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Interventions for successful recycling of nutrients and energy from food waste

How can Swedish municipalities overcome barriers for a sustainable food waste management system?

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In my opinion, a thesis is the final assignment before leaving a secure place (your university) and throwing yourself out into the unknown. If you are lucky, your professors and colleagues have prepared you for the many challenges to come. This last year at the IIIEE has been a long, and sometimes hard, preparation for life post the Masters programme. There has been lots of laughter, practical assignments (even including Play-Doh) and paper writing. Long nights at the library, weekends full of exam preparations and endless memorising of acronyms. Who needs to know what CBA, LCA, PPP, PSS, EMS, B2B, B2C etc. is anyway?? ☺
In all seriousness, this last year at the Masters programme in Environmental Management and Policy has been one of the best years in my life, and I could not feel more prepared professionally, or personally, for what life has to offer me as a graduate.

My classmates in batch 16 (without a doubt the best batch ever) have been the greatest support and have offered the best friendship (and thanks to Lucas the most awesome parties) anyone can ever ask for. I have made friends for life, and I cannot wait to go see you all over the world. Waka Waka to all of you!

With these words I finalise my thesis, and turn the page to the next chapter in my life. But before that, let us have a legendary graduation!

Caroline Steinwig

A sunny day in Lund September, 2011

Abstract

One of the interim targets in the Swedish national Good Built Environment objective states that biological treatment of source separated food waste should be a priority. The goal of biologically treating 35 percent of all municipal food waste in 2010 was not achieved, and a proposed target for 2015 raises the bar even further (40 percent). The way the proposed milestone target is phrased excludes composting as a treatment option by stating that nutrients *and* energy from food waste should be utilised, a requirement satisfied by anaerobic digestion (biogas production). This study assesses barriers experienced by municipalities and other waste actors in terms of implementing food waste collection systems. By interviewing a rather large sample of municipalities, waste companies and waste/biogas experts, and by organising the findings by help of an analytical framework, suggestions for policy interventions have been made. The study concludes that the national government must announce a clear vision for biogas production by including a measurable target, along with other policies like continued tax exemptions on biogas (used as vehicle fuel) and investment grants to support the production and demand for biogas. Successful biogas production paves the way for increased food waste collection. A tax on incineration of food waste should be introduced to make anaerobic digestion more attractive. Municipalities should collaborate more across borders as well as with other actors for knowledge sharing and to help raise investment funding. Finally, a mixture of policy instruments such as including food waste collection in the municipal waste disposal plan (administrative instrument), using environmentally differentiated waste charges as financial incentives (economic instrument) and assessing information activities (informative instrument) comprehensively forms the base of a successful policy intervention on the local level.

Keywords: food waste management, anaerobic digestion, biogas production, policy instruments, Sweden

Executive Summary

According to the revised Waste Framework Directive[1] (WFD) the definition of waste is "any substance or object which the holder discards or intends or is required to discard" (Article 3.1). Waste in the broad sense is something that is generated in all ecosystems. However, what makes nature different from the anthropogenic ecosystem is its ability to recycle all waste products back into a closed-loop, sometimes called an ecocycle.

In Sweden alone, 4.4 million tonnes of municipal solid waste (MSW) were generated in 2010. Reducing these amounts is a goal within the European Union (EU) as well as in Sweden, but so far the main focus has been on treating waste in a sound manner. Sweden being a well developed country with a history and tradition of working with sustainable waste management has stepped away from landfilling and chosen more to rely on incineration and recycling (Avfall Sverige, 2011h).

The three main ways to dispose of organic waste such as food waste are incineration, landfilling and biological treatment. Incinerating food waste makes it possible to use the embedded energy as heat and/or power, but no nutrients from the waste is recovered. When landfilling food waste, a process takes place inside the landfill where there is a lack of oxygen (anaerobic conditions), which breaks down the organic material and methane gas is generated. Landfills that are lacking a proper gas collection system can be major contributors of methane gas, and methane being a much more potent greenhouse gas than carbon dioxide makes this a problem (Berglund, 2006). In a Swedish context biological treatment of source separated food waste comprises two main ways of treatment. The first being composting and the second being anaerobic digestion (AD). Both methods utilise the nutrients in the waste, however, AD also allows for a recovery of the energy through the methane gas produced during the process. The gas produced in AD is referred to as biogas.

In 1999 a series of environmental quality objectives were introduced by the Parliament. The issue of waste is referred to mainly in the Good Built Environment objective, and one of the interim targets concerns municipal and comparable food waste from restaurants, canteens and the like (here forth referred to simply as food waste or municipal food waste[2]). The interim target for food waste was established in 2002 and it states that 35 percent of the source separated food waste should be treated biologically by 2010 (Environmental Objectives Portal, 2011). However, in 2010 merely 25 percent of the food waste undertook biological treatment (Avfall Sverige, 2011b).

An All-Party Committee has proposed a new milestone target. The full wording (in translation to English) is shown below (All-Party Committee for environmental objectives, 2011, p. 118);

> *Resource efficiency in the food chain increases to 2015 by:*
> *- At least 40% of the food waste from households, canteens, retails premises and restaurants is treated biologically so that the nutrients and energy can be utilised.*

[1] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

[2] In this study municipal food waste is defined as food waste from households as well as commercial, industrial and institutional waste, which because of its nature and composition is similar to waste from households (based on the definition of mixed municipal waste as found in Art. 3.3 of the Directive 2000/76/EC on the incineration of waste).

The objective of this study is to contribute with information and suggestions for how to increase the proportion of food waste treated biologically, with the goal of producing biogas (utilising both energy and nutrients).

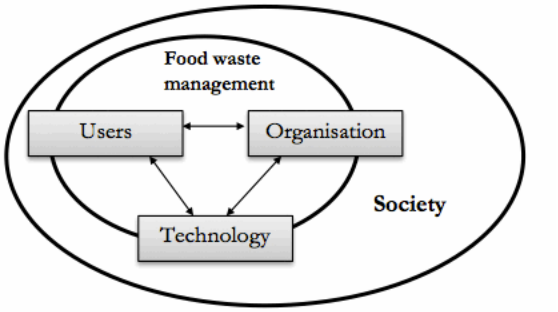
Based on the objective the following research questions served as guidance.

(1) What are the barriers experienced by Swedish municipalities in terms of increasing treatment of food waste biologically, and specifically using anaerobic digestion?

(2) How can the Swedish municipalities be supported in overcoming the identified barriers on (a) a national level and (b) on a local level?

Primary data was collected by interviewing a rather large sample of municipalities[3], waste companies and other actors in waste management, regarding their experiences and reflections on food waste management systems. The findings were organised using an analytical framework. The task also included literature analysis for identifying and suggesting appropriate policy instruments and interventions that could help municipalities overcome the barriers identified by the interviewees. Semi-structured interviews with mostly open-ended questions served as the base for conducting data collection.

The analytical framework used to organise the findings was based on Söderberg and Åberg (2002). The framework was originally developed for assessing urban water systems, but has been used in a study on organic household waste by Refsgaard and Magnussen (2009).



As shown in the figure on the right hand side the three sub-systems *users*, *organisation* and *technology* interact in the food waste management system. Barriers in one of the sub-systems will mutually affect the system as a whole.

Users include residents living in single-family households and multi-family complexes, as well as, business-owners, employees and others responsible for sorting out food waste in available food waste collection systems.

The *organisational* sub-system encompasses the formal structures of the food waste management system such as division of responsibility, decision on collection system and treatment method, collaboration with other municipalities and actors, size and design of waste collection charges as well as rules laid down in the waste plan and waste disposal plan.

The *technological* sub-system comprises physical structures such as the collection system, collection vehicles, containers and treatment plants.

From the literature three types of environmental policy instruments (EPIs) were derived; administrative, economic and informative EPIs. Administrative EPIs are imposed through legislation, examples including permits and emission standards. Taxes, subsidies and the like are examples of economic EPIs, and informative EPIs often include education and information spreading via e.g. public campaigns.

[3] Both municipalities with and without a food waste collection system were interviewed.

The findings show that there is no one-size-fits-all solution to the problem of overcoming barriers and achieving the proposed environmental objective regarding food waste. Measures and policy interventions need to be custom-made for each of the identified regions, and local governments (municipalities) need to focus on the specific problem at hand in their area. It also becomes clear that putting full focus on one of the sub-systems (users, organisation, technology) would not be wise. However, waste education in schools, which already occurs to some extent, is an excellent opportunity to teach our young ones about the unique case of biogas; a renewable form of energy, produced from waste products, such as our food leftovers, which can power our buses and cars and help grow new food.

No general conclusions, except in a few cases, have been possible to be drawn in terms of pointing out specific barriers to specific geographical regions of Sweden. As expected population density, distances and climatic aspects are the prevailing barriers in the most northern parts of Sweden. Since the greatest potentials for biogas production exists in the southern parts of Sweden, most efforts towards food waste collection and AD should be made in those areas. In terms of biogas production, most is produced in the aforementioned regions but in general these regions are falling behind when it comes to collecting food waste from households and establishments.

Most drivers and barriers identified in this study are caused by policies decided nationally or locally.

National government

Policies affecting biogas production per se, also affects municipal food waste collection. Hence, the national government needs to make a long-term decision regarding biogas, including a measurable target for biogas production. Furthermore, biogas used as vehicle fuel should remain exempted from taxes[4] in order to be competitive with fossil-based fuels[5]. More efforts on research regarding bio-fertiliser (digestion residue from the AD process) are needed to securely recycle nutrients in food waste back on arable land. A tax on incineration of food waste should be introduced to make biological treatment less costly (in relative terms), along with investment grants to help support construction of biogas plants. Finally, setting up networks for collaboration and knowledge sharing should be assigned to competent authorities along with coordination of public information campaigns in order to support municipalities and easing the burden of their cost.

Local government

Knowledge sharing and collaboration in order to raise investment funding and assimilating sufficient food waste volumes for AD are key elements for increased utilisation of energy and nutrients from food waste. Informing the users (residents) on how to source separate food waste, along with supplying feedback information and economic incentives are crucial for upholding a good quality of the collected food waste volumes since contamination (poor quality) can cause major implications downstream in biogas production. Finally, a mixture of policy instruments such as including food waste collection in the municipal waste disposal plan (Administrative EPI), using environmentally differentiated waste charges as financial incentives (economic EPI) and assessing information activities (informative EPI) comprehensively forms the base of a successful policy intervention.

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[4] Value Added tax (VAT) obviously excluded in the tax exemptions.

[5] Fossil-based fuels are subject to energy and CO_2-taxes in Sweden.

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Abbreviations

AD	Anaerobic digestion
BMW	Biodegradable Municipal Waste
CAC	Command-and-Control
CHP	Combined Heat and Power
CO_2	Carbon dioxide
EC	European Commission
EEA	European Environment Agency
EEG	Erneuerbare-Energien-Gesetz - Renewable Energy Sources Act
ELV	End-of-Life Vehicles
EPA	Environmental Protection Agency
EPI	Environmental Policy Instrument
EPR	Extended Producer Responsibility
EU	European Union
GHG	Greenhouse gas
KLIMP	Klimatinvesterings Programmet – Climate Investment Programme
LBG	Liquefied biogas
MSW	Municipal Solid Waste
NGO	Non-governmental organisation
VAT	Value added tax
WEEE	Waste Electrical and Electronic Equipment
WFD	Waste Framework Directive
WWTP	Wastewater treatment plant

1 Introduction

1.1 Background

According to the revised Waste Framework Directive[6] (WFD) the definition of waste is "any substance or object which the holder discards or intends or is required to discard" (Article 3.1). Waste in the broad sense is something that is generated in all ecosystems. However, what makes nature different from the anthropogenic ecosystem is its ability to recycle all waste products back into a closed-loop, sometimes called an ecocycle.

In the manmade society there is a strong link between consumption and waste generation. As a result of this the amounts of waste have steadily grown, especially in the western part of the world where the richest part of the global population is continuing to increase their affluence.

In Sweden alone, 4.4 million tonnes of municipal solid waste (MSW) were generated in 2010. Reducing these amounts is a goal within the European Union (EU) as well as in Sweden, but so far the main focus has been on treating waste in a sound manner. Sweden being a well developed country with a history and tradition of working with sustainable waste management has stepped away from landfilling and chosen more to rely on incineration and recycling (Avfall Sverige, 2011h). Waste can, however, be viewed as a resource that can be used to replace virgin raw material.

The organic fraction of MSW in general, and municipal food waste in particular, is an interesting category of waste. Organic MSW, sometimes also called bio-waste, encompasses a great variety of waste such as green garden waste, waste from restaurants and light businesses as well as food such as peels and shells from private homes. Life cycle studies show that as much as 170 million tonnes of carbon dioxide (CO_2) equivalents are being emitted annually due to food that ends up as waste (European Commission, 2010, p. 15).

There are three main ways to dispose of organic waste; incineration, landfilling and biological treatment. Incinerating organic waste makes it possible to use the embedded energy as heat and/or power, but no nutrients from the waste is recovered. When landfilling organic waste, a process takes place inside the landfill where there is a lack of oxygen (anaerobic conditions), which breaks down the organic material and methane gas is generated. Landfills that are lacking a proper gas collection system can be major contributors of methane gas, and methane being a much more potent greenhouse gas (GHG) than CO_2 makes this a problem (Berglund, 2006). In a Swedish context biological treatment of source separated organic waste comprises two main ways of treatment. The first being composting and the second being anaerobic digestion (AD). Both methods utilise the nutrients in the waste, however, AD also allows for a recovery of the energy through the methane gas produced during the process. The gas produced in AD is referred to as biogas.

In waste management, preventing the generation of waste is the first and foremost desired goal for all waste fractions. "Prevention is better than cure", however bearing that in mind strategies, policies and technologies for sustainable means of waste treatment still remains an uttermost necessity. In management of food waste, biological treatment is the only available treatment method that allows for recycling of the embedded nutrients (and energy) back into

[6] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

a closed loop stretching from production to consumption (Tojo, Alexander, & Ingo, 2008). This form of closed-loop recycling is very important for upholding the nutritional balance in society, where we are currently importing almost all food to the cities from rural production areas.

Households having a separate collection system for food waste have shown to generate less residual waste on average. This is a positive rebound effect of the food waste collection system (Avfall Sverige, 2011f; European Commission, 2010). Arguably, improving collection and increasing the biological treatment of municipal food waste can be beneficial both in terms of prevention and recycling of waste.

1.2 Problem definition and justification

In 1999 the Swedish Parliament introduced a series of environmental quality objectives that aim to reflect what state Sweden wants its environment to be in. The issue of waste is referred to mainly in the Good Built Environment objective, and one of the interim targets concerns municipal and comparable food waste from restaurants, canteens and the like (here forth referred to simply as food waste or municipal food waste[7]). The interim target for food waste was established in 2002 and the full wording is found below (Environmental Objectives Portal, 2011).

> *By 2010 at least 35% of food waste from households, restaurants, caterers and retail premises will be recovered by means of biological treatment. This target relates to food waste separated at source for both home composting and centralised treatment.*

However, in 2010 not more than approximately 25 percent of the food waste was biologically treated and hence the 2010 target was not achieved (Avfall Sverige, 2011b).

In July 2010 the government assigned an All-Party Committee with the objective to develop proposals for future milestone targets as well as suggestions for strategies and policy instruments that will help guiding the environmental work towards achieving those targets. The committee includes members of the Parliament as well as experts and advisors in various areas, and the idea is to work in close co-operation with municipalities, business representatives and NGOs. In March 2011 the committee issued an official government report (*SOU* in Swedish) with their suggestions for future targets. The previous term *interim target* is replaced by *milestone target*, indicating that it is a step along the way to achieving the environmental objective and generational goal (All-Party Committee for environmental objectives, 2011; Swedish Environmental Protection Agency, 2011n).

The proposal for next milestone target is 2015 and the suggested share of food waste that should be biologically treated by that year is 40 percent nationally. The phrasing of the proposed 2015 target is such that only food waste undergoing AD as means of treatment will be counted towards the 40 percent share. This is because AD is the only treatment method utilising both nutrients and energy from food waste (All-Party Committee for environmental objectives, 2011). A translation of the milestone target suggested by the advisory committee regarding biological treatment of food waste is shown below (All-Party Committee for

[7] In this study municipal food waste is defined as food waste from households as well as commercial, industrial and institutional waste, which because of its nature and composition is similar to waste from households (based on the definition of mixed municipal waste as found in Art. 3.3 of the Directive 2000/76/EC on the incineration of waste).

environmental objectives, 2011, p. 118).

> *Resource efficiency in the food chain increases to 2015 by:*
> *- At least 40% of the food waste from households, canteens, retails premises and restaurants is treated biologically so that the nutrients and energy can be utilised.*

Recycling, in this case the nutrients and energy in food waste, is high on the EU and, consequently, Swedish waste agenda. The proposed milestone target for food waste is raising the bar even higher and pushing for an increase in biological treatment of food waste, in particular by AD. On account of the fact that the previous 2010 interim target was not achieved, there is a need for evaluating how to proceed towards the 2015 milestone target.

1.3 Objective and research questions

The objective of this study is to contribute with information and suggestions for how to increase the proportion of food waste treated biologically, with the goal of producing biogas. MSW is an area of extensive research, but food waste collection systems, and in particular barriers pertaining to implementing and running these systems, have not been given much attention. It is obvious that there are obstacles hindering the roll-out of separate food waste management since only a fourth of all generated food waste was collected and treated biologically in 2010. By conducting research focusing on the experiences by Swedish municipalities and other waste actors, I am hoping to provide decision-makers with a topical picture of the major barriers of managing source separation of food waste. Finally, I am hoping to contribute with useful suggestions for how decision-makers on various levels can help support municipalities towards achieving increased food waste collection and treatment.

Based on the objective, as stated above, the following research questions have been posed and will serve as guidance in my work.

(1) What are the barriers experienced by Swedish municipalities in terms of increasing treatment of food waste biologically, and specifically using anaerobic digestion?

(2) How can the Swedish municipalities be supported in overcoming the identified barriers on (a) a national level and (b) on a local level?

1.4 Focus and delimitations

The focus of this paper is municipal food waste collection and biological treatment, in particular anaerobic digestion, within Sweden. The phrasing of the proposed milestone target clearly points out AD as the form of biological treatment preferred by the national policy-makers. Although there are several positive aspects regarding composting, among others the lesser costs associated with building a composting facility, AD has other superior advantages. Apart from utilisation of *both* nutrients and energy, AD also causes substantially lower net emissions of GHG compared to composting. In fact, a recently issued report by the European Environmental Agency (EEA) claims that AD of all the MSW that was composted during 2008 in the EU would have caused negative net emissions of 2 million tonnes of CO_2-equivalents (European Environment Agency, 2011, p. 8). It thus seems reasonable to focus primarily on AD.

Primary data will be collected through interviews. It will not be possible to speak to all municipalities and/or waste companies in Sweden, hence samples must be taken to get a good representation and a good overview of the current situation.

Before the start of this study, a set of delimitations has been decided on in order to produce a relevant, yet feasible thesis. These delimitations are discussed below.

Firstly, during this study I will not look into whether or not it is environmentally beneficial to collect and treat food waste separately as opposed to other actions. I have not come across any evidence in the literature suggesting otherwise.

There is an ongoing discussion regarding who should have the responsibility of managing food waste generated in businesses such as retailers and restaurants. According to the Environmental Code[8] municipalities have the responsibility for MSW (which includes comparable food waste), but the definition of what is *comparable food waste* is not clear. Whilst this debate certainly is interesting, I have chosen not to investigate what is the best approach to the problem from an environmental and/or economic perspective. Food waste from the processing industry, on the contrary, is *not* part of the municipal responsibility. There is a separate interim target set up for this waste fraction, and the implications regarding this type of food waste are very different from municipal food waste.

Further on, other types of organic waste, such as manure and agricultural waste, will not be included in the scope of this study. These substrates are important for increasing the production of biogas, but widening the focus to include actors in this area would most likely not add information relevant to the objective of the study.

Sewerage sludge is also excluded from the focus of this study. The All-Party Committee has proposed a milestone target for recycling of phosphorous from sewerage sludge back to arable land. However, there are many implications concerning using this type of sludge as fertiliser and assessing these effects would in itself be a topic of full-scale research.

Although setting up a functioning AD plant is a large investment, it is assumed that the technique as such is not a barrier. Through literature, as well as communication with academics and actors within the waste area, I understand that AD technology is well developed, with obvious room for improvement, but I have not phrased my questions so to include discussions on whether or not the AD technology is good enough when approaching my interviewees.

Finally, a thesis, like most studies, is constrained by its time frame. Municipalities, waste companies, waste experts and a limited number of lobby groups (industry associations) were selected as primary interview objects in order to make best use of the time set aside for this research. Municipalities and publically owned waste companies have been the predominant target for information collection. Although this approach of excluding major government authorities and political groups carries a risk of missing out of certain information, it was deemed more valuable to focus on those interviewees that are most likely to express less politically-influenced views.

[8] 1998:808 The Swedish Environmental Code.

1.5 Intended audience

The outcome of this research is intended to support and guide policy makers, on local as well as national level, in their decisions on improving the waste management system for municipal food waste. While the scale of this work makes it necessary to generalise, not fully taking into account local circumstances, the report can very well still be used as a starting point for analysing a particular municipality's situation.

My hopes are that this research also will serve as an inspiration for other students wanting to learn more about the barriers of municipal food waste management in Sweden or potentially developing the topic further in future thesis work.

1.6 Thesis outline

Chapter 1 introduces the reader to the topic of this thesis and the research problem. The objective and the research questions, which are intended to guide the work towards the objective, as well as the focus and delimitations are also found in this initial chapter. Finally the intended audience is identified.

Chapter 2 describes the methodology used for the collection and organisation of data. The theory behind qualitative interviewing technique and the analytical framework used to structure the analysis are described in further detail.

In **Chapter 3** a synthesis of the existing literature in the area of waste management, particularly municipal food waste management and AD is presented to help the reader(s) get acquainted with the topic. Subjects such as the Swedish waste management system, food waste policy and management in the EU and Sweden as well as an introduction to environmental policy instruments are accounted for in this chapter.

