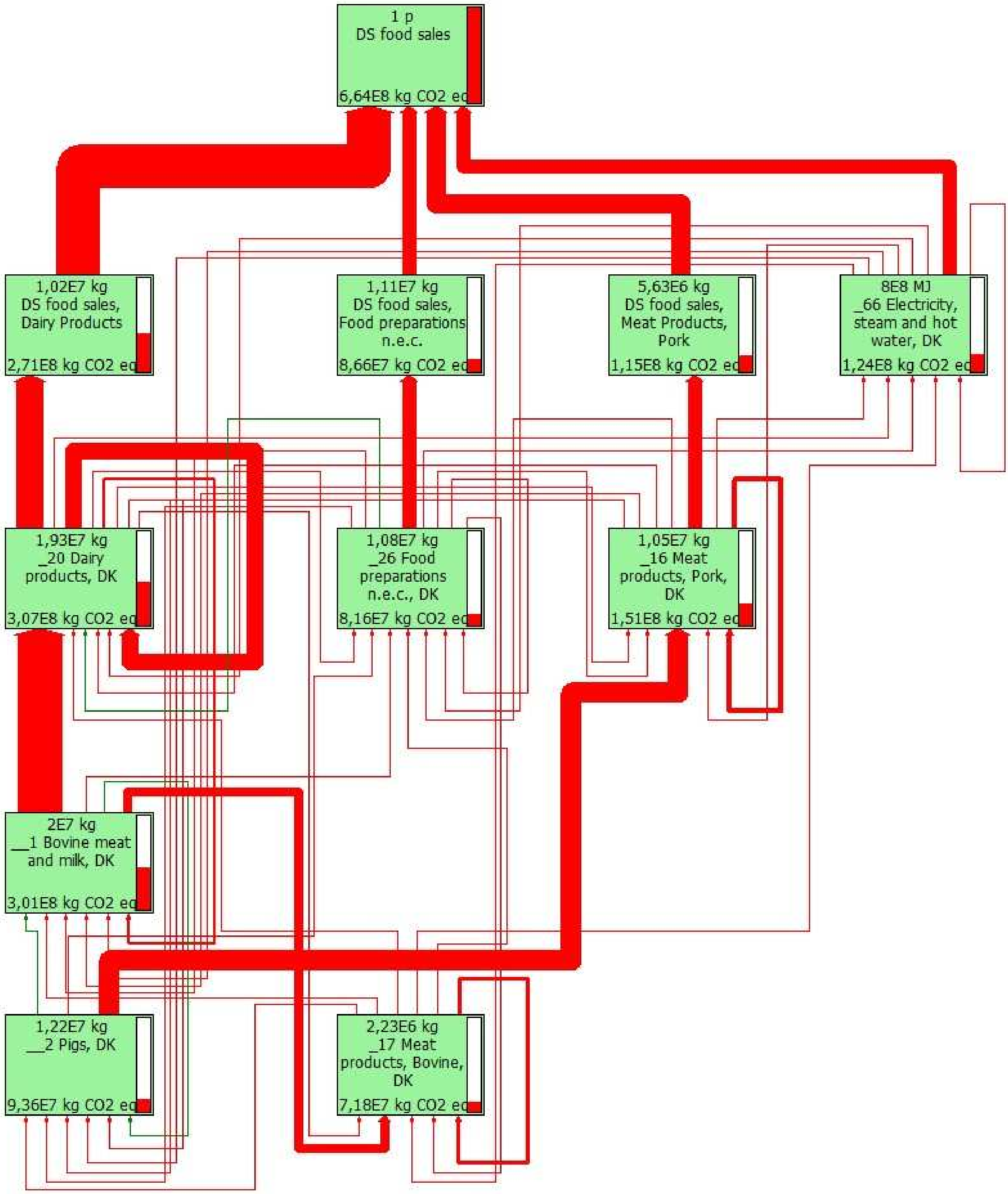

Figure 3 – Supply to Retail Process Network

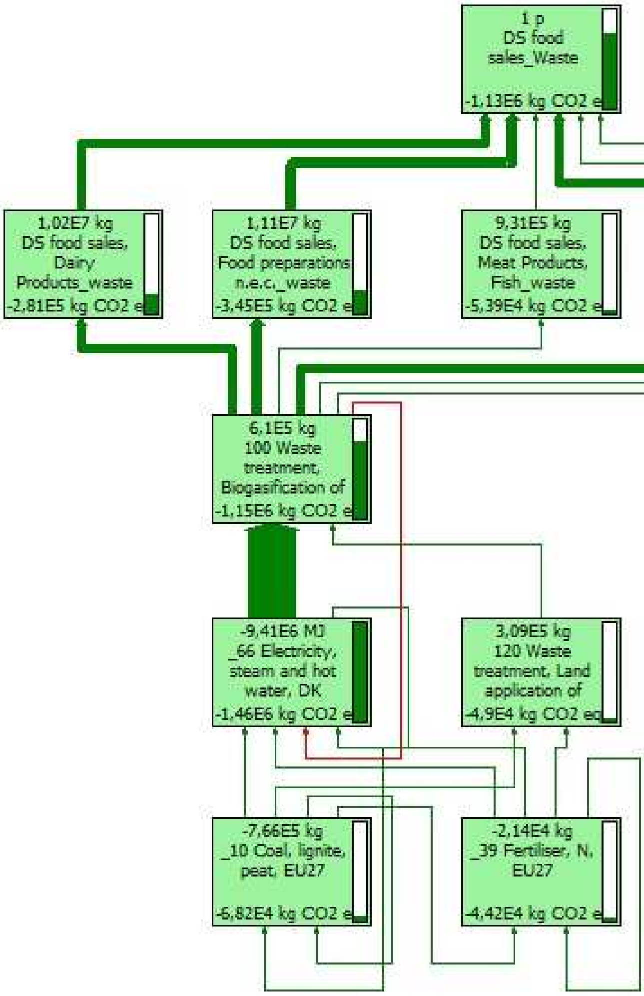