Chapter 4 presents the findings from the collection of primary data.

Chapter 5 includes the analysis and discussion of the findings presented in Chapter 4 as well as reflections from the literature analysis in Chapter 3.

Finally, **Chapter 6** summarises the discussions and conclusions drawn from the findings and analysis. Suggestions for further research finalises this thesis.

2 Research Methodology

2.1 Background

There seems to be a lack of knowledge concerning why the Swedish municipalities, collectively, did not reach the 2010 national food waste target. However, rather than attempting to understand why the target was not reached this study focuses on what barriers need to be overcome and how policy instruments and policy interventions can be applied on a national as well as local level to accomplish future targets proposed.

Bearing the purpose of the study and the research questions in mind one can argue that there are two tasks in this research. Firstly, there is a need to collect primary data from relevant actors in order to understand what barriers are met in various regions of Sweden. This task will primarily be carried out through qualitative research interviews as described in Section 2.2 below.

The second task is to identify and suggest appropriate policy instruments and interventions that can help municipalities overcome the barriers identified by the interviewees. This part of the study includes, inter alia, literature analysis to learn about various types of policy instruments as well as utilising the reflections and experiences collected during interviews.

The findings from the interviews will be organised using an analytical framework (see Section 2.3 below) to help build structure and clarity to the analysis.

When searching for material to be used in the literature analysis part (Chapter 3), electronic databases constituted the primary source of information. Two academic databases, LibHub and EBSCO, were primarily used, as these are very inclusive and accessible via Lund University. The search queries were *organic waste policy*, *"organic waste" policy*, *"organic waste" Sweden*, *waste policy instruments*, *environmental policy instruments* and *environmental policy instruments waste*. The search engine Google was also used for searching of information relevant primarily to the environmental policy instrument chapter. The search queries used on Google were *environmental policy instruments OECD*, *environmental policy instruments EEA* and *styrmedel miljö* (*environmental policy instruments* in Swedish).

Page number in the relevant reference will indicate specific data like years, percentage or other detailed information including quotes.

2.2 Qualitative research interviewing

This study aims at identifying real life phenomena, in this case barriers, rather than aggregating numbers. Hence it is a qualitative study. According to Kvale & Brinkmann (2009, p. 3) a research interview is "a conversation that has a structure and a purpose". The design of the research questions encourages the interviewee to describe in words, rather than numbers, how various aspects are interpreted (Kvale & Brinkmann, 2009).

There is research looking on how users of food waste collection systems experience barriers and functionality (see Refsgaard & Magnussen, 2009), but I have been unable to find similar studies addressing how the organisers of food waste management (in this case municipalities) experience these aspects. Consequently, I was unaware of what answers I would receive prior to my interviews. Hence, the interviewees were approached in a semi-structured manner using mostly open-ended questions allowing for a discussion. A semi-structured interview permits for obtaining descriptions of the interviewee's interpretation of various phenomena,

as it should be regarded as something between a conversation and a questionnaire. It is also a flexible setting where a wide spectrum of aspects can be included (Kvale & Brinkmann, 2009).

According to Avfall Sverige - Swedish Waste Management (2011b) 154 municipalities had a partially or fully implemented food waste collection system in 2010. Early on in this study I indicated all of these municipalities on a map of Sweden in order to see whether or not there were any geographical patterns. As anticipated, the resulting geographical patterns follow very well the population distribution, with most collection actively (in term of numbers of municipalities) taking place in the most densely populated areas. Figure 2-1 and 2-2 displays these geographical patterns.

Figure 2-1: Map of north of Sweden. The flags indicate municipalities having a partially or fully developed food waste collection system (based on Avfall Sverige 2010e; Google maps)

The interviewee selection process took place in collaboration with my contact person at Avfall Sverige, Angelika Blom. Generally the biggest (in terms of population size) and smallest municipalities in each county were selected along with interesting and relevant waste companies and other actors for example industry-specific associations and academic experts. In certain cases the smallest municipality with an existing food waste collection system was selected to learn more about the specific challenges a small municipality face. Due to the specific focus on AD, samples of municipalities reporting to use composting as means of treatment were also selected and contacted.

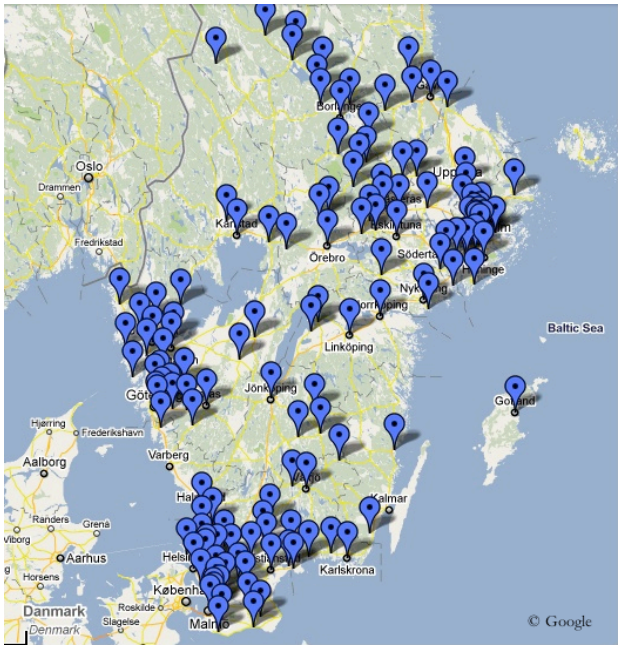

Figure 2-2: Map of south of Sweden. The flags indicate municipalities having a partially or fully developed food waste collection system (based on Avfall Sverige 2010e; Google maps).

After initially selecting roughly equal numbers of interviewees in each county it became evident that more samples should be selected in the southern regions where geographical, demographical as well as climatic aspects makes the conditions for food waste collection and AD treatment more favourable. A complete list of interviewees can be found in Appendix I.

The interviewees were initially contacted via email or telephone. The actual interviews were all but one conducted by telephone, as this was the only viable option. For various reasons, the interview with Andreas Winkler at Halmstad Energi & Miljö (HEM) was conducted via email.

A list of open-ended questions as well as a few factual questions was sent beforehand to the majority of the interviewees. In certain cases the interview was not pre-booked. Most interviews lasted typically twenty to thirty minutes. The questions were not posed as a questionnaire, but rather allowed for the interviewee to elaborate on areas he or she experienced as barriers or success factors. A list of the questions used during interviews can be found in Appendix II.

Although most interviewees were selected in advance a partial snowball sampling technique was adopted as well, meaning that I asked the interviewees to suggest municipalities that they felt have had particular success and/or struggled with implementing a food waste collection system. This led to a few additional interviews, although the suggestions made by the interviewees mostly confirmed already pre-selected interviews. A snowballing effect also took place in terms of contacting various "experts", other than the scheduled interviews, for clarification of specific queries.

The interviews primarily took place early on in the research process mainly due to summer holidays posing a limitation in terms of being able to contact the interviewees. Due to that matter it was important to ask the interviewees permission to come back with complementary questions upon their return from summer holidays.

In parallel to the primary data collection, in this case interviews, literature analysis was conducted in order to obtain useful knowledge about waste management as well as policy instruments.

2.3 The analytical framework

This section explains to the reader(s) how an analytical framework was chosen and utilised in order to organise the primary data collected from the interviews. Furthermore the framework itself is introduced and how it was applied to this specific study.

No existing research has been found that focuses on which barriers municipalities run into when trying to develop food waste management systems utilising AD as means of treatment. Hence, as mentioned in the previous section, the interview questions were designed to be open-ended in order not to cause limitations. In terms of selecting a fitting framework it was important to find a framework that incorporates all aspects of the "food waste chain", from collection to final treatment, so that the answers received during the interviews could be organised accordingly. Since the research methodology utilised in this study followed a rather iterative process, meaning that each interview conducted brought about new input and understanding of the research problem, an analytical framework was not finally chosen until the majority of the interviews had been carried out. Only then, an appropriate framework could be chosen when the width and content of the primary findings (the interviews) was better understood.

Söderberg and Åberg (2002) has developed a conceptual framework, which takes into account the users, the organisation and the technology of an existing system. The framework was originally developed for assessing urban water systems, but have been used in studies on organic household waste as well (see Refsgaard & Magnussen, 2009). For the purpose of this

study the division of aspects, which all influence the food waste management system, into three categories is appropriate in terms of continuing the analysis and discussion on future suggestions in a structured manner.

2.3.1 Framework for food waste management

The framework developed by Söderberg and Åberg has been modified by Refsgaard and Magnussen (2009) with respect to waste management. The modified framework (for the sake of convenience referred to as the food waste framework) will be used to organise the findings from the interviews. A schematic overview of the framework is shown in Figure 2-3 below.

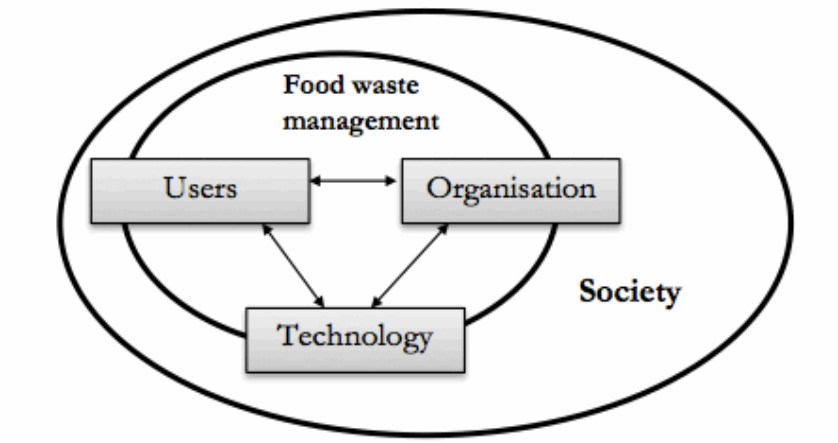

Figure 2-3: The framework used for organising findings from the interviews.
The management system for food waste in society is dependent on the three sub-systems; users, organisation and technology. In order to have a functioning food waste management system the three sub-systems must interact and function together (modified after Refsgaard & Magnussen, 2009).

As shown in Figure 2-3, the three sub-systems *users*, *organisation* and *technology* interact in the food waste management system. Barriers in one of the sub-systems will mutually affect the system as a whole. The framework is further explained below to give the reader(s) an overview before applying the framework in Chapter 4.

According to Vatn (2005, p. 60) institutions are "the conventions, norms and formally sanctioned rules of a society. They provide expectations, stability and meaning essential to human existence and coordination. Institutions regularise life, support values and produce and protect interests". In the framework used by Refsgaard and Magnussen the sub-system organisation is substituted for *institutions*, comprising both formal and informal structures. Institutions, as defined by Refsgaard and Magnussen, takes into account norms and traditions practised by the residents in a community as well as matters such as distribution of responsibility, choice of treatment method and determining fees which are more commonly duties of the formal authorities (Refsgaard & Magnussen, 2009). On the other hand, Refsgaard and Magnussen (2009, p. 762) defines the *users* as "…different stakeholders in the system, i.e. the politicians making the decisions about which system to choose, the operators maintaining the system, and the households being the primary users of the system."

After careful consideration an approach similar to Söderberg and Åberg (2002) was chosen in regards of defining the term *users* strictly as the residents living in households, participating in separation of food waste. Similarly, the term *institutions* have been substituted for *organisation*,

taking strictly into account the formal aspects of waste management practised by the authorities. This approach is a mixture of the framework used by Söderberg and Åberg and the modifications of that framework made by Refsgaard and Magnussen. However, the resulting framework modifications are deemed more suitable for the task at hand as it allows for a more pragmatic and distinct breakdown of the primary data.

Below a more detailed synopsis of the three sub-systems (as defined in this study) is presented. A more elaborate discussion regarding alternative aspects to each sub-system, for example what issues influences users to act in a certain way when it comes to source separation of waste, is found in Chapter 5.

Users

This sub-system comprises the residents living in single-family households and multi-family complexes as well as business-owners, employees and others responsible for sorting out food waste in available food waste collection systems. The actions taken by the *users* directly affect the outcome of the food waste management system. Improper sorting can be devastating for the functioning of an AD facility and/or the quality of the bio-fertiliser in the same way as failing to separate food waste results in less substrate available for AD and hence loss of potential profit. All of these aspects make the *users* a vulnerable and complex part of the food waste management system.

Organisation

The formal structures of the food waste management system such as division of responsibility, decision on collection system and treatment method, collaboration with other municipalities and actors, size and design of waste collection charges as well as rules laid down in the waste plan and waste disposal plan all fall into the term *organisation*. Which organisational body is responsible for the aforementioned aspects varies from case to case. However, the local government (municipality), waste company, public and private entrepreneurs and the national government are the most common organisational bodies represented in this study.

Technology

Physical structures such as the collection system, collection vehicles, containers and treatment plants are all part of the *technology* sub-system. The physical structures are affected by natural conditions, for example climate and surrounding landscape, as well as man-made constructions like housing design and population density.

Following each interview a summary of the answers and reflections made by the interviewee was compiled in a spread sheet. Depending on the interviewee's story and own identification of barriers, an assessment as to which sub-system poses the greatest obstacle for development of a food waste management system utilising AD was carried out. In Chapter 4 the main findings of the interviews are presented, along with tables displaying the result of the "sub-system assessment". Analysis, discussion and reflection of the findings follow in Chapter 5.

3 Literature Analysis

3.1 Introducing Swedish Waste Management

The following chapter introduces the reader(s) to the basics of Swedish waste management in general. A specific focus on food waste, in the EU as well as in Sweden, is found in Section 3.2.

Sweden has a long tradition of environmental protection and working with waste management, stretching back to 1972 and the introduction of the Public Cleansing Act. In 1979 the municipalities were also given the responsibility of treatment of MSW, which meant an extension of their current responsibility of collecting and transporting the waste (CSI Resource Systems Incorporated, 1995).

During the 1980s incineration of waste, as a treatment method, was heavily debated based on the negative environmental and health effects caused by mainly emissions of dioxins, resulting in a moratorium on new construction of waste incineration plants in the mid 1980s (CSI Resource Systems Incorporated, 1995). Since then the technology for flue gas purification has been developed significantly and incineration as a waste treatment method is used extensively. Today almost 50 percent of the MSW in Sweden is incinerated, and the extracted energy is used for heating and/or electricity generation (Avfall Sverige, 2010c).

The requirement for municipalities to develop waste plans was introduced in the 1990 Waste Bill[9] along with a greater obligation for private companies and establishments to supply municipalities with information. Municipalities were also granted to take responsibility for additional waste streams other than MSW (CSI Resource Systems Incorporated, 1995). This possibility ceased in 2000 (Avfall Sverige, 2010f). The Waste Bill stated that source separation was to be implemented to avoid any landfilling of mixed, untreated waste by the year 1994 (CSI Resource Systems Incorporated, 1995).

Extended producer responsibility (EPR) was introduced into Swedish legislation in 1994, following the passing of the Eco-cycle Bill the previous year. The goal of introducing EPR is to make producers take responsibility for the take-back and proper treatment of their products, hence improving the use of materials and resources (CSI Resource Systems Incorporated, 1995).

The EU Landfill Directive[10] entered into force in 1999, followed by the introduction of a landfill tax in 2000. As a response to the Landfill Directive, a ban on landfilling of sorted combustible waste as well as organic waste was adopted in 2002 and 2005 respectively (Avfall Sverige, 2010f).

In 1999 the Environmental Code and associated ordinances and regulations came into force, assembling all of the environmental laws (Avfall Sverige, 2010f). Chapter 15 of the

[9] In Swedish the term "bill" is used for legislative proposals by the government to the Parliament. A bill can include suggestions for new laws or changes to existing laws.

[10] Directive 99/31/EC on the landfilling of waste.

Environmental Code along with the Ordinance on Waste[11] regulates much of the responsibilities of the municipality in terms of MSW.

A tax on the incineration of MSW was introduced in 2006, however taken away in 2010 (Avfall Sverige, 2010f).

The long-term goal of Swedish waste management is to reduce the amounts of waste generated as well as minimise the hazardousness of the waste. However, historically the focus of waste policies and waste regulation has been on increasing recycling and decreasing landfilling. It is the Swedish Environmental Protection Agency (EPA) that has the role of central authority in matters related to the environment. The Swedish EPA takes part in the development of environmental regulation and helps guide other authorities as well as local and regional governments in their work regarding environmental matters (Swedish Environmental Protection Agency, 2011m). The "power" is, however, shared among national, regional and local authorities. The regional authority, the County Administrative Board (*Länsstyrelse* in Swedish), is responsible for matters regarding zoning and environmental protection (CSI Resource Systems Incorporated, 1995). This responsibility can be delegated to the local authorities (municipalities) if deemed more appropriate. Important environmental and waste laws are indicated on the timeline in Figure 3-1.

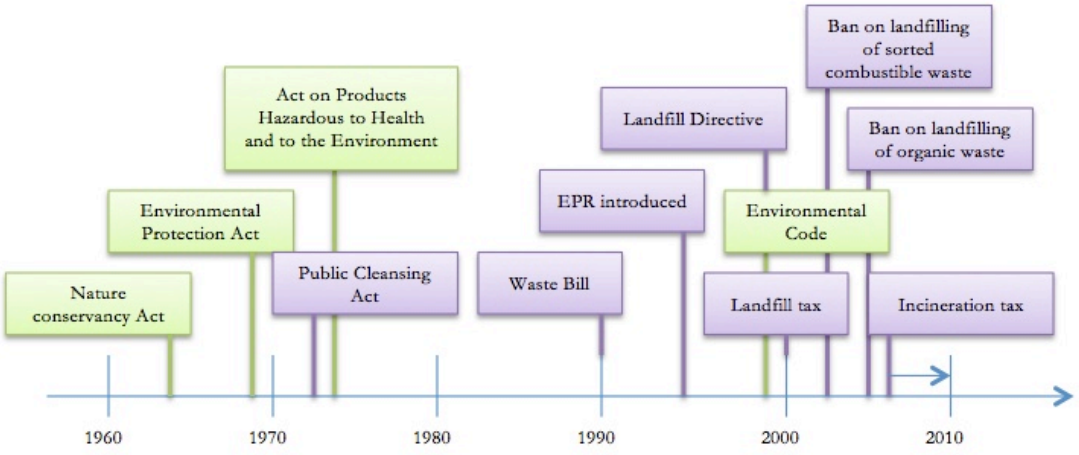

Figure 3-1: Timeline for the introduction of important environmental and waste laws and policy documents in Sweden.
Green boxes indicate general environmental laws, purple boxes indicate waste laws (Avfall Sverige, 2010f; CSI Resource Systems Incorporated, 1995).

Statistics on the development of MSW (in total) during the years 1999-2009 is shown in Figure 3-2 below.

[11] Avfallsförordning [Ordinance on Waste] (2001:1063).

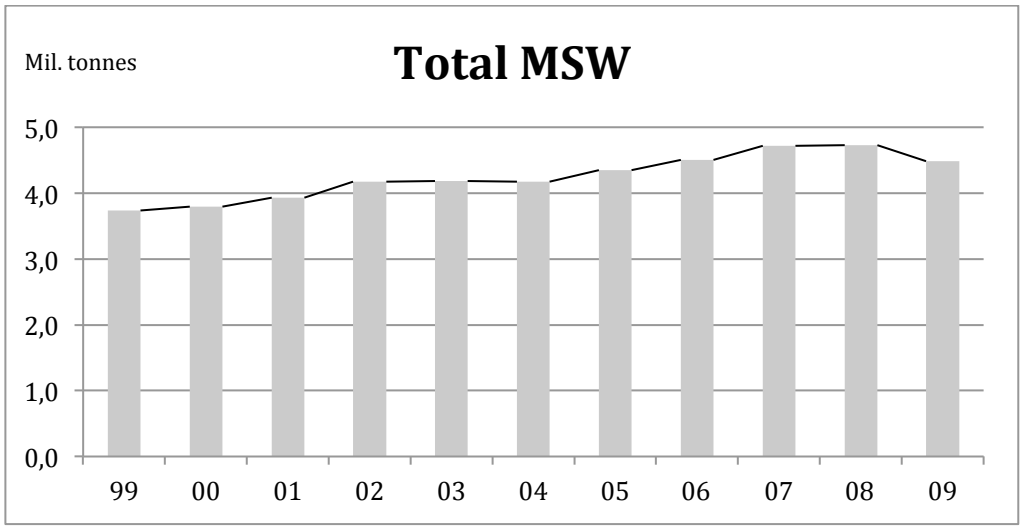

Figure 3-2: Chart showing the production of MSW in Sweden during the years 1999-2009 (Statistical material provided by Jenny Westin at Avfall Sverige).

In order to achieve a fully functioning and sound waste management system, there are three key elements that need to be in place. *Responsibilities* must be clearly assigned. Who is paying for what to whom (the *financial aspect*) and what are the desired *environmental goals* (International Institute for Industrial Environmental Economics (IIIEE), 2011). The relationship between these key foundations is illustrated in the Venn diagram below (Figure 3-3), as well as in the following sub-chapters.

Figure 3-3: Elements needed for a sound waste management system (Wiqvist, 2011 [Interview] in International Institute for Industrial Environmental Economics (IIIEE), 2011, p 17).

3.1.1 Responsibilities in the Swedish waste management system

As indicated in Figure 3-3 above one of the corner stones of a sound waste management system is to have clearly defined responsibilities. Responsibility of waste can be divided into physical (having to collect, transport and treat the waste) and financial responsibility (having to finance the collection, transport and treatment as discussed in Section 3.1.2). There are four main actors having responsibility of waste in Sweden, being;

- Municipalities,
- Consumers,
- Facility operators, and
- Producers of products included in the producer responsibility

Municipalities

Municipalities are responsible for collecting, transporting and ensuring proper treatment of waste generated by households within their jurisdiction. Waste that is generated by businesses and is comparable to MSW in terms of its nature and composition is also the responsibility of the municipality (Avfall Sverige, 2010a).

Each municipality has to decide on a waste plan, as required by the Environmental Code[12]. The waste plan should cover all waste generated in the municipality and specify which actions need to be taken to ensure proper treatment. Regulation by the Swedish EPA and County Administrative Boards controls the content of the municipal waste plans (Avfall Sverige, 2010a).

Although the physical responsibility of collecting, transporting and treating MSW lies with the municipalities, they have the option to hire contractors (private or publically owned companies) to manage their operations (Swedish Environmental Protection Agency, 2011a).

Consumers

Consumers, in this case municipal residents, are obliged to handle their waste according to the stipulations made by the local government in the waste disposal plan. This includes properly sorting out packaging and other waste included in the producer responsibility as well as hazardous waste (Swedish Environmental Protection Agency, 2011l). Municipalities having a food waste collection system have the possibility to making it mandatory or voluntary for households and/or businesses to sort out the organic fraction.

Facility operators

Facility operators, such as business-owners, must ensure that the waste generated is managed and treated according to regulation. Depending on the size of the operation, the facility operator must register or apply for a permit from the competent authority. The registration or permit gives the facility operator license to run the business and generate waste. Facility operators are responsible for the treatment of their waste and can freely chose whom should collect and treat this waste, unlike MSW, which is included in the municipal monopoly (Swedish Environmental Protection Agency, 2011l). However, waste generated by a business

[12] Chapter 15, Article 11.

and which is comparable to MSW is still the responsibility of the local government (Förordning (1998:899) om miljöfarlig verksamhet och hälsoskydd).

Producers of products included in the producer responsibility

Producers of packaging, tyres, newsprint, vehicles (that become End of Life Vehicles - ELV), and electrical and electronic equipment (EEE) are responsible for collection and treatment of their respective waste. The regulation applies for manufacturers as well as importers of the aforementioned products. A voluntary responsibility for office paper, construction waste and agricultural plastic film exist as well (Swedish Environmental Protection Agency, 2011l).

3.1.2 The financial aspect of waste management

The financial responsibility must be clearly assigned in order to run a waste management system towards the intended vision. Who is paying whom and how the revenue of taxes should be distributed are some of the many issues that need to be solved. Below is a short recapitulation of the financial responsibilities among municipalities, facility operators and producers of products included in the producer responsibility.

Municipalities

Every household or homeowner, including businesses generating waste comparable to MSW, are obliged to pay a waste charge to the municipality. The municipal council (*kommunfullmäktige* in Swedish*)* decides the size of the waste charge based on the cost of running the collection and treatment system. Administrative costs of waste management are also financed through the waste charge. The law[13] stipulates that the waste charge must be set at cost price, meaning no revenue can be generated to the municipality (Kommunallag [Local Government Act] (1991:900); Miljöbalk [Environmental Code] (1998:808)). The municipality can, however, decide how to set up the charge in order to encourage certain behaviour. Examples of this steering effect include weight-based billing and environmentally differentiated waste charges.

Facility operators

The facility operator solely covers the cost of collecting, transporting and treating the waste generated by their business(es). Renting containers for mixed or source separated fractions of waste is the most common way for facility operators to manage their waste. The contractors hired for transporting and treating industrial waste must have a permit (Millbäck, 2011 [Interview] in International Institute for Industrial Environmental Economics (IIIEE), 2011).

Producers of products included in the producer responsibility

The consumers of products included in the producer responsibility pay an extra charge, which is supposed to cover the cost of collection and treatment. The producers decide the size of the charge and are responsible for setting up systems for collection, for example recycling stations for packaging waste (Swedish Environmental Protection Agency, 2011k).

[13] Local Government Act Chapter 8, Article 3c and Environmental Code Chapter 27, Article 5.

Environmental charges and taxes are often used interchangeably, however they are profoundly different. Taxes, such as the landfill tax, can only be levied and altered by the Swedish Parliament. Charges, unlike taxes, must be earmarked for a specific purpose and can be levied by public authorities, whilst taxes generate general revenue for the state (Swedish Environmental Protection Agency, 2011e).

3.1.3 Environmental goals and visions

The EU waste hierarchy (explained in more detailed in Section 3.3) guides all member states on how to prioritise in terms of waste management. In short, the waste hierarchy says that prevention of waste should be at the top of all member states' priority-lists, followed by reuse, material recycling, energy recovery and at the very end disposal by landfilling (Swedish Environmental Protection Agency, 2011f).

Reducing the amounts of waste is high up on the Swedish agenda, however, not much progress has been made in that area. During 2009 there was a reduction in total MSW corresponding to almost 5 percent most likely due to the regressing economy and much more work remains to de-couple waste generation from the affluent society Sweden is part of (Avfall Sverige, 2010f).

As previously mentioned in Section 1.2 there are sixteen national environmental quality objectives that serve as guidance towards the preferred environmental status of Sweden. Waste, and more specifically food waste, is mentioned in the Good Built Environment objective. In 2002 an interim target was set, expressing that 35 percent of the municipal food waste should be treated biologically (Avfall Sverige, 2011b).

Additionally, waste management is connected to the objective concerning Reduced Climate Impact. By increasing recycling of metal and plastic as well as boosting the production of biogas, a reduction of GHG can take place (Swedish Environmental Protection Agency, 2011h). The environmental objectives concerning Clean Air and A Non-Toxic Environment are also affected by how well we manage our waste (Swedish Environmental Protection Agency, 2011i).

The Swedish EPA is in charge of preparing the new national waste management plan, which is based on the requirements in the revised WFD and incorporates the goals of the environmental objectives and add action plans for how to achieve these. The national waste management plan is scheduled to be published in fall 2011 (Swedish Environmental Protection Agency, 2011j).

According to the Environmental Code[14] each municipality must have a local waste plan[15], which is part of the municipality's waste disposal plan[16] (*renhållningsordning* in Swedish) (Swedish Environmental Protection Agency, 2011o). Goals for waste management and actions plans for how to conduct collection and treatment of the MSW are parts of the municipal waste plan. The waste disposal plan also dictates how the residents and businesses

[14] Chapter 15.

[15] The content of the municipal waste plan is regulated by the Swedish EPA regulation NSF 2006:6 Content of municipal waste plans and collations by County Administrative Boards.

[16] The content is regulated by the Environmental Code and Renhållningsförordning [Ordinance on Waste Disposal] (1998:902).

should dispose of their MSW, for example source separation of food waste (Avfall Sverige, 2010b).

3.2 Food waste

This section starts by introducing the reader(s) to food waste policies and food waste issues on the EU level. Since the focus of this thesis is Sweden, a more detailed description of food waste management and national waste policies will follow in Section 3.2.1.

Food waste is defined as "waste composed of raw or cooked food materials and includes food materials discarded before, during or after food preparation, in the process of manufacturing, distribution, retail or food service activities, and includes materials such as vegetable peelings, meat trimmings, and spoiled or excess ingredients or prepared food. Food waste can be both edible or inedible." (European Commission, 2010, p. 199).

According to a study by the European Commission (EC) an estimated 90 million tonnes of food waste was discarded in the EU in 2006 (baseline year), causing the release of an estimated 170 million tonnes of CO_2-equivalents[17]. Breaking down the amounts of food waste generated in 2006 results in an equivalent of almost 179 kg[18] per capita. The amounts of food waste are projected to increase to 126 million tonnes annually by 2020 due to population growth and escalating consumption, if waste policies do not manage to curb the development (European Commission, 2010, pp. 11, 16-17).

As shown in Figure 3-4, the largest amounts of food waste are generated by households due to, among other issues, improper handling, attitudes and/or socio-economic factors. Households alone are estimated to produce 76 kg of food waste per capita every year in the EU (European Commission, 2010, p. 13). A list of identified reasons[19] for generating food waste in households is shown in Appendix III.

The food service sector is estimated to generate 25 kg[20] of food waste per capita and year. Wastage of resources and raw material constitutes a great cost, both for households and businesses, with studies showing households wasting as much as 25 percent of their purchased food (by weight) (European Commission, 2010, p. 13).

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[17] Estimations made based on the life cycle of the food ending up as waste.

[18] This figure includes the food manufacturing/processing sector as well as the other sectors usually included in MSW.

[19] The UK Waste and Resource Action Programme (WRAP) have conducted surveys on the prevailing reasons for food waste generation in households in the UK. It is likely that the causes for food waste in households vary in the EU at large due to, inter alia, cultural differences. However, the study provide guidance on what needs to be further explored in order to battle rising amounts of food waste.

[20] Data for EU-15 show an average of 28 kg of food waste per capita, whilst EU-12 show 12 kg per capita. Hence, there is a noteworthy difference (European Commission, 2010, p. 13).

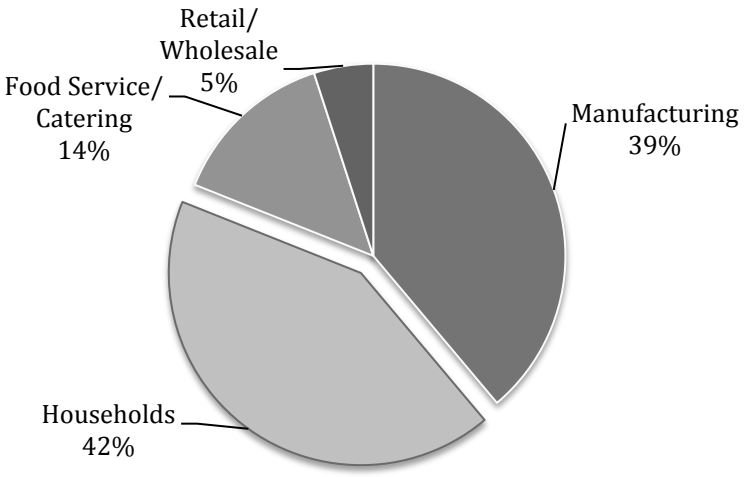

Figure 3-4: Percentage of food waste generated by various sectors within the EU-27 (adapted from European Commission, 2010, p. 13).

The same study by the European Commission (2010) concludes that current waste policies aiming at avoiding landfilling of food waste are important in order to control the treatment of food waste, but they fail to battle the problem of rising amounts of food waste. The study also recommended the adoption of five policies in order to tackle the rising amounts of this fraction of MSW. One of these options is especially interesting for this thesis since it is focused on the implementation of separate food waste collection systems in households and the food service sector.

Separate food waste collection systems have shown empirically to reduce the amounts of food waste, most likely because it makes the waste producer aware of the quantities. The noted phenomenon has, however, not been statistically proven yet. Apart from the preventative focus, separate food waste collection systems make it possible to use the waste as a resource by treating it biologically and hence retrieving the nutrients and energy (if AD) (European Commission, 2010). The remaining product, in this case compost or digestate, can be used as a soil improver or fertiliser and hence contribute to an increased capability of the soil for carbon sequestration. This is beneficial in terms of combating climate change. More information on the methods used in biological treatment is found in Section 3.2.1.

Implementing separate collection systems for food waste as well as promoting biological treatment of food waste is supported by the revised WFD[21]. Composting and AD are the means of treatment that best align with the EU waste hierarchy because they enable recycling of nutrients (and energy), while diverting organic waste from landfills. Specifically Article 22 of the revised WFD promotes biological treatment over incineration, as it is more in line with the priorities in the waste hierarchy. How to design and implement separate collection systems is left in the hands of the member states, which allows for adaptability to local and cultural circumstances. The EC, however, recognises that implementing separate collection systems adds administrative as well as infrastructural costs, which should be subject to subsidies (European Commission, 2010).

[21] Specifically pointed out in Recital 35.

3.2.1 Municipal food waste in Sweden

The following sub-chapter is by no means supposed to contain a detailed technical description of the various methods available for treatment of biological waste. Rather the aim is to introduce to the reader(s) an overview of the pros and cons of available means of treatment used for food waste in Sweden today. The purpose is also to familiarise the reader with the terminology used in biological treatment.

Through waste analysis it has been estimated that every Swede, on average, generates 126 kg of food waste each year[22]. Since most of this waste is incinerated the possibility of recycling embedded nutrients back to arable land is lost (Avfall Sverige, 2010f).

During 2009 close to 180 000 tonnes of food waste was treated biologically, corresponding to 21 percent of the food waste volumes generated by households (Avfall Sverige, 2010f). Composting is still the most common type of biological treatment, while only 8-9 percent (out of the 21 percent) of the food waste was treated using AD (Blom, 2011 [Interview]). Although the official data for 2010 has not yet been published, Avfall Sverige's preliminary calculation show that approximately 25 percent of the total municipal food waste was biologically treated in 2010 (Avfall Sverige, 2011b). Hence, a small increase but not enough to reach the national goal of 35 percent. Figure 3-5 shows the recent development of biological treatment of food waste.

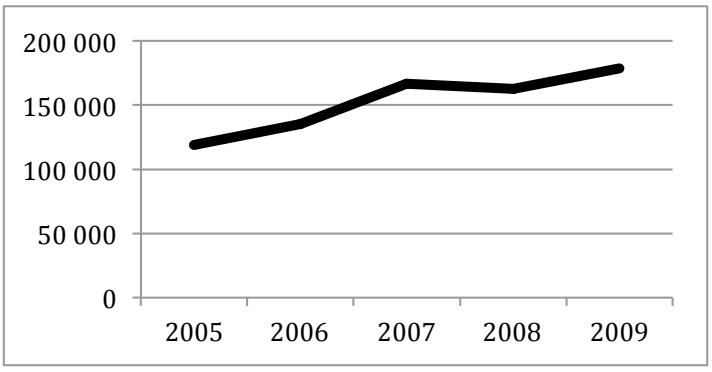

Figure 3-5: Amounts of food waste (in tonnes) being treated biologically (excluding home composting) during the period 2005-2009 (based on Avfall Sverige, 2010f, p. 18)

As landfilling of biodegradable waste is prohibited in Sweden since 2005, there are mainly two types of treatment options available for food waste. These options are incineration (the most commonly used) and biological treatment. Biological treatment incorporates two main practices; composting that allows for recycling of the nutrients, and AD that allows for recycling of nutrients as well as energy (Avfall Sverige, 2010f).

[22] Avfall Sverige (previously RVF – Svenska Renhållningsföreningen) estimated 1.9 kg of food waste per person weekly, resulting in 98.8 kg annually. Generic figures for food waste generated by restaurants, canteens and the like was established by RVF in 2006 (see RVF - Svenska Renhållningsföreningen, 2006, p. 3), and re-calculated by Linné et al (2008, p. 7) for Sweden as a whole. These estimations show 27.2 kg per person annually. Adding the two sources of food waste results in 126 kg per capita and year.

Waste-to-energy

The absolute majority of the waste incineration facilities in Sweden are equipped with technique to recover the energy in waste as heat and/or electricity; hence it is referred to as waste-to-energy facilities. Waste incineration constitutes a considerate share of the total district heating in Sweden (approximately 20 percent), and proponents argue that fossil fuel sources are being replaced with waste, which would have otherwise been put in landfills (Avfall Sverige, 2011c). Whilst this form of treatment offers a possibility to recover the energy in food waste, it does not enable a closed-loop where harvested nutrients embedded in the food waste are returned to agricultural land.

Composting

Composting is a process where biologically degradable waste, such as food waste, is broken down by microorganisms in the presence of oxygen. The remaining products are CO_2, water and compost. The compost is rich in nutrients and its texture makes it very suitable as a soil improver and/or for the production of topsoil to be used in agriculture or for coverage of closed landfills. Apart from adding nutrients compost also adds humus to the soil (Avfall Sverige, 2011c). Compost can be certified according to the rules set up in SPCR 152, which is a guarantee that the product is traceable and its quality has been carefully checked. In Sweden there are about 25 composting facilities that treat source separated food waste, and several others treating solely biological waste from public parks and gardens (Avfall Sverige, 2011e; Swedish Environmental Protection Agency, 2011d).

There are some problems related to composting. Unless properly managed, leachate from the composting site, which contains nutrients and organics, can cause eutrophication of surrounding water bodies. Odour and the release of nitrous oxide and ammonia are also problems associated with ill managed composting facilities (Swedish Environmental Protection Agency, 2011d).

Anaerobic digestion

In anaerobic digestion (AD) organic material, such as food waste, is broken down by microorganisms in an anaerobic (i.e. oxygen-free) environment inside a digestion chamber. Pre-treated food waste is fed into the digestion chamber on its own or along with other substrates such as manure and agricultural waste (called co-digestion). During the process biogas is formed. Biogas mainly consists of methane (~ 60 percent) and carbon dioxide (~ 40 percent) as well as small amounts of "impurities" such as nitrogen gas, ammonia and hydrogen sulphide. The raw biogas can be used for heat and/or electricity production, as well as vehicle fuel (Berglund, 2006, p. XI).

The greatest environmental benefits, in terms of climate change, takes place when the biogas is used to substitute fossil fuel in vehicles (Davidsson, la Cour Jansen, Appelqvist, Gruvberger, & Hallmer, 2007; European Commission, 2008). This is because the CO_2 released from the production and utilisation of biogas was sequestered by plants shortly (in relative terms) before the digestions process, making it a carbon-neutral energy alternative. CO_2 released from the combustion of fossil fuels was sequestrated by plants millions of years ago, hence adding to the present GHG concentration in the atmosphere. During the production of biogas fossil fuel is used, for instance in transporting the substrate to the AD plant. However, less fossil fuel is needed for production compared to the volumes that can be replaced by biogas in vehicles, resulting in a reduction of the overall emissions of GHG

(Berglund, 2006). In order to use the biogas in vehicles it must be upgraded to increase its energy content, in other words cleaned from CO_2 and other impurities, so that the methane concentration reaches about 96 percent (Avfall Sverige, 2011d). The upgraded biogas is compressed to 200 bar before it is delivered to refuelling stations and can be utilised as vehicle fuel (Biogasportalen, 2011c).

Upgraded biogas still has approximately ten percent lower energy content compared to natural gas. By adding for example propane the properties of the two gases become similar and the biogas can be fed into the natural gas grid (Avfall Sverige, 2011d; Biogasportalen, 2011a).

After the biogas has been subtracted from the digestion chamber a highly nutrient-rich digestate (sludge) remains, which can be used as bio-fertiliser. The nutrients, mainly nitrogen, phosphorous and potassium, in the digested substrate remain in the bio-fertiliser and are easily accessible to the plants, making it an appropriate substitute to conventional fertiliser in agriculture (Avfall Sverige, 2011a; Berglund, 2006). A certification scheme, SPCR 120, exist for bio-fertiliser produced from bio-waste. The certificate guarantees traceability and the quality of the fertiliser. Bio-waste mixed with digestate from sewage sludge cannot be certified according to SPCR 120 (Avfall Sverige, 2011g).

Unless properly managed, biogas production plants and upgrading facilities can experience leakage of methane. Back up systems for flaring of the methane during production shut downs is very important to avoid these emissions of GHG. Continuous work such as leakage detection and quality assurance of the incoming substrate and the outgoing bio-fertiliser is crucial.

Figure 3-6 shows the production of biogas as a flow-chart.

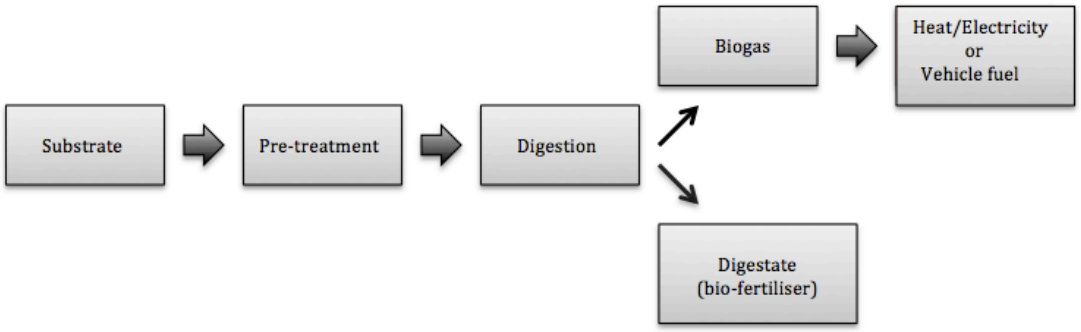

Figure 3-6: Schematic overview of the biogas process (adapted from Biogasportalen, 2011b)

Which treatment method poses the greatest environmental and economic advantage depends on the local conditions (European Commission, 2008, p. 2). For example, highly populated areas that generate a lot of food waste within short transport distances, coupled with agricultural areas nearby that can receive compost or bio-fertiliser makes an excellent case for biological treatment methods.

When the end product of biological treatment, in this case compost or bio-fertiliser, can be returned to agricultural land, it is considered recycling. If not it is rather a method of pre-treatment before disposing of the end product.

Transports of food waste

From an energy perspective, a reasonable distance to transport various substrates for AD depends on the substrate's biogas yield. Studies by Berglund (2006, p. XII) and Mc Cann[23] (9 June. 2011) show that organic household waste can be transported some 600-700 km on the surplus energy produced by the AD.

What transport distance makes economic sense is far more complex to calculate. Depending on the region, the level of competition etc. biogas plant owners charge different gate fees for the treatment of various substrates. The study by Mc Cann (9 June. 2011) show that some highly valued substrates such as abbatoir waste sometimes is purchased by the owner of the biogas plant, with no gate fees charged at all. The results of the specific study show that organic household waste is the cheapest substrate[24] to transport (in terms of SEK/MWh biogas) apart from abbatoir waste and whey. Whey is, however, rarely used in AD but rather used in the production of animal feed (Mc Cann, 9 June. 2011).

Potential of biogas production from food waste

Various studies have attempted to estimate the biogas potential from Swedish substrates. An often cited study by Linné et al (2008) looked at all possible waste streams that could be utilised for AD and estimated that the full potential for biogas production (assuming 100% of substrates are utilised) is 15.2 TWh excluding forest waste products. The *limited scenario*, taking into account that all substrates will not be possible to be exploited due to geographical, economic and technological reasons, show a biogas potential of 10.6 TWh.