Figure 4 –Retail Waste Treatment Fraction Process Network

100% Composting Alternative Scenario

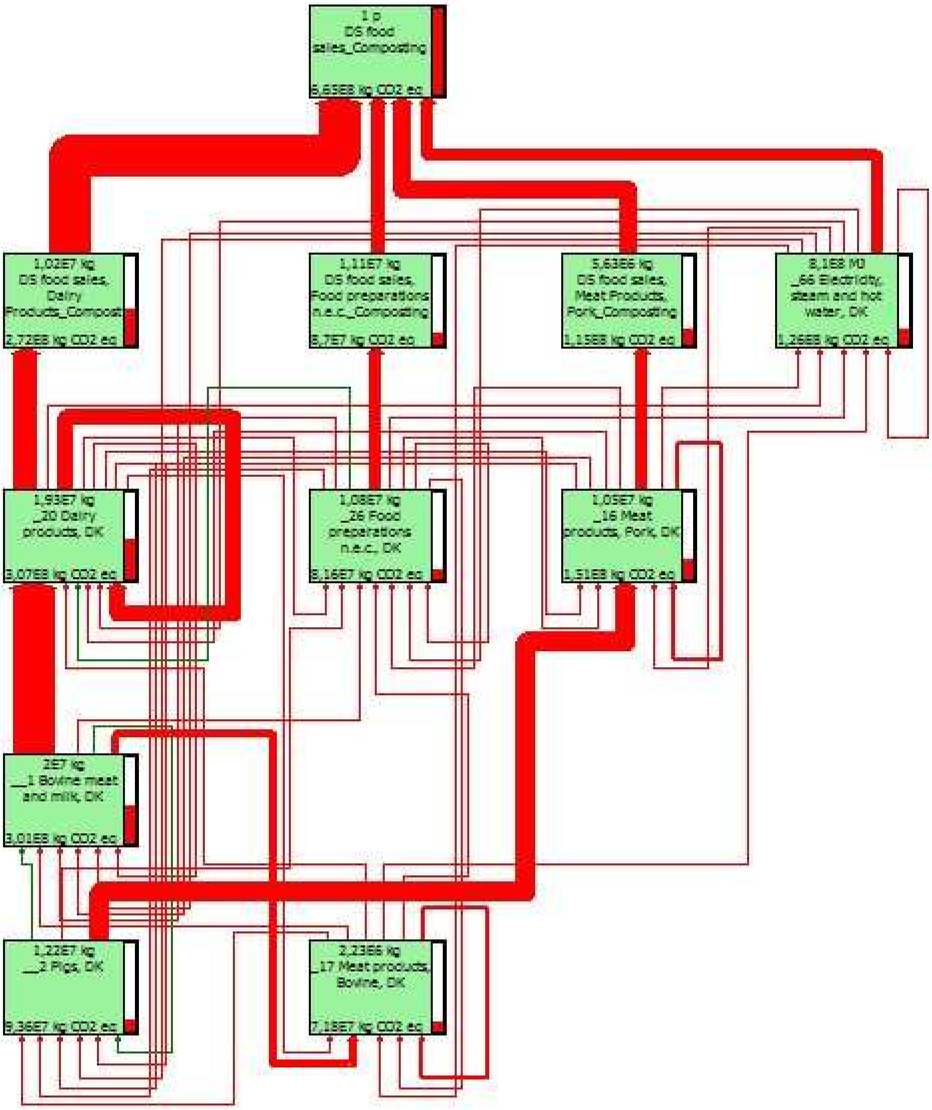