In 2008 1.4 TWh of biogas was produced in Sweden, hence substantially less than the estimated potential (both full and limited) (Energigas Sverige, 2010). In the case of food waste[25] from households, restaurants and the like, the limited scenario assumes 60 percent of total food waste collected and treated using AD resulting in 760 GWh of biogas, or seven percent of the total biogas potential (10.6 TWh) in the limited scenario (Linné, et al., 2008, p. 2).

Västra Götaland and Skåne are the two counties in Sweden with the greatest potential to produce biogas, both due to population density and the closeness to arable land where the bio-fertiliser can be spread (Linné, et al., 2008). However, if the full potential of biogas is to be utilised the capacity must be further increased by constructing more biogas plants (Mc Cann, 9 June. 2011).

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[23] Study yet unpublished, however results presented at Skånes Energiting in Malmö 9 June 2011. The study covers the counties of Västra Götaland, Skåne, Halland, Örebro, Blekinge, Kronoberg, Värmland and Jönköping. According to the study the energy needed for transportation of organic household waste is 1.34 kWh/km, resulting in a viable transport distance of 673 km.

[24] The studied substrates included organic household waste, abbatoir waste, whey, liquid manure from pigs and cattle, and wet draff from the production of consumer spirits.

[25] The study by Linné et al (2008) assumes 128 kg of food waste per resident annually. This is slightly more than the generic number used by Avfall Sverige, which is 126 kg/person/year.

3.3 Policy instruments within the context of waste management

According to Vedung (1998, p. 21) "Public policy instruments are the set of techniques by which governmental authorities wield their power in attempting to ensure support and effect or prevent social change". Policy makers, whether it is on an international, national or local level, use policy instruments to achieve pre-determined policy objectives such as lower emissions and increased recycling of waste. The choice of policy instrument(s) depends on the "goal" set by the policy makers. Ultimately, the goal is to make *individual* decision-makers, such as households, firms and citizens, act in a way that is aligned with the objectives of the authorities (Lindeneg, 1992).

OECD (2001) has developed six generic categories for environmental policy instruments (EPIs). However, for the sake of this study a less refined typology is needed, and hence the OECD identified categories has been divided into three types; administrative, economic and informative EPIs, see Table 3-1 below. This approach is supported by Tojo et al (2008) in their work on policy instruments used in waste management in the EU.

Table 3-1: Classification of environmental policy instruments (EPIs) into three main categories; administrative, economic and informative EPIs.
(based on Lindeneg, 1992; OECD, 2001, p. 132, Table 5.2; Tojo, et al., 2008).

Administrative EPIs	
Command-and-control instruments	E.g. permits, emission standards and prohibition bans
Liability and damage compensation	E.g. strict liability rules, compensation funds
Economic EPIs	
Economic instruments	E.g. taxes, subsidies, deposit-refund systems
Informative EPIs	
Education and information	E.g. public campaigns, eco-labelling
Voluntary approaches	E.g. public voluntary schemes
Management and planning	E.g. environmental management systems, land use planning

Each of the three categories of EPIs referred to in this study are briefly described below.

Administrative EPIs

Administrative EPIs, often referred to as command-and-control (CAC), can be more or less coercive. When imposed through legislation, administrative EPIs force the concerned target to adhere to requirements, cease certain behaviour and/or alter its operation. However, administrative EPIs also include softer mechanisms such as including demands in public procurement documents and guidelines (Tojo, et al., 2008).

Economic EPIs

Unlike the traditional command-and-control approach (legislation), economic EPIs such as taxes, subsidies and tradable permits allow for companies and individuals to be more innovative and respond according to abatement costs. By allowing the concerned target to find the most cost efficient way to submit to the new conditions, whether it be paying the taxes or altering ones behaviour towards less "polluting activities", it is likely that the problem will be solved in the most cost efficient way. By granting subsidies to those with "correct" behaviour, the authorities distort the market making it more favourable for the preferred activities to continue. Economic instruments are often referred to as incentive-based measures. Apart from the effect in behavioural change, tax revenues can also be used

for further improving the environmental status (Tojo, et al., 2008).

Economic EPIs must be accepted by the general public in order to be enforceable politically. If waste authorities and the public are not on board, the intended outcome of the instrument is likely to fail (Tojo, et al., 2008).

Informative EPIs

The idea of informative EPIs is that people who are informed make different and hopefully better choices as apposed to the choices they would have made without the information (Tojo, et al., 2008). In waste management, informative EPIs are often public campaigns, marking of waste bins, public meetings and leaflets sent through mail or handed out.

Summary of EPIs

Each of the above mentioned EPIs have its pros and cons. The command-and-control approach has historically been the preferred choice of the Nordic countries, including Sweden. By, for example, setting a limit for emissions from a landfill or a power plant, the authorities can easily control who is adhering and who is not. However, this approach can become costly, both for the "polluter" and the "commander". The abatement cost varies between companies, and pollution control can as well become expensive if the number of firms to be controlled is plenty (Tojo, et al., 2008). One must also take into account the credibility and reliability of the government in the specific country. Many countries have excellent laws and policies, but are lacking the enforcing power due to lack of, for instance, funding and/or corruption (Lindeneg, 1992). In the case of Sweden this is, however, not perceived as a barrier.

Economic EPIs are designed to work as incentives for the individual decision-makers to change their behaviour in a desired way (OECD, 2003). A simple example is the landfill tax, which makes it more expensive, and therefore less attractive, to use landfilling as means of waste treatment. The desired behaviour is hence to make waste producers chose a more favoured way of treatment. Economic EPIs have the possibility to be more cost-efficient in terms of abatement costs.

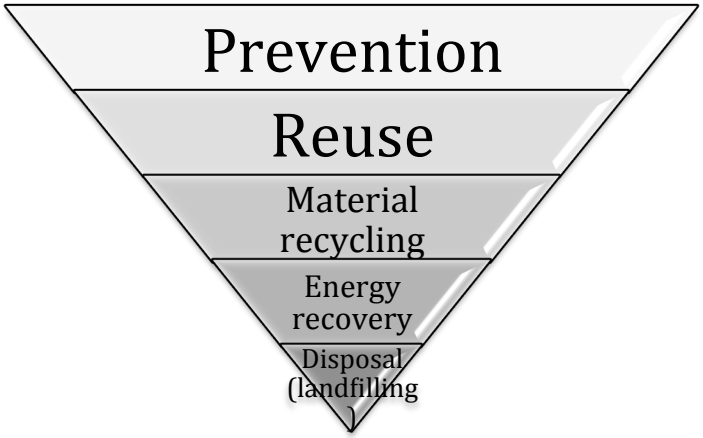
It has been shown that a mix of EPIs is necessary to combat the complexity of environmental problems in society (Lindeneg, 1992). As a response to this, the diversity of EPIs used in Sweden has increased over time (Finnveden, Björklund, Reich, Eriksson, & Sörbom, 2007; Lindeneg, 1992; Persson, 2006; Vedung, 1998). The essence of policy instruments is that they are measures that affect other actors. Policies and subsequent policy instruments can be decided on different levels by different authorities. When using a number of different EPIs simultaneously it is typically referred to as a policy intervention (Tojo, et al., 2008). Below is a short summary of existing policies and EPIs that are relevant for food waste collection and treatment in Sweden viewed from three levels; EU level, the Swedish national government and the local government (the municipalities).

EU level

The foundation of all waste policy in the EU is the EU waste hierarchy, which is shown in Figure 3-7 below. In terms of legislation, the Landfill Directive and the revised WFD are the two most influential guidance documents for the support of increased biological treatment of food waste, although neither of the two are focused specifically at that task. The waste

hierarchy was first mentioned in the Fourth Environmental Action Programme, and adopted in the 2006 WFD. It has, however, been used as guidance in waste policy development in the European community since the late 1980s (Tojo, et al., 2008).

Every member state must conform to the waste policies decided in the EU. Directives are transposed into national law, and give some flexibility for member states to make local adaptations, whilst EU regulation is directly applied and hence homogenous among all member states. Although waste policy is high up on the EU agenda and the member states must take into account directives and regulations concerning waste management, this is an area where the subsidiary principle comes into practice. In this setting, the subsidiary principle mean that matters regarding the implementation of EU legislation and how to adapt in order to fulfil requirements and goals is left in the hands of the least centralised competent authority, most often the municipality. This makes sense since the local authority has the



knowledge and skills needed to decide which system should be used and how in the local context (Tojo, et al., 2008).

Figure 3-7: The EU waste hierarchy (based on Swedish Environmental Protection Agency, 2011f).

The revised WFD oblige member states to develop waste management plans, which adhere to the priorities of the waste hierarchy. In addition to the waste management plans, the revised WFD also enquire member states to develop national waste prevention programmes, including measureable benchmarks for progress analysis. These programmes are to be fully developed by end 2013. Although targets for food waste are not specified in the revised WFD, separate collection and treatment of food waste is highly encouraged through the outline of the Thematic Strategy on the prevention and recycling of waste (Commission of the European Communities (CEC), 2005; Persson, 2006).

Diverting biologically degradable waste from landfills is a prioritised matter among the EU policy makers. The methane emissions that are released when organic matter is broken down inside an oxygen-restricted landfill are highly potent GHG, and must be reduced in order to combat climate change. The Landfill Directive, which was transposed into national law in 1999, states the following (European Commission, 2010, p. 114; Tojo, et al., 2008, p. 17);

- By 2006[26] Biodegradable Municipal Waste (BMW) being landfilled must be reduced to 75 percent (by weight) of the amounts produced in 1995.
- By 2009[27] BMW being landfilled must be reduced to 50 percent (by weight) of the amounts produced in 1995.
- By 2016[28] BMW being landfilled must be reduced to 35 percent (by weight) of the amounts produced in 1995.

Sweden – national level

As previously mentioned in this report, the Swedish Parliament has adopted sixteen national environmental objectives, which guide authorities on all level towards what state the environment should be in. These environmental objectives have been and still are very important guidance for decision-makers when developing policies. Below in Figure 3-8 is an overview of the existing policy interventions in the area of waste management.

[26] Optional deadline is 2010 for countries landfilling more than 80 percent of their MSW in 1995.

[27] Optional deadline is 2013 for countries landfilling more than 80 percent of their MSW in 1995.

[28] Optional deadline is 2020 for countries landfilling more than 80 percent of their MSW in 1995.

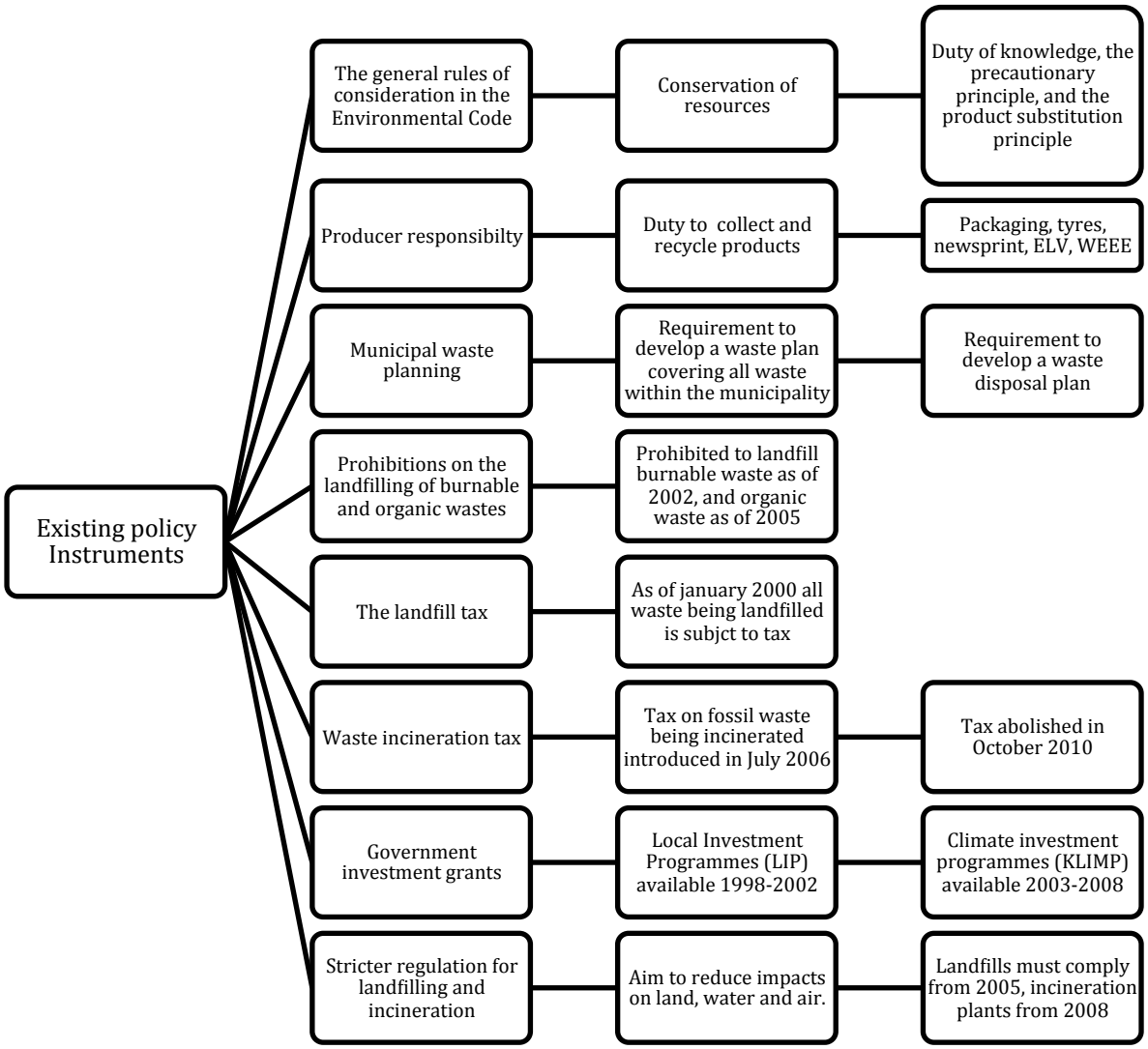


Figure 3-8: Schematic overview of the existing national policy interventions in Swedish waste management (based on Swedish Environmental Protection Agency, 2011m).

Sweden – local level

The local government, in this case the municipality, has the responsibility of the MSW management within its district. The waste charge, which is paid by all households and firms generating MSW, is decided by the municipal council (*kommunfullmäktige* in Swedish). According to the Swedish constitutional law the municipalities are entitled to decide how they want to organise their waste management, whether that be on their own, or in collaboration with other municipalities through publically owned waste companies or as a local government federation (*kommunalförbund* in Swedish) (Avfall Sverige, 2010g).

The municipal self-governance allows for an adaption of policy instruments into the local context, as well as a more flexible structure in comparison to policy instruments decided by the EU or the national government. Examples of policy instruments utilised by the Swedish municipalities are (Avfall Sverige, 2010b);

- **The waste plan**, which clarify targets for waste management and measures for how collection and treatment shall take place.
- **The waste disposal plan**, which lays out responsibilities for property owners, households and businesses (generating MSW). Municipalities' choosing a mandatory food waste collection approach incorporates that into the waste disposal plan.
- **The waste charge** can be used as an incentive to make the residents change their behaviour. Households sorting out food waste can be rewarded by having a lower waste charge in comparison to households with mixed waste, known as environmentally differentiated waste charge.
- **Information** is a very important policy instrument for municipalities. By informing the residents on how to sort their waste, where to dispose of it etc. waste management can be improved. Many municipalities work a lot with information campaigns and have personnel hired specifically for coordinating information and meeting with the citizens.

4 Findings

In the following chapter the main findings of the interviews are presented. Analysis, discussion and reflections of these findings are presented in Chapter 5.

During the period June-September 2011 a total of 46 interviews took place. Full lists of the interviewees as well as the questions[29] asked are shown in appendices I and II. There are 290 municipalities in Sweden. Many of the waste companies interviewed are serving more than one municipality, hence the interviews conducted covered information regarding 93 municipalities in total, representing more than 30 percent of Sweden's municipalities, see Appendix IV.

The responses from the interviews were summarised and the findings categorised into appropriate sub-system (users, organisation, technology) according to the analytical framework presented in Section 2.3.

The focus of this assessment is on AD of food waste. This is mainly because the All-Party Committee for environmental objectives clearly has pointed out AD as the preferred option in their proposal of a new milestone target for food waste treatment (see Section 1.4 Focus and delimitations). Hence, municipalities reporting composting as means of treatment were asked what the barriers are for switching to AD. Below is a summary of the findings in general. For the sake of convenience Sweden has been divided into eleven regions, for which the findings are presented and generalised. Further analysis of the findings and the implications, strategies for overcoming the barriers etc. is presented in the following chapter.

The geographical regions are indicated on maps displayed subsequent to each section. These regions are by no mean completely in line with county boundaries, but rather serve as guidance for the reader(s).

South of Sweden - 1

In the most southern county of Sweden, Skåne, there seems to be a general barrier caused by the organisation in the various municipalities. For example, the political willingness to prioritise food waste management is not uniform across all municipalities, and the presence of a large waste-to-energy plant seems to have delayed the implementation of food waste collection systems. Some municipalities have recently started collecting food waste and their systems are not fully implemented. Apart from organisational issues, many municipalities indicate that there is a need to work with the users in order to increase the amounts collected.

Southeast of Sweden - 2

In the counties of Blekinge and Kalmar there is a general tendency to point to a lack of technology, in this case lack of AD capacity. There are plans to build an AD facility in Blekinge and there are ongoing discussions on whether to build an AD facility and if so where in the county of Kalmar. Organisational issues, such as collaboration between

[29] Appendix II shows the questions posed to municipalities and waste companies. Other interviews, not directly related to the performance and implementation of food waste management in municipalities (e.g. biogas experts) were customised for the occasion with a set of individual, relevant questions.

municipalities, play a crucial role in the development of food waste collection systems in this area. An exception is Gotland (the island east of the mainland), which is struggling to make the users, mainly the tourists, sort out more food waste

Southern Sweden (mid and west) - 3

In the counties of Kronoberg, Halland and Jönköping there seems to be problems in organising collaboration among the municipalities. In Halmstad (Halland) the focus has been on food waste from businesses and the local policy makers have not yet agreed on whether or not collecting food waste from households should be a priority. Lack of technology to treat packaged food waste has been mentioned by several interviewees.

Figure 4-1 below shows a rough overview of the geographical regions 1-3 as presented in the above sections. Table 4-1 indicate which sub-systems, in accordance to the analytical framework, have been identified based on the interviews.

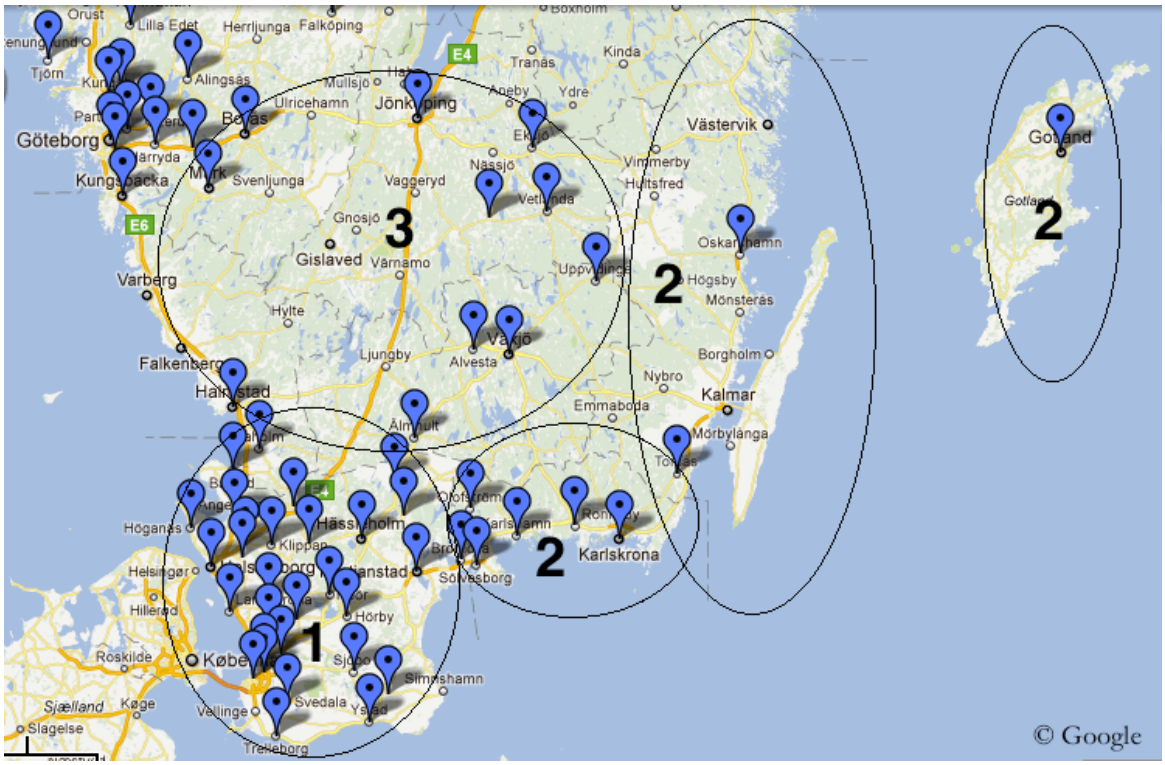


Figure 4-1: Regions 1-3 of Sweden assessed based on the barriers to food waste management identified in the interviews (based on Avfall Sverige, 2010e; Google maps).

Table 4-1: Identification of sub-systems responsible for barriers to food waste management in selected interviewed municipalities and waste companies in Skåne, Blekinge, Kalmar, Gotland, Kronoberg, Jönköping and Halland.
Dark grey with diagonal stripes indicates major barrier, whilst horizontal stripes indicates minor barrier.