Figure 5 – Supply to Retail Process Network

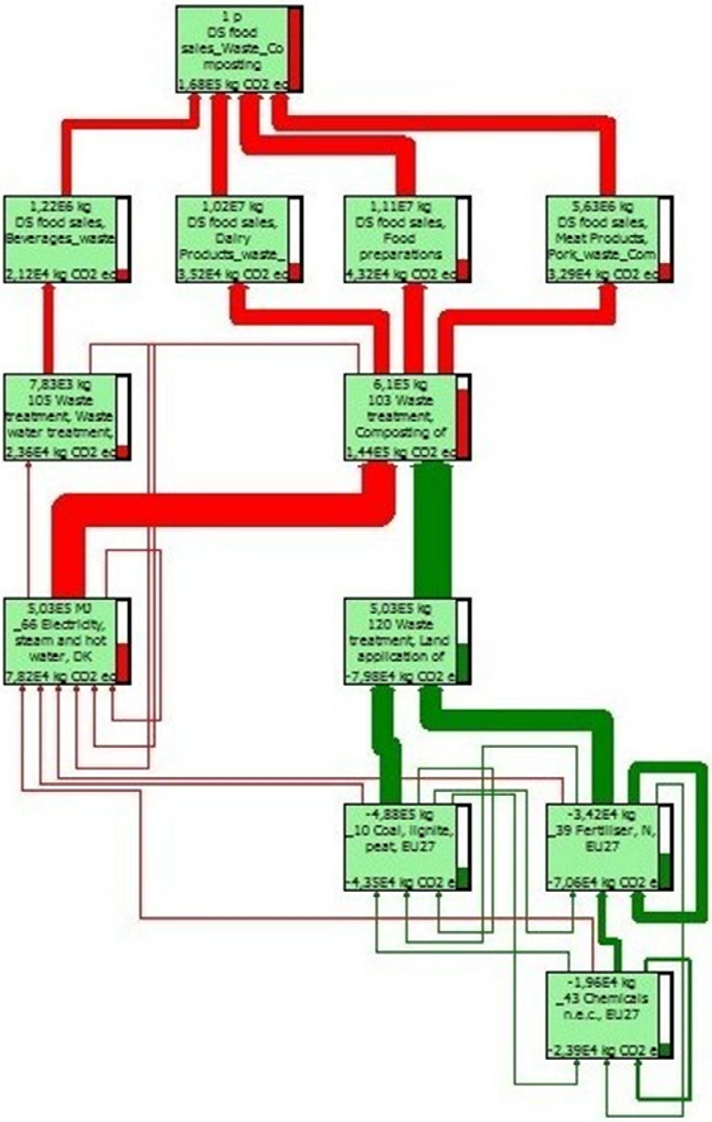

Figure 6 – Waste Treatment Fraction Process Network