Interviewee	Includes the following municipalities	Users	Organisation	Technology
Skåne (1)				
Nårab	Klippan, Perstorp, Örkelljunga			
NSR	Bjuv, Båstad, Helsingborg, Höganäs, Åstorp, Ängelholm			
VA Syd	Malmö, Burlöv			
LRV	Lund			
Merab	Eslöv, Hörby, Höör			
Sysav	Burlöv, Kävlinge, Lomma, Lund, Malmö, Simrishamn, Sjöbo, Skurup, Staffanstorp, Svedala, Tomelilla, Trelleborg, Vellinge, Ystad			
Blekinge (2)				
VMAB	Karlshamn, Sölvesborg, Olofström			
Kalmar (2)				
KSRR	Kalmar, Mörbylånga, Nybro, Torsås			
Oskarshamn	Oskarshamn			
Gotland (2)				
Gotland	Gotland			
Kronoberg (3)				
Växjö	Växjö			
Uppvidinge	Uppvidinge			

Jönköping (3)				
Jönköping	Jönköping			
Gislaved	Gislaved			
Halland (3)				
HEM	Halmstad			

Western Sweden - 4

In the area around Gothenburg (*Göteborg* in Swedish) in the county of Västra Götaland there seems to be two main barriers hindering the development of food waste management. Firstly, the municipality of Gothenburg is struggling to increase the amounts of collected food waste. They are battling this matter by hiring extra personnel to work with quality and quantity related issues among the users. Secondly, many municipalities around Gothenburg have recently started implementing food waste collecting systems (hence lack of "technology"). Implementing such systems are time consuming and the results of their efforts cannot yet be assessed. No interviewee has reported lack of capacity for AD to be a barrier in this area.

Mid-eastern Sweden – 5

In the counties of Östergötland, Örebro, Västmanland and Södermanland there seem to be two main barriers; the users and the organisation. In Västmanland food waste collection systems have been in place for many years and the current focus is on increasing the amounts sorted out by the users, both households and businesses. However, in Södermanland and Örebro politicians do not fully support the collection of food waste and/or the switching to AD from current practises of composting. Some municipalities have quite recently started implementing food waste collection systems and have not yet assessed the results.

Eastern Sweden - 6

Generally the focus in the area around Stockholm has been, and still remains, on food waste from businesses such as restaurants and canteens. To be able to access the majority of the food waste the focus must be expanded to households as well. Failure to do so can be regarded as an organisational issue. Due to the high density of population and the physical structures, implementing a food waste collection system is often difficult. There are a number of different systems used at present and coordinating and evaluating the effectiveness of these systems has proven most difficult. An exception is Uppsala, where food waste from households has been a priority for a long time. Good results in terms of percentage of collected food waste have been achieved, but focus remains on achieving a higher collection percentage whilst still keeping a good quality.

Region 4-6, as defined above, are presented in Figure 4-2 along with a summary of the findings, based on the analytical framework, in Table 4-2.

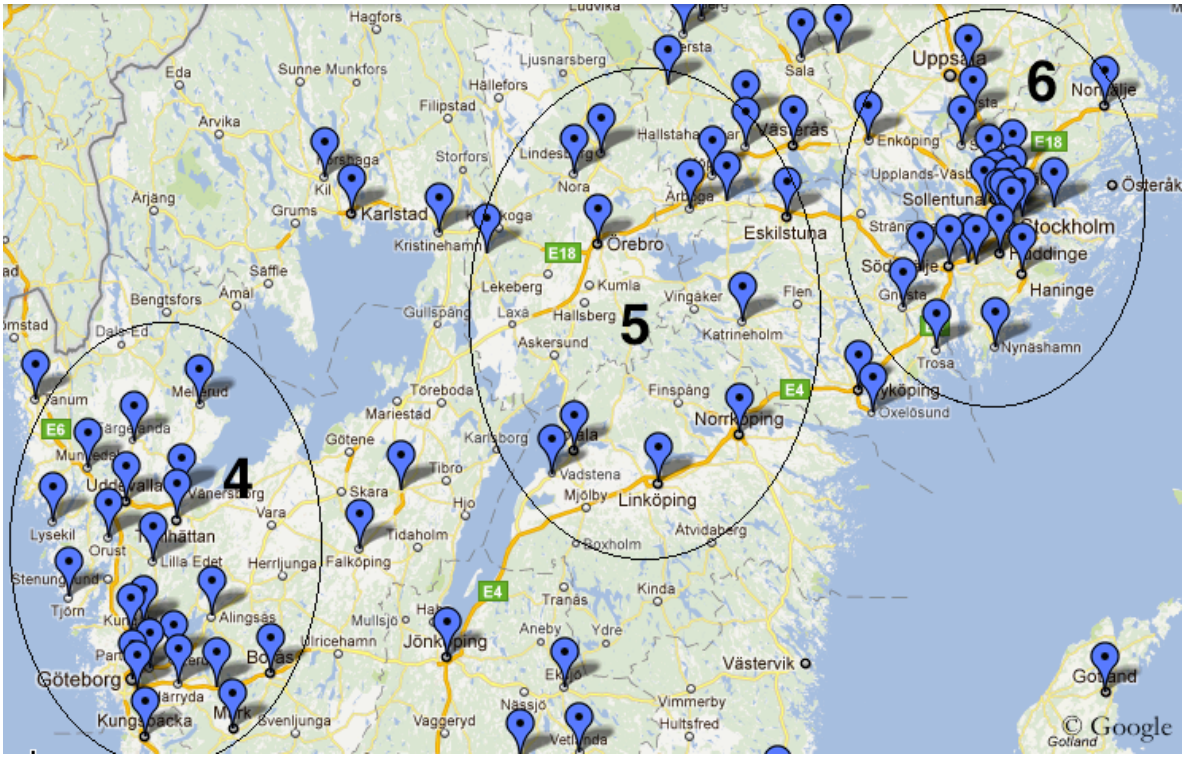


Figure 4-2: Regions 4-6 of Sweden assessed based on the barriers to food waste management identified in the interviews (based on Avfall Sverige, 2010e; Google maps).

Table 4-2: Identification of sub-systems responsible for barriers to food waste management in selected interviewed municipalities and waste companies in Västra Götaland, Västmanland, Örebro, Östergötland, Södermanland, Stockholm and Uppsala.
Dark grey with diagonal stripes indicates major barrier, whilst horizontal stripes indicates minor barrier.

Interviewee	Includes the following municipalities	Users	Organisation	Technology
Västra Götaland (4)				
Göteborg	Göteborg			
Västmanland (5)				
Vafab Miljö	Arboga, Fagersta, Hallstahammar, Kungsör, Köping, Norberg, Sala, Skinnskatteberg, Surahammar, Västerås, Heby, Enköping			
Örebro (5)				
Örebro	Örebro			

Östergötland (5)				
Norrköping	Norrköping			
Tekniska Verken	Linköping			
Södermanland (5)				
Eskilstuna Energi & Miljö	Eskilstuna			
Sörmland Vatten	Flen, Katrineholm, Vingåker			
Stockholm (6)				
Stockholm	Stockholm			
SRV Återvinnare	Huddinge, Haninge, Salem, Nynäshamn, Botkyrka			
SÖRAB	Danderyd, Järfälla, Lidingö, Sollentuna, Solna, Stockholm, Sundbyberg, Täby, Upplands Väsby, Vallentuna			
Uppsala (6)				
Uppsala Vatten	Uppsala			

Mid-west of Sweden - 7

In the county of Värmland there are very few municipalities that have started sorting out food waste. The interviewees indicated that this is most likely due to low political priority or the fact that many municipalities await starting up until they have learned from municipalities with existing systems and/or until there is an existing AD facility in place in this region. It thus seems to be a matter of organisational capability and lack of satisfying technology. In the municipality of Karlstad, which has an existing food waste collection system, the focus is on increasing the amounts of food waste sorted out by the existing users as well as trying to get more multi-family complexes to join the collection system.

Mid Sweden - 8

There are some similarities in the barriers experienced by the counties of Dalarna and Gävleborg. In the county of Dalarna, there is an existing collaboration among the municipalities around lake Siljan. There are ongoing discussions in this collaboration on whether or not to invest in an AD facility, but no decisions have yet been taken. There is little available infrastructure for biogas, hence large investments are needed in order for the municipalities to be able to switch to AD instead of today's composting. On the other hand, the municipalities in Gävleborg have come a long way in terms of the collection system and are collecting much of the food waste from households and businesses. The existing

infrastructure for composting is well developed and the two main barriers for switching to AD are a long contract with the local composting facility and a political fear to run into problems with, for example, utilising the bio-fertiliser as a result of switching to AD. To be able to treat more food waste, technology for treating packaged food waste from retailers is needed, which is currently lacking in this region.

Figure 4-3 and Table 4-3 below show the regions, as defined in the previous section, as well as a summary of the findings and barriers identified during the interviews.

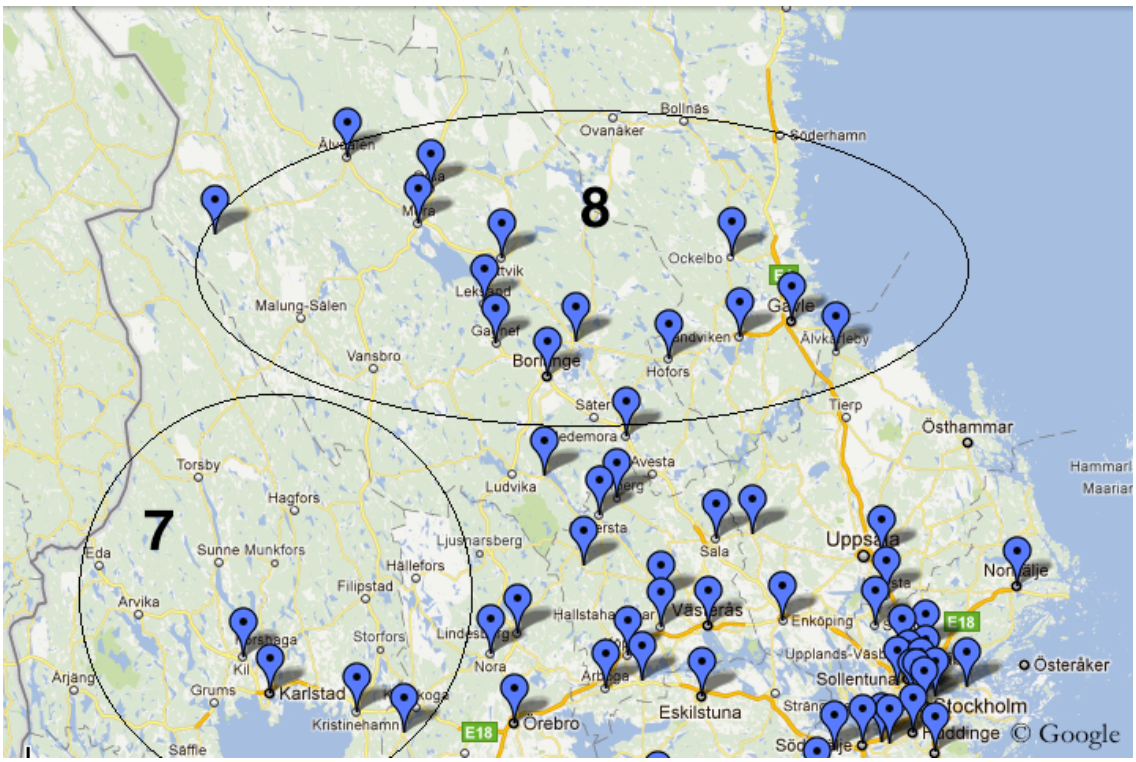


Figure 4-3: Regions 7-8 of Sweden assessed based on the barriers to food waste management identified in the interviews (based on Avfall Sverige, 2010e; Google maps).

Table 4-3: Identification of sub-systems responsible for barriers to food waste management in selected interviewed municipalities and waste companies in Värmland, Dalarna and Gävleborg.
Dark grey with stripes indicates major barrier, whilst lighter grey indicates minor barrier.

Interviewee	Includes the following municipalities	Users	Organisation	Technology
Värmland (7)				
Karlstad Energi	Karlstad			
Kristinehamn	Kristinehamn			
Dalarna (8)				
Falun Energi &	Falun			

Vatten				
NODAVA	Mora, Orsa, Älvdalen			
Smedjebacken Energi	Smedjebacken			
Gävleborg (8)				
Gästrike Återvinnare	Gävle, Ockelbo, Hofors, Sandviken, Älvkarleby			

Mid-north Sweden – 9

In this region of Sweden the only two municipalities collecting food waste are Östersund (in the county of Jämtland) and Sundsvall (in the county of Västernorrland). Both are currently composting the food waste, but there are ongoing discussions regarding an AD facility in Sundsvall that would treat food waste from both of the municipalities. Apart from lack of AD capacity in the vicinity, there is also a lack of technology to treat packaged food waste from retailers. Sundsvall started collecting food waste quite recently and has not been able to assimilate enough volumes to make it profitable to build an AD facility without receiving food waste from other municipalities.

Both interviewees report that other municipalities in this region consider the sparse population to be a barrier for collecting food waste. The extra transports needed for this purpose would not be environmentally or economically justifiable and waste analysis show that the amount of food waste remaining in the mixed fraction is already very low.

North-western Sweden - 10

Again, only two municipalities in the region collect food waste, namely Umeå and Skellefteå. The collection system in Umeå is not fully implemented due to existing contracts with entrepreneurs. To further increase the amounts collected the municipality is focusing on getting businesses, such as restaurants and canteens, to join the collection system. The interviewee indicated similar tendencies as in Västernorrland and Jämtland (the counties south of Umeå), meaning the sparse population and the lack of manpower as being the primary barriers for other municipalities in the region to set up food waste collection systems.

The geographical regions 9-10 are displayed in Figure 4-4 below along with Table 4-4, which summarises the identified barriers for each county based on the structure of the analytical framework.

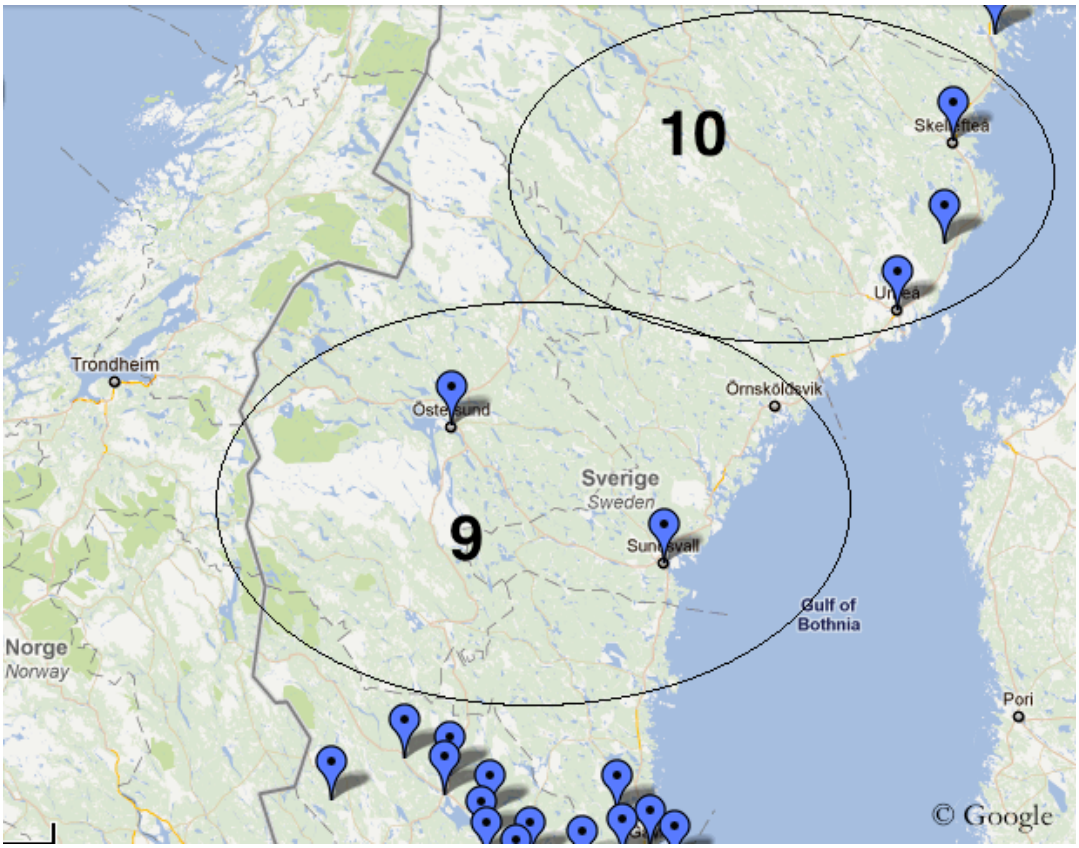


Figure 4-4: Regions 9-10 of Sweden assessed based on the barriers to food waste management identified in the interviews (based on Avfall Sverige, 2010e; Google maps).

Table 4-4: Identification of sub-systems responsible for barriers to food waste management in selected interviewed municipalities and waste companies in Jämtland, Västernorrland and Västerbotten.
Dark grey with diagonal stripes indicates major barrier, whilst horizontal stripes indicates minor barrier.

Interviewee	**Includes the following municipalities**	**Users**	**Organisation**	**Technology**
Jämtland (9)				
Östersund	Östersund			
Västernorrland (9)				
Sundsvall Energi	Sundsvall			
Västerbotten (10)				
UMEVA	Umeå			

North of Sweden – 11

Similar to the counties south of Norrbotten this is a sparsely populated region of Sweden, and several interviewees have reported this aspect as a major barrier for municipalities to set up food collection systems. All of the municipalities in Norrbotten that have existing food collection systems are using composting as means of treatment. In terms of switching to AD there seems to be two prevailing barriers in place, one being long contracts with the private composting facility that have been signed by the municipalities utilising this service. The other barrier seems to be connected to population density, since several interviewees pointed out that the amounts of food waste are too low for it to be profitable to build an AD facility. Finally, there is a lack of technology available to treat packaged food waste from retailers. This is a barrier for moving further in terms of increasing percentage of food waste collected.

The geographical region of Norrbotten is indicated in Figure 4-5. Table 4-5 show a summary of the barriers, in accordance to the analytical framework that was identified through the interviews.

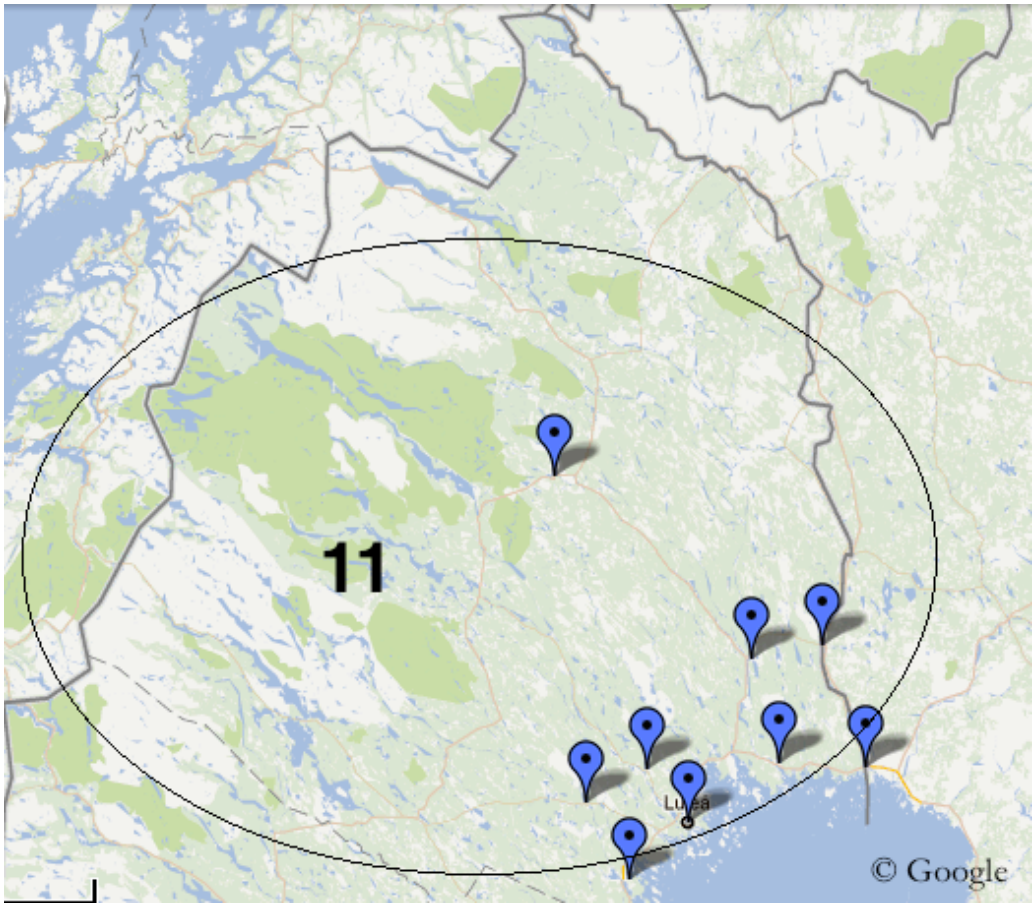


Figure 4-5: Region 11 of Sweden assessed based on the barriers to food waste management identified in the interviews (based on Avfall Sverige, 2010e; Google maps).

Table 4-5: Identification of sub-systems responsible for barriers to food waste management in selected interviewed municipalities and waste companies in Norrbotten.
Dark grey with diagonal stripes indicates major barrier, whilst horizontal stripes indicates minor barrier.

Interviewee	Includes the following municipalities	Users	Organisation	Technology
Norrbotten (11)				
Luleå	Luleå			
Gällivare	Gällivare			
Överkalix	Överkalix			

Below is a map of Sweden showing all of the eleven defined regions. The purpose of the map is to give the reader(s) a better idea of how the regions are dispersed in Sweden, from north to south and east to west.

Figure 4-6: Map of Sweden displaying the eleven regions defined in Chapter 4 (Google maps).

5 Analysis

The following chapter builds on the findings addressed in Chapter 4. Firstly, an attempt to conclude the general drivers and barriers to treatment of food waste using AD will be presented followed by individual sections for each of the sub-systems (users, organisation, technology) defined in the analytical framework.