100% Incineration Alternative Scenario

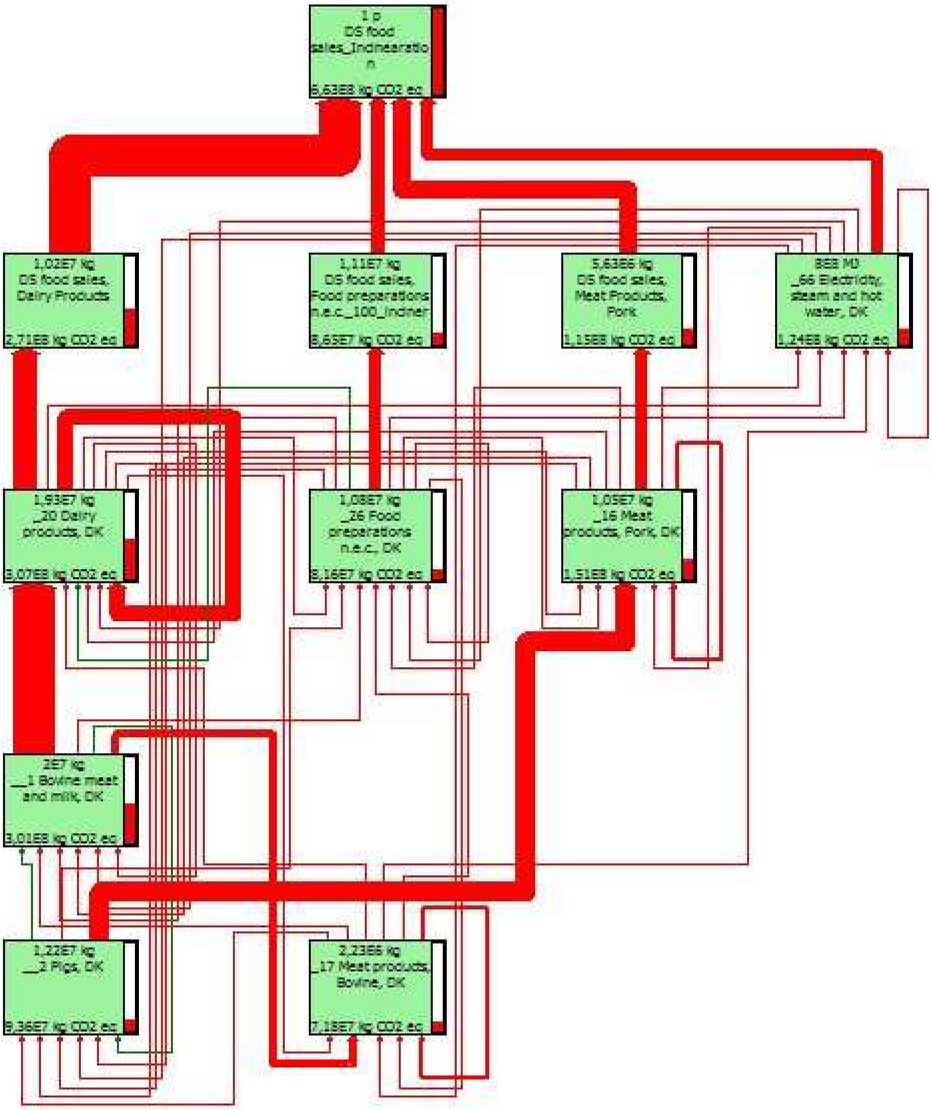

Figure 7 – Supply to Retail Process Network

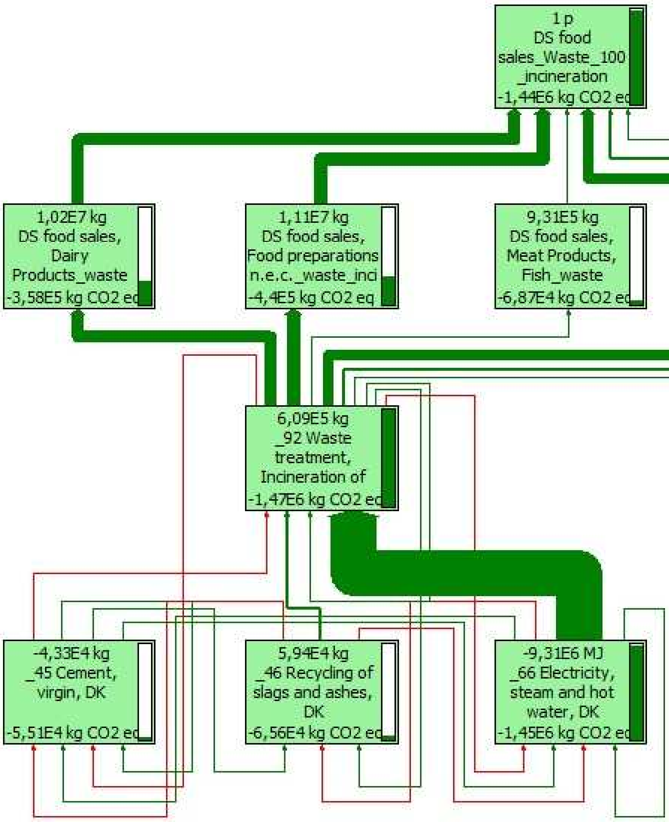

Figure 8 - Retail Waste Treatment Fraction Process Network

100% Animal Feed Alternative Scenario

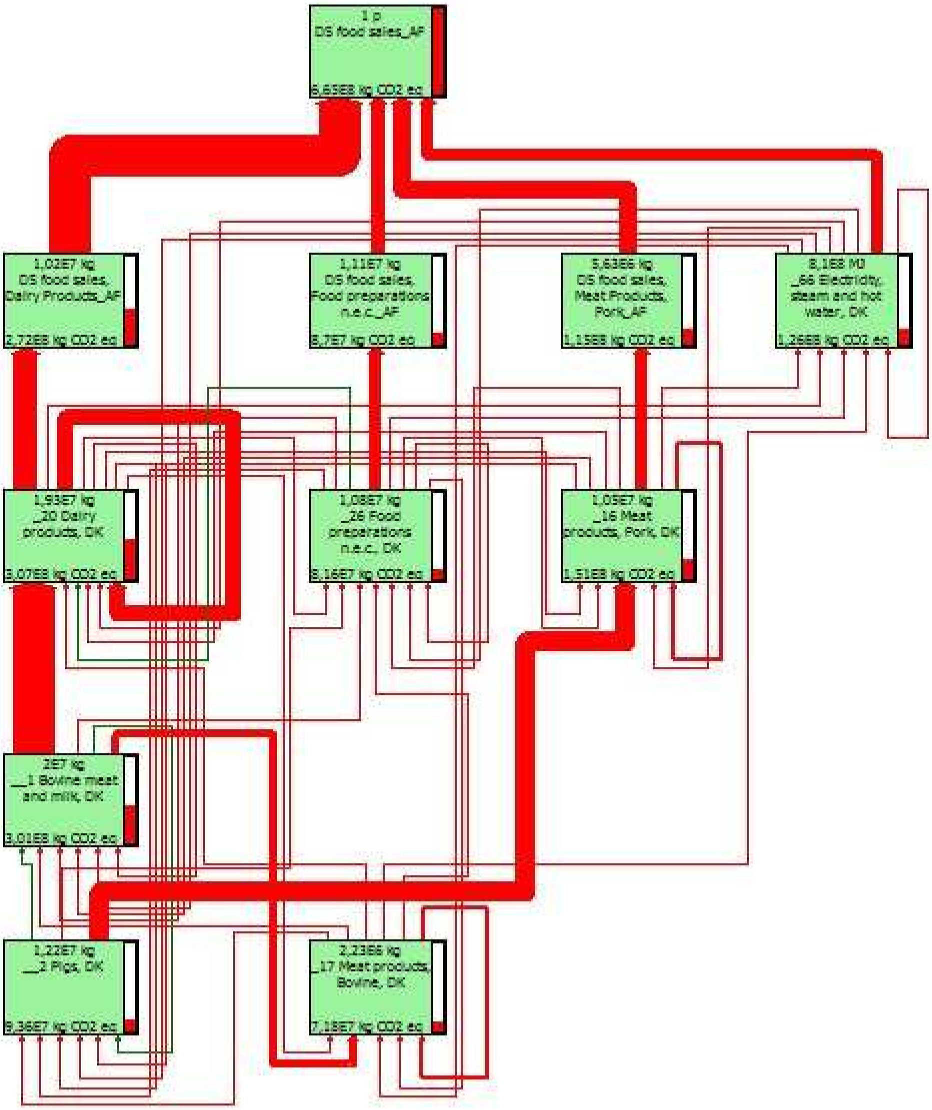