5.1 General drivers and barriers

During this study I have come across a series of obstacles that seem to hinder the spread out and increased usage of AD as means of treatment of food waste. However, there are also several factors that work in favour of AD.

Generally, there seems to be a high awareness of the positive aspects of using biological treatment for this fraction of MSW. The majority of the interviewees reported that the national environmental objective regarding food waste had been a major driver in terms of setting up food waste collection systems or assessing the possibility to do so. Many even said the objective was the determining factor, otherwise waste management would have carried on as business as usual. These statements are supported by the findings presented in the Proposal for a Sector-transverse Biogas Strategy, which was published by the Swedish Energy Agency in 2010 (Swedish Energy Agency, 2010).

On the EU level the Landfill Directive and the revised WFD are policies that strongly focus on diverting waste from landfills. However, these policies do not seem to have any substantial impact on the increase of biological treatment since incineration of waste also is rendered acceptable as an alternative option to landfilling. I have come across discussions on introducing a tax on food waste being incinerated as a way to promote biological treatment. However, it would be very difficult or even politically impossible to initiate such a tax as long as the EU member states do not agree on whether waste incineration is disposal or recovery of waste.

Apart from obvious drivers, such as the national environmental objective concerning food waste, there are several indirect drivers that affect food waste management in one way or another. Nationally, there are some indications of a political will to increase the production of biogas, which is shown, inter alia, through the issuing of a sector-transverse biogas strategy. The region of Skåne has taken the issue of biogas one step further by presenting a road map for how to develop the biogas production in the region, with the goal of reaching 3 TWh by 2020 (Region Skåne, 2010b, p. 3). Although the focus is not specifically on food waste, all substrates will be needed to achieve this very ambitious goal, which is a ten-fold increase of today's production. Nationally there is no quantitative goal for biogas production, although the Region of Skåne and the Region of Västra Götaland have been trying to convince the national government to set a goal of 20 TWh of biogas by 2020 (Region Skåne, 2010a). Their attempts have been unsuccessful so far.

As mentioned above, the Swedish government has commissioned the Swedish Energy Agency, the Swedish Board of Agriculture and the Swedish Environmental Protection Agency to look into how a sector-transverse strategy for biogas could look like, in an attempt to increase the production of biogas (Swedish Energy Agency, 2010). The report concludes, among other things, that biogas production from waste products should remain the primary focus. The strategy also states that food waste collection by municipalities should be further developed, and those municipalities utilising composting should consider switching to AD. Among the many things proposed in the strategy, introducing a tax on commercial fertiliser

to promote bio-fertiliser and a need for further research on refining of bio-fertiliser to make it more profitable are noticeable. The report also concludes that any future grants for the production, upgrade and/or distribution of biogas should be focused on AD of waste, sludge and manure. However, the authors also state that the production side, rather than the demand side, is in most need of economic support..

Finally, the report establishes that biogas production from waste products has unique benefits, which no other forms of renewable energy can offer and the greatest benefits of biogas arise from utilising the biogas as substitution for diesel in heavy vehicles such as public transport (Swedish Energy Agency, 2010). All in all the proposed sector-transverse strategy for biogas presents some beneficial elements, but few tangible policy instruments, for further development of biogas production from food waste. Would the proposed strategy have been more outspoken regarding suggestions for hard measures it would have served, at least in theory, as a driver for municipalities to invest in food waste collection systems. However, in its current phrasing the strategy offers little or no re-assurance to municipalities regarding the government's position on future biogas production support.

There are a few interesting drivers for increased usage of biogas as vehicle fuel. One example would be the EU policy for road transports which states that ten percent of all road transports should be powered by biofuels in 2020 (WWF, 2007). This policy coupled with the Swedish government's vision of a fossil-independent vehicle fleet by 2030 makes an interesting case for biogas (Svensk Energi, 2009-03-11). Non of these policies, however, have a direct effect on biogas production from food waste, but it is important to consider all aspects that have positive as well as negative influences on any part of the biogas production chain.

5.2 Overcoming barriers identified during this study

The approach taken in this study highly rely on the experiences of selected interviewees in terms of obstacles as well as success factors when it comes to the collection and treatment of municipal food waste. The main findings from the interviews are presented in Chapter 4, and these lay the foundation for the following analysis.

Figure 5-1 below shows an overview of some of the general barriers that were mentioned by several interviewees. Using this figure as a starting point, the following three sections will attempt to assess the underlying reasons for the experienced barriers and most importantly trying to analyse the second research question; *How can the Swedish municipalities be supported in overcoming the identified barriers on (a) a national level and (b) on a local level?*

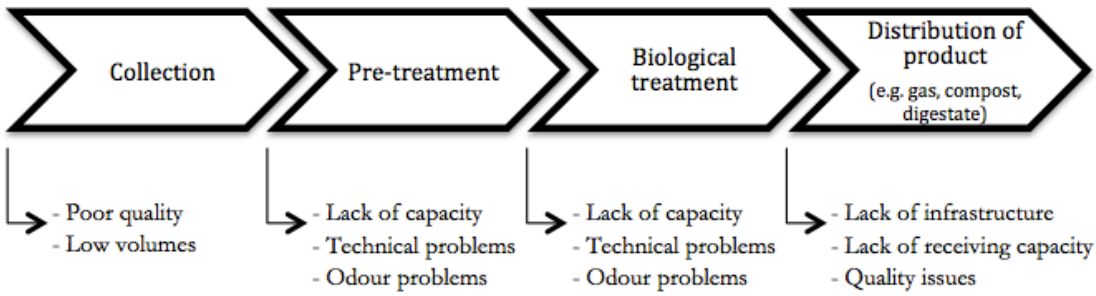


Figure 5-1: A schematic overview of the food waste management chain in Sweden.
The author has identified common barriers for each step in the process.

5.2.1 Barriers caused by users

As shown in various tables in Chapter 4 some municipalities have been assessed as having their greatest barriers caused by the sub-system *users*. The following examples of aspects were mentioned by interviewees, and categorised as barriers pertaining to users;

- Low participation in source separation of food waste by users (households and/or businesses) who has joined an existing food waste collection system.
- Low willingness among users (households and/or businesses) to join an existing food waste collection system.
- Poor quality, in this case contamination, of the collected food waste fraction.

According to the framework used in this study the *users* are those living in households, whether it be single-family or multi-family households, as well as employees and business-owners working in establishments that produce what is considered as municipal food waste. Several municipalities have reported that low volumes and/or poor quality of the collected food waste are barriers for further development of the food waste management system. Poor quality seems to be less of a problem, although what is considered as poor quality is relative depending on what type of pre-treatment is utilised and how the end product is used. In general, municipalities using composting as means of treatment experiences contamination as less of a problem and hence spend less effort on trying to uphold a good quality of the collected food waste. This is an interesting observation since it is likely to take considerable informative actions to raise the quality if the municipality decided to switch to AD (where supreme quality is a precondition). Information activities are expensive, and adding those costs to the costs of switching to AD risks discouraging local decision-makers. It should therefore be a goal for each municipality to always strive for excellent quality of collected food waste.

There seems to be an invisible upper limit for how much a municipality can collect from its residents. Some municipalities which have had a food waste management system in place for a long time report that somewhere around 60 percent of the total estimated available food waste per resident is collected. Beyond that limit it seems to take a large effort, both in terms of time and money, to raise the bar even further. These municipalities often express a need for new technology, which allows them to access packaged food waste from retailers in order to reach higher quota.

There is plenty of available research on what factors motivate *users* to source separate waste, and why some members of the society choose not to do so. Most research I have come across has focused on source separation of packaging, newsprint and other producer responsibility waste products, but there are a few studies, for example Refsgaard and Magnussen (2009) who has looked specifically at organic household waste. Fenech (2002) studied public participation in source separation of waste in Sweden and Malta. In her research she combined various established theories for public participation with empirical findings and identified several motivational factors specific for the Swedish population. Hence, her findings are very interesting to apply in this context.

Although the Fenech framework was developed for waste separation in general, it can be assumed that her conclusions are valid, to a great extent, also for separation of food waste. Hence, the analysis of barriers caused by *users* will largely be based on Fenech's study, although incorporating findings made by other authors as well. Fenech's framework of motivational factors for Swedes is shown schematically in Figure 5-2.

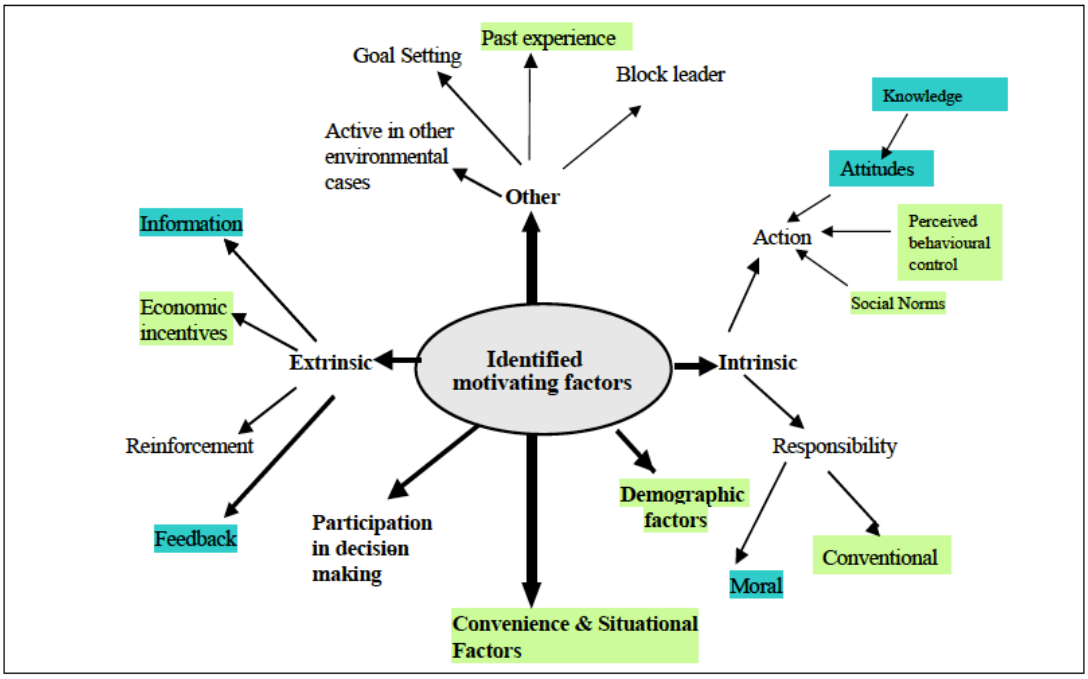


Figure 5-2: Motivational factors in Sweden.
Factors highlighted in blue (darker) represent aspects that have the most important influence in motivating recycling behaviour, green (lighter) highlighted factors show factors that are less important, while those not highlighted have the least importance (replicated with permission from M. Fenech. Fenech, 2002, p. 56).

Attitudes and responsibility

According to Fenech the attitudes towards the environment and the knowledge of why it is important to source separate and recycle waste plays and important part in the Swedish waste management context. Research has shown that attitude formation is an ongoing process in which our attitudes are formed before as well as after carrying out a certain behaviour (Fenech, 2002). This conclusion suggests that information campaigns may very well have a substantial impact on the attitude of residents in a municipality. Below is a more elaborate discussion regarding information interventions.

Two types of *responsibility* was identified in the Fenech study; *moral* and *conventional* responsibility. What differs the two is that moral responsibility is based on moral concepts "[…]such as welfare and the rights of others and fairness considerations." Whilst, conventional responsibility rather is based on knowledge about what authorities as well as social customs and traditions expect of you (Fenech, 2002, p. 16). The study by Fenech showed that moral responsibility is a stronger driver in source separation of food waste, although conventional responsibility also plays a minor part. These conclusions are very useful for policy-makers when trying to understand how to design policy interventions with substantial effects on *users*.

Information and feedback

Information on how to separate your waste was also identified as a crucial factor for Swedes. Fenech concluded that feedback information, for example how much waste was separated and what were the environmental benefits achieved, was lacking in Sweden. Another study

by Refsgaard and Magnussen (2009) on organic waste from households in two Norwegian municipalities displayed similar findings. The participants in their study specifically emphasised that, apart from a user-friendly system, information on how to use the system along with information and assurance that the separated waste was actually recycled was of utter importance. During the interviews several municipalities mentioned that they use the result of waste analysis and/or the result of food waste collection as a base for information campaigns. The observations made in this study regarding the extent of using feedback information are inconclusive with findings from the literature. Hopefully more and more municipalities understand the importance of feedback in order to gain the residents trust and encourage further effort in waste separation. All in all, awareness raising regarding how to source separate food waste, why it is important and the positive benefits of doing so seems to be a very important aspect and should be prioritised by the local policy makers (Tojo, et al., 2008). A few interviewees pointed out awareness raising among children and adolescents as a specific intervention that their respective municipality was engaged in. Mostly these interventions included implementing food waste collection systems in school canteens and in kindergartens. The goal is obviously to raise awareness in a bottom-up perspective by starting with the younger generation and letting them educate and spread the message along to their parents. Similar attempts have been made in several municipalities were food waste collection systems were implemented in municipal institutions to act as good example. None of the municipalities could, however, report any evaluations of these interventions.

Finally, an interesting observation made by Refsgaard and Magnussen (2009) is that people tend to have a more positive attitude towards their existing system for waste handling. This aspect makes it more challenging in terms of designing good information material for a start-up of a new waste management system, since it both needs to be explanatory and convincing. Further on, a piece of advice given by many interviewees is to go slowly when implementing a food waste collection system and give time to the participants to get used to the new way of managing their waste. These conclusions are in line with Refsgaard and Magnussen (2009, p. 769) where they argue that "Changes in collection systems need time to settle. Belief in the action being undertaken and feelings that such action has a significant effect are likely to enhance behaviour." Thus, early focus on convincing the users that a change in waste handling system will result in something significantly positive for the environment increases the chances of success. When food waste is used to produce biogas, and the biogas is utilised locally in, for instance, public transport it seems easier to visualise for the users the positive aspects of their actions.

Economic incentives

In the Fenech study, economic incentives were identified as being a less important factor in terms of motivating residents to source separate their waste. Fenech looked primarily at weight-based billing as the instrument used by some municipalities to encourage better sorting of waste. In this study few of the interviewees reported utilising weight-based billing, and the very essence of the instrument rather motivate users to divert food waste from central collection to home-composting, which is a less preferred option when it comes to increasing biogas production from food waste. Rather the economic instrument most commonly applied in the municipalities interviewed in this study was environmentally differentiated waste charges, meaning that households that separate their food waste pay a lower waste charge than those with mixed waste. Two risks have been identified with this approach. Firstly, finding the correct balance in the environmentally differentiated waste charge so that the difference is large enough to encourage residents to start soring out their food waste, while still being designed in such a way so that it is politically accepted and

economically viable. Secondly, some interviewees have expressed concern regarding having a too large gap in environmentally differentiated waste charge between the charge for mixed waste and the charge for separate food waste. The risk would be contamination of the food waste fraction due to low interest in the actual act of separating food waste from the residual fraction. If money is the sole reason for sorting out food waste, then caring about the quality of the separated food waste becomes secondary, which obviously poses a lower risk if environmental concern is the underlying factor in separating food waste. Bearing these reflections in mind there still seems to be a strong correlation between having an economically encouraging waste charge and separating more food waste (in weight) per resident. Environmental concern is an important element and the power of informing residents on environmental issues should not be taken lightly, however financial incentives appears to be a very important ingredient in designing a successful waste management system from the users' perspective. Refsgaard and Magnussen (2009) as well as Tojo et al (2008) all point out economic incentives as major drivers for users to engage in source separation of (organic) waste. Yet, other studies (see e.g. Constantino, 2008; Huhtala, 1999) have shown that waste charges compose such a small share of the total household budget that many households often do not know the size of their charge. These inconsistences are difficult to explain, yet however should be taken into consideration when designing local waste policies so that additional aspects other than financial incentives are part of the decisions made. For example, residents living in multi-family complexes where most charges are included in the rent probably need incentives, other than monetary, to engage in food waste separation.

Convenience and situational factors

Fenech also talks about convenience and situational factors and their role in users' participation in waste separation. Even though her findings show that these factors are of somewhat less importance it is concluded that even the most environmentally aware person can deter from what is considered desirable behaviour if the situational setting makes it very difficult to act accordingly. Examples could be lack of available infrastructure for source separating food waste, but also the context which you are living in, such as a multi-family household. All of the interviewees have reported that multi-family houses separate less food waste per resident and the separated food waste contain on average more contaminants. Most likely this is a result of two factors, one being the inconvenience of having to separate into multiple fractions when there is generally less space available and the distance to waste collection bins is commonly longer than for families living in single-family houses. The second reason is the anonymity that residents in multi-family houses have, which single-family houses do not have, which can be an explanation for the larger share of contaminants in food waste from these buildings.

A similar case of anonymity emerges in businesses and other institutions. It is less obvious who is to be blamed for contamination of the collected food waste in restaurants, canteens and the like. It seems that convenience and the user-friendliness plays a very large role in terms of maximising the collection of food waste from these settings. Even though it was out of the scope of this study to specifically look at what factors contribute to a successful collection of food waste from establishments other than households there has been some indications from interviewees that convenient solutions and engaged management are success factors. It seems reasonable, even though a deeper analysis is not possible is this study.

When assessing the role of convenience and situational factors one must keep in mind that technological aspects such as infrastructure and the collection system are the primary driver

for these factors to arise in the first place. It is therefore difficult to make a proper assessment since the outcome is bordering, on one hand, on the psychology of the user and, on the other hand, the man-made part of the system (infrastructure and the like). It is therefore impossible to isolate one factor from the other and drawing conclusions based on merely the psychology of the users or the infrastructure in place.

Miscellaneous

During the many interviews other aspects have been raised which are difficult to categorise into merely one of the above categories. For example, it has become evident that social behaviour and norms differ, especially in urban and rural areas. Due to sparse population in some of the northern municipalities of Sweden it was not deemed as environmentally or economically defendable to implement a food waste collection system. However, what was very interesting is also results from waste analysis which show that the proportion of food waste in the mixed fraction was often as little or less than the proportion of food waste in the residual fraction in neighbouring municipalities that had a separate food waste collection system. It seems the traditions and ways of living in some of these sparsely populated northern municipalities has rendered a food waste collection system obsolete. Causes for these observations could include, apart from a less wasteful lifestyle, the presence of domestic pets such as hunting dogs, which consume much of the leftover food (Bjarnhagen, 2011 [Interview]; Skarin, 2011 [Interview]).

5.2.2 Barriers caused by the organisation

The following examples of aspects, mentioned during interviews, has been the background for assessing *organisational* barriers;

- Lack of regional collaboration in order to enable large-scale food collection and/or biogas production from food waste. Both in terms of economic feasibility and required volumes of food waste.
- Ongoing contracts with waste collection entrepreneurs and/or composting facilities.
- Problems pertaining to the Public Procurement Act.
- Lack of support by local policy-makers in terms of implementing separate waste management for food waste.
- Resistance to AD by local policy-makers.
- Lack of staff available to manage a food waste collection system.
- Contradicting national policies.
- Insufficient national policies.

Common organisational barriers

The most common causes for organisational barriers are lack of collaboration and political unwillingness to support the implementation of a food waste collection system. All of the interviewees reported a general political interest in waste issues and especially in biogas. However, in some municipalities the political interest is not enough to motivate the additional costs associated with a change in the waste handling system. A few interviewees stated that their management was not convinced that biological treatment of food waste was the most environmentally beneficial option. Interestingly enough, statements like these correlate very well with municipalities having access to waste incineration facilities owned by themselves or by a publicly co-owned waste treatment company.

Extensive contracts and the Public Procurement Act

Apart from the above-discussed organisational barriers there are other barriers mentioned during the interviews, which fall under the organisational sub-system, but are not as straight forward. Examples include long contracts with composting plants and the Public Procurement Act (*Lagen om offentlig upphandling* in Swedish). Whilst extensive contracts is a straight forward barrier, which solves itself at a certain point in time the Public Procurement Act is a more complex barrier. The reason several interviewees has mentioned the Public Procurement Act as a barrier is mainly due to two reasons. When it comes to procuring a waste treatment service for collected food waste, composting plants have often won since they can deliver a biological service at a considerably lower price. This argument is, however, rather weak considering that a well-written procurement can specify which type of treatment (AD or composting) is sought by the commissioning municipality. The second reason for the Public Procurement Act being a barrier is that several municipalities have brought forth the uncertainty caused by public procurement when it comes to assuring a certain volume of substrate for a planned AD facility. In other words some municipalities have reported that there are plans to build AD capacity but since it cannot be guaranteed to win the public procurement it is difficult to get investors on-board. Similarly, it is difficult to persuade private companies to invest in a biogas plant when the municipality cannot make promises regarding their food waste being delivered to the specific plant.

Ambiguity regarding the definition of household waste

Many interviewees mentioned packaged food waste to be an untapped source of food waste, but due to lack of available technology to access this fraction it remains unexplored. During the course of this study there has been several debate articles published regarding whether or not food waste from businesses, such as for example retailers and restaurants, should be included in the municipal responsibility. Waste from establishments that due to its nature and composition are similar to household waste falls under the municipal monopoly. There are pros and cons of such a legal definition. The pros mainly being that the municipality gets access to larger volumes of food waste and hence can maximise the profitability of biological treatment such as AD. This system also allows the municipalities to plan the logistics so that businesses are included, hence avoiding unnecessary transports. The cons, on the other hand, includes ambiguity regarding exactly what waste is regarded as household waste (Swedish Environmental Protection Agency, 2011g). The problem is currently solved by each municipality making their own assessment and acting accordingly. It creates uncertainty, especially in cases with retail chains that want to procure services for the whole organisation, but due to differing assessments in different municipalities where they are present makes it impossible to do so (Stenmarck, 2011 [Interview]; Östlund, 2011 [Interview]). Many interviewees mentioned lack of technology to handle food waste from retailers as a barrier to developing the food management system. Although this specific example falls under the technology sub-system, the underlying organisational aspect regarding who is the rightful "owner" to this fraction of waste is of the uttermost importance.