Figure 9 – Supply to Retail Process Network

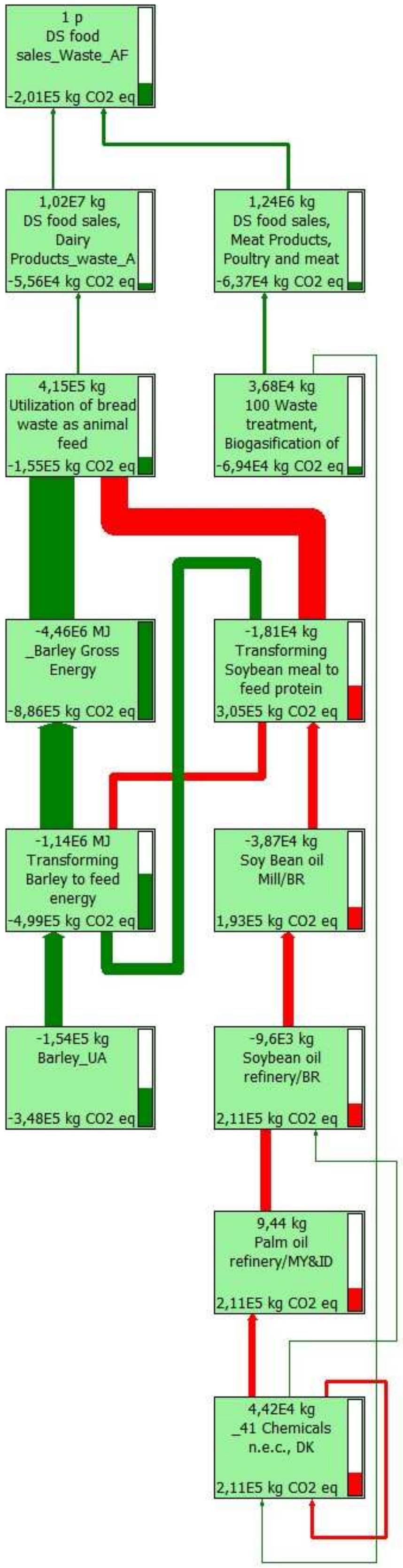

Figure 10 –Retail Waste Fraction Process Network