Organisational issues from the national government perspective

Another aspect of organisational issues is the signals transmitted by the Swedish national government. As pointed out in a debate article on the Swedish financial newspaper *Dagens Industri*, the All-Party Committee has proposed a rather ambitious increase of the existing environmental target for food waste but their report does not include any proposals for economic support or other policy instruments to help achieve the proposed target (Falck, 14 June. 2011). This can be interpreted either as low interest from the government in biological treatment of food waste or as a belief by the national government that the market for treatment of food waste and biogas production is well developed and that the "wheels are now spinning" on their own. However, well-defined guidelines and policies is a necessity in order to support those municipalities that have not yet started food waste collection and for further re-assurance to those that have started that they are on the right track. This is because separate collection of food waste is, and probably will remain for a long period to come, entirely an additional cost to the municipality. Hence, a pre-requisite for municipalities to engage in such an action is to have a strong belief in the environmental benefits as well as a degree of altruism.

Although there is an additional cost embedded in food waste management the policy decisions made by the national government affects the extension of these costs. For example rescindment of the waste incineration tax in October 2010 resulted in a larger gap between the cost of incinerating food waste in a mixed fraction and treating it biologically, making biological treatment relatively more expensive. This statement has been backed-up by several interviewees. Having visions, such as the environmental objectives, is very important. But it is still only a vision and as long as there is no financial support or firm policies to back up the vision it loses some of its power (Eliasson, 2011 [Interview]).

National policy instruments indirectly affecting food waste management

Several policies decided on the national level eventually affect food waste management on the local level (municipality). Most of these policies pertain to the production and/or usage of biogas. Since the present focus in food waste management is on AD, these policies are highly relevant. Four key policies have been identified as playing a major role in strengthening or weakening the competiveness of biogas, and hence ultimately the needs for food waste as a substrate in biogas production. These policies are: *taxes on biogas*, *taxable value of fringe benefits on biogas vehicles*, *investment grants (e.g. KLIMP)* and *tax on conventional fertilisers*. The arguments regarding tax on conventional fertilisers are described below in Section 5.2.3 due to its close correlation to technology barriers.

Biogas used as vehicle fuel has been exempted from CO_2 taxes since 2002 and energy taxes since 2004, with the exception of value added tax (VAT) (Savola, 2006). However, the tax situation changed in August 2010 when biogas became taxable following the implementation of the Law on sustainability criteria for biofuels and bioliquids (SFS 2010:598). With the introduction of the EU Renewable Energy Directive 2009/28 EC (called the EU RED), biofuels (including biogas) must fulfil certain sustainability criteria in order to continue being non-taxed. The sustainability criteria cover several areas, but most importantly biogas must be produced, in a "well-to-wheel" perspective, so that the resulting CO_2 reduction is more than 35 percent in comparison to the fossil fuel it is substituting. Biogas derived from waste products, such as food waste, generally causes 70-80 percent reduction of CO_2 and, consequently, should not have any problems fulfilling the RED sustainability criteria. However, substantial methane releases from biogas production or upgrading facilities could

decrease the overall CO_2 reduction, and hence must be avoided (Aulik, 2011 [Interview]; Engström, 2011 [Interview]). There seems to be consensus among all waste actors regarding the importance of tax exemptions for biogas as a precondition for its development and competiveness.

Reduced taxable value on fringe benefits (*förmånsvärde* in Swedish) on biogas vehicles has also been pointed out as an important policy instrument for strengthening the demand-side. Taxable value on fringe benefits refers to companies who purchase vehicles to be used as company cars. The government recently announced an extension of the reduced taxable value on fringe benefits on biogas vehicles in their spring budget. The current reduction of 40 percent lower taxable value will run until 2013. Since companies are responsible for the largest purchasing volumes of biogas vehicles, Aulik (2011 [Interview]) points out the importance of stimulating sales of biogas cars via this policy. These vehicles will eventually become available to private consumers through the second-hand market for cars, which makes company cars an important input passage.

Investment grants are a highly discussed topic among the actors in food waste management. In particular the Climate Investment Programme (KLIMP), which aims at reducing emissions of GHG, has been mentioned due to its strong correlation to support of biogas investments. In short, the government put aside close to two billion SEK during the years 2003-2008, which were to be used as financial support to public and private actors planning to invest in projects with GHG emission reductions. Although the window for applications has been closed there are still ongoing KLIMP-financed projects running until 2012. A significant part of the total KLIMP investment grant was used for biogas-related projects, and the results of these projects have been described and evaluated in a report issued by the Swedish EPA. In total 200 projects pertaining to production, upgrade or distribution of biogas was granted financial support through KLIMP. The monetary volume of the grants corresponds to SEK 622 million, or close to one third of the financial means put aside for the KLIMP programme. Calculations of the GHG savings due to biogas-related projects have been estimated to 170 000 tonne CO_2 equivalents/year (Swedish Environmental Protection Agency, 2011c, p. 7). Apart from financial support, the report shows that the KLIMP programme has been a very important signal to the investors and has created stability and faith regarding biogas. The presence of the investment grant for biogas projects has assured the many actors that biogas is a prioritised subject nationally, and that it is something that the government wants to back up. Subsequent grants include the Swedish Energy Agency, which has been given the task of distributing minor sums of financial support to development of biogas technology, but no continuation of larger investment grant programmes similar to KLIMP has been announced by the government. Börjesson (2011 [Interview]) and Eliasson (2011 [Interview]) along with several other interviewees has expressed a need for investment grants for further development of the biogas market, as well as to stimulate technological development and optimisation of existing infrastructure. All actors seem to agree that investment grants is the best way for the national government to give clear and long-term signals vis-à-vis their intentions regarding biogas. However, there is no consensus as to whether or not future investment grants should focus on all biogas technology or primarily focus on innovations. The authors of the sector-transverse biogas strategy also identified investment grants as necessary for continued development of the biogas sector, with special focus on technology development of existing biogas plants as well as small-scale AD (Swedish Energy Agency, 2010).

Biogas production and technology is still a relatively young sector and it needs time and financial support to mature and strengthen its competiveness in relation to the fossil fuel

sector (Ahlm, 2011 [Interview]; Swedish Energy Agency, 2010). Investment grants concerning biogas relates to both the *organisational* and *technological* sub-system, in the food waste management framework. However, awaiting political decisions regarding future financial grants makes it an organisational barrier more than a technological obstacle.

5.2.3 Barriers caused by the technology

Certain aspects, pointed out by interviewees, have been categorised as *technological* barriers. Below are examples of such aspects;

- Lack of pre-treatment and/or AD capacity in the region.
- Lack of available technology for AD of packaged food waste from, for example retailers.
- Existing AD technology is not satisfying.
- Problems pertaining to the bio-fertiliser, such as lack of arable land for distribution of the fertiliser.
- Lack of infrastructure for distribution and/or storage of biogas, such as gas refuelling stations and gas network.
- Problems pertaining to the infrastructure of the food waste collection system.
- Incomplete implementation of food waste collection system.

Barriers that are caused by a lack of satisfying technology seem straightforward at first glance. However, during this study a strong correlation between technological barriers and organisational barriers has been observed. It has thus been somewhat difficult to separate some arguments into one sub-system. Another observation reflects the fact that most barriers appertain to the technology used in the production of biogas, rather than the technological solutions used for the collection of food waste. However, regardless of where in the food waste management chain these technological barriers arise it ultimately will affect the municipality in charge of the food waste management. Below follows the analysis regarding why and how barriers caused by technology emerge and how they are related to the organisation.

Lack of AD capacity

Firstly, it can be concluded that lack of AD capacity in the vicinity has been a very rare argument put forth by the interviewees. Peter Mellbo (2011 [Interview]) at KSRR, the waste company operating in the area around the county of Kalmar, pointed out that there is a lack of AD facilities in the nearby area and that plans regarding building an AD plant exist. This is interesting since many other interviewees reported that food waste could be transported very long distances without substantial losses of energy. This statement is backed up by Berglund (2006) and Mc Cann (9 June. 2011). Obviously, long distances are also an economic issue, why there are many reasons for wanting to build regional biogas production capacity. In the most northern counties of Sweden many interviewees also reported a lack of AD capacity. This is, however, to be expected since the conditions for AD are less beneficial due to less available substrate and lack of arable land for deposition of bio-fertiliser.

It has been argued that lack of AD capacity is a major barrier for an expansion in production of biogas in the Stockholm-area. However, this study does not show any indication of this argument being correct. A recently published report issued by Kommunförbundet Stockholms län (KSL – The municipalities federation of Stockholm county) backs up my findings. According to the report the demand for biogas is greater than the supply and since

municipal food waste along with sludge from wastewater treatment plants[30] (WWTP) are the primary substrates for biogas production there is a need to increase the collection of food waste. Further, the authors conclude that there is available capacity for both pre-treatment and AD of food waste in the county (KSL, 2011). It is interesting to see that the authors of the KSL report also identify the organisation (in this case the local decision-makers) as the largest barrier to increased collection and treatment of food waste in the Stockholm area. Although the infrastructure as such in this highly populated region makes it physically difficult to set up food collection systems, what really is a barrier is that there is a lack of coordination regarding biogas production from food waste. A collected effort to map the potential and most importantly a definite decision to start collecting food waste, especially from households, is key in order to boost biogas production. Hence, there is definitely a strong correlation between the organisational sub-system and the technological sub-system in this part of Sweden.

Financial support for biogas plants

Currently, there is no financial support for production of biogas. It has been proposed in the sector-transverse biogas strategy to introduce a methane reduction support programme of SEK 0.2 per kWh (approximately € 0.02) of biogas produced from manure (Swedish Energy Agency, 2010). Although this has no direct effect on food waste, such a production support programme could stimulate actors to build more AD capacity and increased competition for substrates could in the long run make it cheaper for municipalities to deliver food waste since this waste in itself is an excellent substrate for co-digestion.

A report by Hahn et al (2010) looked at biogas projects in various European countries, excluding Sweden. Three preconditions for biogas projects were found, namely; "good and stable legislative framework conditions, easy and transparent permitting procedures, as well as access to financing." (Hahn, et al., 2010, p. 3). Whilst two of the three preconditions seem to be relatively well met in Sweden, the financing precondition is less so. Hahn et al mention Germany as a good example of a European country that has been very successful in implementing biogas projects. The majority of biogas installations in Germany are agricultural biogas plants, hence of a smaller scale. Another difference is that in Germany, as well as the rest of Europe, there is very little upgrade of biogas to vehicle fuel and much more focus on electricity and heat production from biogas (Börjesson, 2011 [Interview]). This primarily is due to two reasons. Firstly, Sweden already has relatively low cost production of electricity and heat from hydropower generation and biomass. Secondly, due to predominant energy (electricity and heat) production from sources considered as low environmental impact there is little encouragement from policy-makers on producers of energy to utilise biogas. In the Swedish case it makes more (environmental) sense to substitute diesel in buses with biogas rather than substituting biomass in combined heat and power (CHP) plants. Germany, on the other hand, has a power mix that is based on a larger extent on fossil sources. Hence, the German government desires to increase the usage of renewable sources in the production of energy (Börjesson, 2011 [Interview]).

Renewable energy production in Germany is stimulated by a legislative framework called the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, or EEG), which has introduced a feed-in tariff scheme for electricity production. Since 2009 biogas is included in the EEG feed-in tariff scheme. In short, the feed-in tariff scheme is designed so that

[30] The potential for biogas from WWTP sludge is realised to its full potential according to the report (KSL, 2011).

producers of biogas are guaranteed compensation for the electricity fed into the grid during twenty years. This system allows for investors in biogas capacity to better make calculations on expected revenue, as well as knowing that they will receive financial compensation for an extended period (Hahn, et al., 2010). Various similar policies have been discussed among biogas actors in Sweden, and several suggestions, including a tradable certification system have been proposed by the CEO at SRV Återvinning, one of the largest waste treatment companies in the Stockholm area (see Falck, 14 June. 2011).

Barriers pertaining to the bio-fertiliser

Difficulties selling the bio-fertiliser produced during AD of food waste have been mentioned during the interviews. In some cases these difficulties pertain to lack of arable land fitted for utilising bio-fertiliser. However, the most common problem refers to an absence of confidence in the quality of the product. A few organisations such as the Swedish Dairy Association (*Svensk Mjölk*) has presented a policy, which does not permit their members, the Swedish dairy farmers, to use bio-fertiliser from biogas plants utilising municipal food waste as a substrate. The arguments put forth in favour of such a ban pertain to risks of contamination of the bio-fertiliser since traceability of food waste is difficult (Svensk Mjölk, 2010). Other arguments that have been raised in the ongoing debate are lack of risk assessments on the utilisation of bio-fertiliser. Some interviewees also mention regional traditions among the farmers as an important factor when it comes to selling bio-fertiliser. Whatever reason is the primary cause for problems disposing of the bio-fertiliser, it has become clear during the course of this study that successful AD facility operators have full focus on marketing and building trust among the local landowners. Another interesting approach mentioned by one of the interviewees was to involve the local farmers early on in the process of planning for a biogas plant. This way the farmers could take part in the full process and gained a better understanding of what the bio-fertiliser consisted of and how it could be used most successfully. Similar problems in terms of disposing of the remaining product post composting has not been reported by any of the interviewees. However, most municipalities utilising composting say that the remaining composted product is often used as a soil improver in municipal parks or used in the production of topsoil for covering old landfills. Hence, compost products are less often subject to sales externally and therefore requires less marketing efforts.

As of January 2010 the tax on conventional fertiliser was abolished. This makes it more difficult for bio-fertilisers to compete, and the willingness to pay for the bio-fertiliser among the farmers has gone down. Since sales of bio-fertilisers are part of the revenue for a biogas plant the tax abolishment caused implications. However, in the sector-transverse strategy for biogas a review of the possibility of re-introducing a tax on conventional fertiliser is proposed, as a way to strengthen the value of bio-fertilisers (Swedish Energy Agency, 2010, p. 49). This seems very contradictory since such a tax was recently abolished, making it safe to assume that all biogas plant operators will closely follow the development of this specific issue.

Collection systems for food waste

An interesting observation made during the many interviews is that the choice of collection system for food waste is highly adapted to the local circumstances, and no collection system for food waste seems to be overrepresented. However, without any prior knowledge of the collection systems applied in the selected municipalities the interviews showed that the most common collection system is separate bins. Most commonly paper bags are distributed to the

households, in which the food waste can be thrown and later stored in the separate bin awaiting pick up and transport to a pre-treatment facility. Interestingly enough separate bins as most preferred choice of collection system reflects Sweden as a whole, according to Avfall Sverige (2010d).

Other municipalities have reported using an optical system where the food waste is sorted into a coloured plastic bag (most often a green bag), whilst the residual fraction is sorted into a differently coloured bag. The bags are then collected in the same waste truck and sorted by colour in an optical sorting facility. The pros of this system include lower implementation costs due to the possibility of avoiding using multiple bins. The optical collection system is especially appreciated in less densely populated areas since there is no need to increase the number of vehicles and/or switching to multiple compartment trucks. However, a report issued by Avfall Sverige (2011f) looked at different collection systems for food waste and concluded that there is a statistically significant difference between the volumes of food waste collected using different collection systems. The four-compartment system, used for instance in Lund municipality, came out on top in terms of collected volumes of food waste per person. The same study showed that food waste collected using the optical collection system was the most contaminated. Apart from these observations, another interesting result is that households having a separate food waste collection system, regardless of the type of collection system, generated on average less waste (Avfall Sverige, 2011f). This is not a new phenomenon, but makes an interesting case since waste reduction is at the top of the EU waste hierarchy.

Infrastructure for distribution of biogas

In August 2011 Energigas Sverige (the Swedish Association for Energy Gases) announced in a press release that sales of vehicle fuel gas[31] (*fordonsgas* in Swedish) increased with 35 percent during the first six months of 2011 (Energigas Sverige, 24 August. 2011). There has been a steady increase in sales of biogas in recent years, which has lead to a need for more gas refuelling stations. According to Energigas Sverige (24 August. 2011) the cost of building a gas refuelling station is approximately four times greater than a conventional refuelling station. A financial grant for, among others, the establishment of gas refuelling stations was abolished during 2010, which makes it more difficult to acquire funds for further projects (Swedish Environmental Protection Agency, 2011b). Whether or not the revoked grant has an effect on future biogas sales remains unknown, but this action indicates that the national policy-makers believe that the market for biogas sales now is strong enough to make it without extra financial support.

An issue that has been raised during some interviews as well as in debate articles on the Internet pertains to the expansion of the natural gas pipeline network, which today exists in southwest of Sweden. Some interviewees have argued that lack of a natural gas network makes it difficult to distribute the produced biogas and hence is a barrier to future expansion and development. Others claim that such an expansion of the natural gas pipeline would be unnecessarily costly and risk causing a situation where we become more dependent on natural gas. There is, however, an interesting correlation between the geographical dispersion of the natural gas pipeline and the areas of Sweden where usage of biogas is mostly developed. This suggests positive synergy effects between the two gases since such a network

[31] The mixture of natural gas and biogas is referred to as *fordonsgas* in Swedish. The reason for mixing natural gas with biogas is simple that there is not enough biogas to meet the demand. However, biogas comprises around 60 percent of the mixture on a national average (Aulik, 2011 [Interview])

allows for full utilisation and storage of the produced biogas. A gas pipeline also enables a constant supply of gas (in other words acts as a back-up), which makes it a more reliable fuel source for vehicles in need of gas. These observations are supported by several well-versed experts in the field (Ahlm, 2011 [Interview]; Börjesson, 2011 [Interview]; Eliasson, 2011 [Interview]). Instead of further expanding the natural gas network, a regional biogas pipeline running between municipalities with substantial biogas potential would be more cost efficient according to Ahlm (2011 [Interview]) and Börjesson (2011 [Interview]). This idea is currently being realised in parts of Stockholm were the local gas provider, Stockholm Gas, is connecting gas refuelling stations via a pipeline (Energigas Sverige, 24 August. 2011).

Miscellaneous

The EU is currently working on establishing end-of-waste criteria for a range of waste streams. End-of-waste criteria refer to when waste ceases to be waste and instead "becomes" a by-product (Avfall Sverige, 22 August. 2011). Such criteria could potentially have implications for the management of bio-fertiliser and compost, depending on how the EU chooses to define it. Was the EU to define bio-fertiliser/compost as a product, rather than waste, it is likely to be subject for various other regulation including the chemical regulation REACH[32] (Blom, 2011 [Interview]). No final end-of-waste criteria have yet been established for bio-fertiliser/compost, hence an assessment of future effects is not possible at this stage.

5.3 Synthesis of the analysis

Residents taking part in source separation of waste (in this study called users) will always be potential barriers for municipalities in developing successful waste collection systems. In the case of food waste, users are tremendously important since they are the determining factor for quality of the collected food waste, and eventually the quality and usefulness of the end-product (compost or bio-fertiliser). Informing the users on how to use the system, designing convenient collection systems and providing feedback are key elements that every municipality must work with. Feedback information is a sometimes overlooked aspect, and whether it be publishing collected volumes of food waste on the municipal website or public campaigns demonstrating how buses as running on food scraps (raw material for biogas production) it remains utterly important. Information activities are, however, expensive and require personnel. Hence, local policy-makers must make clear and long-term decisions regarding food waste management and sufficient support for implementation. Economic incentives coupled with outspoken targets and vision for food waste management is key.

In terms of organisational issues causing barriers to increased food waste collection and biogas production of the waste, there is a strong connection between policies decided on the national level and actions taken on the local level. Waste incineration is, currently, a far more dispersed and utilised way of disposing of waste, including food waste. In 1999 when the Landfill Directive came into force, the Swedish policy makers took quite drastic actions banning landfilling of all organic waste as of 2005. This decision did not leave much time for local governments (municipalities) to assess viable options for waste management of this fraction beyond 2005. The interviews have shown that some municipalities saw this as an opportunity for adapting biological treatment, but most municipalities chose to rely on incineration, most likely since waste-to-energy technology is a more developed technology. It is rather obvious that the Swedish government is positive towards waste incineration. Few waste policies are opposing waste-to-energy, and the waste incineration tax implemented in

[32] REACH stands for Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals.

2006 was abolished in 2010. Hence, waste-to-energy plants are strong competitors to biological treatment, especially AD since it is more costly compared to composting. It has been suggested that waste incineration should be part of the EU emission trading scheme (ETS), and such an inclusion would most likely make waste incineration more expensive and hopefully favouring biological treatment (Östlund, 2011 [Interview]).

During the current politically favourable climate for waste-to-energy, it is necessary for the national policy-makers to make up their minds and be clear in their intents regarding biogas production. The proposed milestone target for 2015 clearly express that AD of food waste is what is preferred, but policy instruments and support are needed to get there. Some brave, curious and environmentally interested municipalities have already started on the path towards large-scale utilisation of energy and nutrients from food waste, but far too many municipalities need an extra push to get started. It is expensive to switch from conventional waste management (incineration) to biological treatment, and local decision-makers need to know that investing in this switch does not lead to a dead-end but rather something that Swedish policy-makers will support in the long-term.

Locally, there is plenty of room for organisational improvement in terms of food waste management. From north to south there have been reports of lack of collaboration as well as some evidence of territoriality when it comes to waste management in general. Biological treatment, especially AD, is a rather new phenomenon in comparison to landfilling and incineration and it often takes skills beyond traditional engineering to pull off a successful operation of an AD plant. This in itself can seem scary for local waste managers and their superiors (local decision-makers). Again, it has become evident that collaboration, both in terms of knowledge sharing, accumulating satisfying food waste volumes and to raise financial funds, is a precondition to pull off biogas production from food waste. But collaboration should also be expanded beyond the traditional actors to include other substrate owners such as farmers and food-industry. Involving farmers also opens up for a dialog regarding utilisation of bio-fertiliser, which is a barrier in itself would the bio-fertiliser not have a receiver post AD.

Technology for composting and AD has not stood out as a barrier to increased biological treatment of food waste in this study. A few interviewees have pointed out lack of AD capacity in the region as a hinder, but it does not seem to be the determining factor for implementing a food waste collection system or not. However, a situation where lack of biogas plants is a problem would occur if the majority of all municipalities were to start collecting food waste, and those that already have would drastically increase the collected volumes. Hence, construction of new AD facilities should carry on, but without financial instruments available to support investments there is a chance of a catch-22 situation occurring where municipalities await AD plants before introducing separate food waste collection, and AD investors wait for municipalities to start collecting. Some evidence of this phenomenon has been reported by interviewees in mid-Sweden (the counties of Jämtland and Västernorrland).

More research on risks associated with bio-fertiliser as well as how to make it a more competitive product is needed. If bio-fertiliser from biogas production using food waste as substrate gets traduced the same way digested sewerage sludge has, then it can be a substantial barrier findings alternative ways of disposing of it. Furthermore, closing loops and recycling nutrients back to arable land is one of the greatest aspects of biogas production and hence the task should not be taken lightly.

Distribution and sales of upgraded biogas has not been discussed to any greater extent in the interviews. What can be concluded is that demand for biogas is greater than supply, and consequently producers of upgraded biogas has no problems in selling their product. Ways of distributing biogas have been discussed, and the interviewed actors' views are somewhat inconclusive. There are pros and cons as to whether biogas is distributed in pipelines or by road transports in compressed tanks. Furthermore, the ongoing technological development concerning liquefied biogas (LBG) makes it difficult to assess if distribution of biogas will be a significant barrier in the future.

6 Conclusions

In the following chapter conclusions drawn based on the findings (Chapter 4) and analysis (Chapter 5) are presented. Reflections on the methodology as well as suggestions for future research are submitted as well.

6.1 Revisiting the research questions

There is no one-size-fits-all solution to the problem of overcoming barriers and achieving the proposed environmental objective regarding food waste. Measures and policy interventions need to be custom-made for each of the identified regions, and local governments (municipalities) need to focus on the specific problem at hand in their area. It also becomes clear that putting full focus on one of the sub-systems (users, organisation, technology) would not be wise. However, waste education in schools, which already occurs to some extent, is an excellent opportunity to teach our young ones about the unique case of biogas; a renewable form of energy, produced from waste products, such as our food leftovers, which can power our buses and cars and help grow new food.

In a way, AD is a lock-in technology. It is a large investment, and AD plants have a long payback time. However, the numbers of studies showing the positive benefits of biogas production are overwhelming and it is safe to say that taking a political decision to go for biogas production could not be criticised as a rushed decision. Biogas production from waste products does not compromise society's needs for land to grow food and raise cattle, unlike some other forms of renewable fuels.

Two research questions have been used as guidance during the course of this study. The first research question has been addressed in Chapter 4 and discussed in Chapter 5.

> *(1) What are the barriers experienced by Swedish municipalities in terms of increasing treatment of food waste biologically, and specifically using anaerobic digestion?*

No general conclusions, except in a few cases, have been possible to be drawn in terms of pointing out specific barriers to specific geographical regions of Sweden. As expected population density, distances and climatic aspects are the prevailing barriers in the most northern parts of Sweden. Since the greatest potentials for biogas production exists in the southern parts of Sweden, most efforts towards food waste collection and AD should be made in those areas. In terms of biogas production, most is produced in the aforementioned regions but in general these regions are falling behind when it comes to collecting food waste from households and establishments.

The second research question has been touched upon in Chapter 5.

> *(2) How can the Swedish municipalities be supported in overcoming the identified barriers on (a) a national level and (b) on a local level?*

Most drivers and barriers identified in this study are caused by policies decided nationally or locally. Below, however, are the conclusions drawn concerning how national and local governments should support the municipalities.

National government

Firstly, the national government must signal long-term policy instruments that are in line with the formulated goals in the proposed milestone target for biological treatment of food waste. A national measurable biogas target, similar to the one adapted by the Region of Skåne, is a precondition for providing stability and trust in biogas being a priority area.

Although food waste management is the focus of this study, competitive and profitable biogas production is a prerequisite for municipalities engaging in AD of food waste at all. Hence, strong policies regarding biogas production, distribution and usage is a must. The government needs to take every action necessary to keep biogas non-taxed, as this is a precondition for its ability to compete with well-established fossil fuel options. Furthermore, investment grants and/or programmes for favourable investment loans for construction of biogas plants are an evident part of increased biogas production in Sweden.

Funding of research programmes, especially on issues regarding bio-fertiliser, has the possibility to greatly assist AD plant owners, including municipalities. If we want to close the loop between production and consumption, we must find ways to securely recycle nutrients back to arable land. Such research programmes are preferably coordinated by competent authorities, such as the Swedish EPA, for creditability and efficiency reasons.

Interventions specifically aiming at supporting municipalities in food waste collection and treatment include focusing on waste incineration. As discussed in the previous chapter, Swedish policy-makers are signalising positivism towards waste-to-energy by abolishing the incineration tax. Instead, a tax on incineration of food waste would be a very strong signal in favour of biological treatment, and would most likely get more municipalities on board with the idea of separately collecting food waste. Alternatively, the management at waste treatment companies can choose to distort the market by adopting policies similar to environmentally differentiated waste charges. An active decision to do so could include setting the gate fee for waste being incinerated higher than waste going to biological treatment. This option is, however, not in the hands of the national government per se, but rather a more local level possibility. Whatever policy instrument chosen, it is apparent that waste-to-energy plants are major competitors to biological treatment and they are, at least partly, responsible for the slow development of biogas production from food waste.

Networks for closer and better collaboration among the many waste actors, especially the municipalities and public waste companies, needs to be improved. Collaboration is key if we are to achieve large enough quantities of food waste to make it profitable to use AD, and in order to efficiently plan logistical issues. The national government could assist by assigning more centralised authorities, for example the County Administrative Boards, responsibility for setting up networks where needed and help existing networks coordinate their work on issues including knowledge sharing, assessment of food waste volumes available for AD and the like.

Finally, there is a large cost involved in implementing a food waste collection system. Much of the cost is associated with operating the system as such, but a non-neglected part of the cost is associated with informing the users. I believe that the national government could assist the municipalities in this area by, for example assigning the Swedish EPA a more active role as a national coordinator of material for public campaigns. Financial means could also be allocated to influential actors such as interest-associations in order for them to distribute information among their members.

Local government

The local policy makers have to realise the unique educational value of implementing food waste collection systems. By collaborating with other municipalities and exchanging experiences there are great possibilities for "leapfrogging" the missteps taken by other early adapters. There needs to be clear political decisions allowing enough time and manpower to thoroughly assessing the right technical system, as well as support, for example mandatory collection included in the waste plan or environmentally differentiated waste charges to make a food waste management system successful.

Informing the participants, in this case the residents, on how to use the system, as well as feedback information is crucial. Enough resources need to be put aside for these matters. The work also needs to be systematic, preferably with early involvement of stakeholders such as property owners and farmers.

To some extent it can be argued that the national government has not been clear in their visions regarding food waste management and biogas production. However, it is most unlikely that the national decision-makers will pass any policies strictly opposing future development of biogas production. Hence, local decision-makers should adapt policy instruments in favour of separate food waste collection and AD. By combining command-and-control policies (including food waste collection in the waste disposal plan), economic instruments (environmentally differentiated waste charge) and informative actions (public campaigns) a successful policy intervention can take place.

Finally, municipalities play a significant role in the biogas production chain, since it is up to them to make their users separate food waste satisfyingly. Contamination of the food waste causes complications downstream and informative actions thus become utterly important. As pointed out by Fenech (2002) and discussed in the previous chapter, getting participants (users) to separate out food waste is far more complex than just supplying convenient systems and information on how to use it. These aspects should be taken into consideration by every municipality, and again knowledge sharing becomes evident as an ingredient for designing good public campaigns and other policy interventions. One must keep in mind that policy instruments decided at a national level regarding waste management most often are designed to change the behaviour of less centralised authorities (in this case the municipalities), whilst waste policy instruments implemented by the local government are aiming at changing the behaviour of all individual decision-makers (in this case the users). The latter assignment is generally far more difficult.

6.2 Reflections on the method used

Looking back on the study it would have been interesting to interview an even larger sample of actors in the waste area. From a time perspective, however, that would have not been possible. Also, a chance to interview several people from the same organisation would have been fascinating in order to see if their respective views of the current waste management situation matched.

Another reflection made is that the list of municipalities having a fully or partially implemented food waste management system was not always correct. As I discovered there are municipalities which have no system in place what so ever on that list, certainly there must also be municipalities that are not on the list but do have a system in place. For the sake of this study it played an insignificant role, but I would recommend a new inventory to compile a fully updated list of the current food waste management situation in Sweden.

The choice of method as such, using interviews to compile information, were in my view fully satisfactory. The design of the interviews, which all but one took place by telephone, followed a structure of open-ended questions. This is very important to point out, otherwise I believe much information would have been left out. As an interviewer I have tried my hardest to remain neutral, not asking any leading questions. However, since I have worked on my own not having a colleague to assess me I cannot be completely sure of my performance as an interviewer.

6.3 Suggestions for further research

All in all this study has been on a macro level, generalising which barriers municipalities run into when implementing food waste management systems. Each and every municipality could have been a topic for thesis on its own, and I would be fouling myself if I though that there are not as many regional differences as there are municipalities. Bearing that in mind there are, however, some interesting areas that came to mind during the study, which would be interesting for future research.

- Looking further into what factors influence people working in establishments (for example restaurants, retailers, canteens) when it comes to source separation of food waste. There is quite a lot of research on residents living in households, but the phycology behind actions taken at work has not been explored as far as I can tell.

- Many interviewees mentioned school canteens and kindergartens as areas where the policy makers have made an effort to implement food waste collection, in an attempt to spread the behaviour to parents and other adults. It would be very interesting to evaluate such attempts, as there seems to be no studies on this.

- My impression from the interviews is that there is insufficient information regarding how much food waste is actually generated in establishments. Currently generic data is used in the reporting of this fraction of food waste. It could be very valuable to gain a better understanding and update on municipal food waste generated by non-households.

- Finally, further research on techniques for pre-treatment of food waste, optimisation of AD of food waste as well as possibilities to concentrate the nutrients in bio-fertiliser would be very useful for several actors in this area.

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Legislation

European Community

Directive 99/31/EC on the landfilling of waste.

Directive 2000/76/EC on the incineration of waste.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Sweden

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Appendix I

List of interviewees.

Name	**Organisation**	**Position (in Swedish)**	**Date**
Ahlm, Mårten	Biogas Syd	Projektledare	July 14, 2011
Andersson, Jan	Örebro kommun	Avfallsrådgivare	July 5, 2011
Andersson, Jeanette	Karlstad Energi	Miljötekniker	July 7, 2011
Aulik, Daniel	Energigas Sverige	Vikarierande biogasansvarig	August 31, 2011
Bissmont, Mimmi	VA Syd	Utvecklingsingenjör	June 17, 2011
Bjarnhagen, Cecilia	Sundsvall Energi	Utredningsingenjör	July 1, 2011
Björnfot, Jörgen	Eskilstuna Energi & Miljö	Affärsområdeschef Återvinning	August 22, 2011
Blom, Angelika	Avfall Sverige	Rådgivare biologisk återvinning	Various occations during June – September 2011
Boberg, Ann-Sofi	Oskarshamns kommun	Utredningsingenjör	June 29, 2011
Börjesson, Pål	Institutionen för Teknik och Samhälle vid Lunds Tekniska Högskola LTH	Professor i Miljö- och Energisystem	August 16, 2011
Egelstrand, Anna	Norrköpings kommun	Vikarierande avfallsingejör	July 5, 2011
Eliasson, Gabriella	Biogas i Simrishamn Tomelilla Ystad	Projektledare	June 28, 2011
Engström, Lina	Swedish Energy Agency	Handläggare	September 8, 2011
Flodman, Magnus	Gästrike Återvinnare	Handläggare	June 28, 2011
Genander, Linda	Tekniska Verken i Linköping AB	Kommunikatör och verksamhetsutvecklare	June 30, 2011
Gustavsson, Gunnar	Gislaveds kommun	Miljöingenjör	June 30, 2011
Hallmer, Martin	Sysav Biotech	Planeringsingenjör	June 13, 2011
Hannu, Gun-Marie	Gällivare kommun	VA/avfallsplanerare	July 5, 2011

Heden, Melviana	Falu Energi & Vatten AB	Utvecklingsingenjör	July 11, 2011
Helmin, Mikael	Vafab Miljö AB	Marknads- och kommunikationschef	August 2, 2011
Holmblad, Cecilia	Nordvästra Skånes Renhållnings AB (NSR)	Renhållningschef	June 17, 2011
Johansson, Jonas	NODAVA AB (Norra Dalarna Vatten & Avfall)	Miljöingenjör	July 4, 2011
Jönsson, Erik	Överkalix kommun	Arbetsledare	July 1, 2011
Knutsson, Inger	Smedjebacken Energi & Vatten	Miljötekniker	July 1, 2011
Liwing, Björn	Merab	Miljöingenjör	June 10, 2011
Lundström, Erika	Luleå kommun	Avfallsingenjör	July 5, 2011
Mattsson, Jan	Kristinehamns kommun	Teknisk chef	July 12, 2011
Mattsson, Josefin	Jönköpings kommun	Kommunikatör	June 20, 2011
Mellbo, Peter	Kalmarsundsregionens Renhållare (KSRR)	Utredare	June 16, 2011
Nilsson, Johanna	Trafikkontoret, Stockholms stad	Samordnare	June 30, 2011
Nilsson, Katarina	Region Gotland	Miljöingenjör	June 29, 2011
Nilsson, Pernilla	Växjö kommun	Projektledare	June 29, 2011
Nyberg, Ann-Christine	Sörmland Vatten & Avfall AB	Renhållningschef	June 29, 2011
Olsberg, Elisabeth	Uppvidinge kommun	Gatu- och VA-ingenjör	June 16, 2011
Olsson, Ingrid	SÖRAB	Miljö- och utvecklingschef	June 29, 2011
Persson, Michael	Uppsala Vatten	Avfallschef	June 30, 2011
Persson, Sandra	Norra Åsbo Renhållnings AB (Nårab)	Renhållningsansvarig	June 15, 2011
Pettersson, Sara	Kretsloppskontoret, Göteborgs stad	Processledare	June 30, 2011
Rensvik, Åsa	SRV Återvinnare	Utvecklingsingenjör	June 27, 2011

Rudsten, Moa	UMEVA	Miljöingenjör	June 29, 2011
Skarin, Ola	Östersunds kommun	Renhållningschef	June 28, 2011
Stenmarck, Åsa	IVL – Swedish Environmental Research Institute	Avfallsexpert	June 16, 2011
Sternsen, Göran	Västblekinge Miljö AB	VD	July 5, 2011
Wilhelmsson Göthe, Anna	Lunds Renhållningsverk	Miljö- och marknadschef	June 17, 2011
Winkler, Andreas	Halmstads Energi & Miljö AB (HEM)	Avdelningschef	August 11 & 22, 2011
Östlund, Catarina	Swedish EPA	Handläggare	June 8, 2011

Appendix II

Examples of questions posed to the interviewees (municipalities and waste companies). The questions have been translated into English.

Interview questions (municipalities having a food waste collection system)

1. How do you organise your work?
    a. Collect food waste using own manpower or via contract with entrepreneurs?
    b. Who is responsible for information efforts, e.g. on how to sort out food waste?
    c. Who is responsible for fulfilment of goals and targets?

2. When (what year) did you begin collecting food waste separately?
    a. How did you go about starting up? Pilot trials, single-family houses first etc.?
    b. What kinds of information efforts were taken in connection with the start-up of food waste collection?

3. When (what year) was the political decision taken regarding implementing food waste collection?
    a. What was the background for such a decision?

4. Did you cooperate with other municipalities/actors prior to the implementation of a food waste collection system?
    a. For example study visits?

5. How far have you come in food waste collection?
    a. How much (in percent) is collected?
    b. How is this measured?
        i. For example waste analysis of the residual fraction?
    c. How is the collected food waste treated?
        i. Composting or AD?
        ii. If AD, food waste digested separately or co-digested with other substrate?
        iii. Is pre-treatment of the food waste undertaken by your organisation?
        iv. Are there any economic incentives for biological treatment of food waste rather than incineration (e.g. cheaper gate fees/treatment fees)?

6. From which sources do you collect food waste and how much?
    a. Establishments such as canteens, restaurants, retailers and the like?
    b. Single-family households?
    c. Multi-family households?

7. Which system is used for food waste collection?

8. Is sorting out food waste mandatory or voluntary?
    a. If voluntary, are there any economical benefits of engaging in food waste collection?

9. How is the quality of the collected food waste?

10. In your opinion, what is needed to increase the amounts of collected food waste?

11. Is there a food waste collection target, for example in tonnes or percentage?
    a. When (year) are you aiming to reach the target? Time plan?

12. Which barriers have you come across during the implementation of a food waste collection system?
    a. Where does these barriers arise?
    b. Why do you think these barriers exist?

13. Any success factors?

14. Have you noticed any positive or negative side effects of food waste collection?

15. What is the primary driver for working with food waste collection and biological treatment?

16. Have the national environmental objective regarding waste affected the decision to implement a food waste collection system?
    a. Is a new national milestone target for 2015 going to affect your work in any way?

17. How do you stand in terms of home composting?
    a. Is it encouraged by offering a lower waste charge?

Interview questions (municipalities NOT having a food waste collection system)

1. How do you organise your work?
    a. Collect waste using own manpower or via contract with entrepreneurs?

2. Are there any plans, or have there ever been any plans, to introduce a food waste collection system?
    a. If No, why not?

3. What are the barriers for introducing a food waste collection system?
    a. Lack of/low political support?
    b. Too expensive?
    c. Lack of capacity for biological treatment?
    d. Ongoing entrepreneurial contracts?
    e. Other?

4. What does the municipality look like, meaning;
    a. Mostly single-family households
    b. Mostly multi-family households
    c. Sparsely populated
    d. Densely populated

5. Any drivers for environmental work of other kinds?

6. Any collaboration with other municipalities in other environmentally related matters?

7. Any targets/goals within waste management?

8. How do you stand in terms of home composting?
    a. Is it encouraged by offering a lower waste charge?

Appendix III

Reasons for food waste in the Household sector (European Commission, 2010, p. 10).

Food waste from meal preparation, leftovers, and purchased food not used in time comprise food waste in the household sector. Causes for this waste involve:

- Lack of **awareness** of (1) the quantity of food waste generated individually, (2) the environmental problem that food waste presents, and (3) the financial benefits of using purchased food more efficiently.

- Lack of **knowledge** on how to use food efficiently, for example by making the most of leftovers, cooking with available ingredients.

- **Attitudes**: food undervalued by consumers, lack of necessity to use it efficiently.

- **Preferences**: many (often nutritious) parts of food are discarded due to personal taste: apple skins, potato skins, bread crusts for example.

- **Planning issues**: 'buying too much' and 'lack of shopping planning' frequently cited as causes of household food waste.

- **Labelling issues**: misinterpretation or confusion over date labels is widely recognised as contributing to household food waste generation, leading to the discard of still edible food.

- **Storage**: suboptimal storage conditions lead to food waste throughout the supply chain, including in the Household sector.

- **Packaging issues**: packaging methods and materials can impact the longevity of food products.

- **Portion sizes**: includes issues such as "making too much food" hence leading to uneaten leftovers as well as purchasing the correct portions of food; individually sized portions can minimise food waste but often create additional packaging waste.

- **Socio-economic factors**: single person households and young people generate more food waste.

Appendix IV

List of interviewed municipalities and waste companies.

Name	**Including**
Eskilstuna Energi & Miljö AB	Eskilstuna
Falu Energi och Vatten AB	Falun
Gislaved	Gislaved
Gotland	Gotland
Gällivare	Gällivare
Gästrike Återvinnare	Gävle, Ockelbo, Hofors, Sandviken, Älvkarleby
Göteborg	Göteborg
Halmstad Energi & Miljö (HEM)	Halmstad
Jönköping	Jönköping
Kalmarsundsregionens Renhållare (KSRR)	Kalmar, Mörbylånga, Nybro, Torsås
Karlstad Energi AB	Karlstad
Kristinehamn	Kristinehamn
Luleå	Luleå
Lunds Renhållningsverk (LRV)	Lund
Nordvästra Skånes Renhållnings AB (NSR)	Bjuv, Båstad, Helsingborg, Höganäs, Åstorp, Ångelholm
Norra Dalarna Vatten & Avfall (NODAVA)	Mora, Orsa, Älvdalen
Norra Åsbo Renhållnings AB (Nårab)	Klippan, Perstorp, Örkelljunga
Norrköping	Norrköping
Smedjebacken Energi AB	Smedjebacken
SRV Återvinnare	Huddinge, Haninge, Salem, Nynäshamn, Botkyrka
Stockholm	Stockholm

Sundsvall Energi AB	Sundsvall
Sydskånes avfallsaktiebolag (Sysav)	Burlöv, Kävlinge, Lomma, Lund, Malmö, Simrishamn, Sjöbo, Skurup, Staffanstorp, Svedala, Tomelilla, Trelleborg, Vellinge, Ystad
Söderhalls Renhållningsverk AB (SÖRAB)	Danderyd, Järfälla, Lidingö, Sollentuna, Solna, Stockholm, Sundbyberg, Täby, Upplands Väsby, Vallentuna
Sörmland Vatten	Flen, Katrineholm, Vingåker
Tekniska Verken	Linköping
UMEVA	Umeå
Uppsala Vatten	Uppsala
Uppvidinge	Uppvidinge
Va Syd	Malmö, Burlöv
Vafab Miljö	Arboga, Fagersta, Hallstahammar, Kungsör, Köping, Norberg, Sala, Skinnskatteberg, Surahammar, Västerås, Heby, Enköping
Västblekinge Miljö AB (VMAB)	Karlshamn, Sölvesborg, Olofström
Växjö	Växjö
Örebro	Örebro
Östersund	Östersund
Överkalix	Överkalix