Organic Waste Management and the Creation of a Collection Pathway in Denmark

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ABSTRACT

Organic waste within Denmark is not utilized to its fullest potential. Denmark incinerates the vast majority of its organic waste, which has potential to be utilized by biogasification plants. The current issue is the fact that there is not an organic waste sorting system within households to support a biogasification expansion. Our project focuses on assessing the organic waste sorting methods in Denmark as well as the factors that can hinder developing new sorting practices in the Danish population. Our findings will reveal the barriers and motivations that are most important to the citizens of Denmark in implementing a household organic waste sorting system.

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1.0 INTRODUCTION

In the evolving economies of the world, resources are becoming increasingly limited and waste is being produced at a rapidly increasing pace. Around the world, 2 billion tons of municipal solid waste (MSW) were produced per year as of the new millennium (Giusti, 2009). In recent years, however, populations have undergone a paradigm shift in which waste is regarded as a potential resource and not as a health or environmental problem. This has motivated initiatives to convert waste into a usable material, with systems such as incineration and recycling. Biogasification is one of these systems, where organic waste is used as raw material for methane production. However, new technologies such as these lack the proper infrastructure. Given that different waste types require separate management systems; one of the main setbacks to these initiatives is that in most cases, waste is collected without sorting.

Each year Denmark incinerates 1 million tons of organic household waste (Copenhagen Cleantech Cluster, n.d.). Denmark's incinerators are some of the cleanest in the world, but even the best incinerators can only reduce waste volume by 70-80%, meaning that waste still gets sent to landfills (Danish Government, 2013). Furthermore, the full potential of organic waste will never be realized if it continues to be incinerated. Denmark wants to be fossil fuel independent by 2050, and they are working toward this goal by investing heavily in sustainable technologies. While the majority of sustainable energy in Denmark is created through wind power, an important component of wind power production depends on wind speeds, which fluctuate significantly over time. Denmark needs to supplement wind energy with other, flexible energy sources, and this is where organic waste comes in.

Biogasification is a system in which organic waste is decomposed by microorganisms. This process produces methane and a phosphorus-rich material which can be used for heat, electricity and as a fertilizer (Al Seadi, 2010). However, most municipalities across Denmark do not have an organic waste sorting system currently implemented and there is not enough waste available to increase biogas capacity (Ministry of Environment and Energy, 1999). As of 2011, about one quarter of the total waste produced in Denmark is household waste (Danish Government, 2013), but without biogasification this resource goes unused. On the national level, the government has set a goal to separate 300,000 tonnes of "wet" organic waste by 2022 (Danish Government, 2013). Our sponsor, Dansk Affaldsforening (Danish Waste Association), wants to further

understand the technical and motivational factors that will come into play when implementing household food waste sorting in municipalities across the country.

The goal of this project is to assist Dansk Affaldsforening in its goal of understanding these factors while also maximizing the use of organic waste as a resource. The team will assess organic waste sorting practices already in place as well as the psychology concerning organic waste sorting at the household level. We will achieve this through surveys, personal interviews, and by reviewing current outreach information programs. The team hopes to gain particular insight into organic waste sorting systems when visiting neighboring countries Germany and Sweden. From our research we will present our findings to our sponsor which will aid them in future efforts to encourage a organic waste sorting behavior in Danish citizens.

2.0 LITERATURE REVIEW

International and Danish communities are currently facing a rise in waste production and increasing political demands for sustainable and environmentally friendly waste management. A need has arisen for the installment of new and more efficient methods of treating waste and the creation of an infrastructure to support biogasification. Additionally, the Danish government has implemented a new model for waste management which focuses on treating waste as a resource rather than as an expendable factor.

This section will give an overview of the current organic waste management system in Denmark, and focuses on the sustainability goals and new directions in policy that have emerged. Next we will discuss the current waste management methods of landfilling, incineration and biogasification. We will delve into the Danish waste model, practical aspects of household food sorting in Denmark, and examples of sorting methods already implemented. Finally the team will examine the social implications of recycling which will include past studies on Danish recycling behaviors and elements of successful information campaigns along with specific examples.

2.1 Organic Waste Management in Denmark

Using organic waste to produce biogas has the potential to reduce greenhouse gas emissions as well as contribute to global sustainability goals in general (Hoogijk, van den Broek, Berndes, Gielen, & Turkenburg, 2003). Biogas could potentially become a major global primary energy source over the next century if countries around the world commit to developing the necessary infrastructure to make it a feasible energy source (Berndes, Hoogwijk, & van den

Broek, 2003). There has been increased awareness about the environment over the last couple of decades around the world. This increased environmental awareness has led to many countries trying to decrease their reliance on fossil fuels and decrease the carbon footprint overall. Denmark has been one of the leaders of this movement and by starting to view waste as a resource has led them to become a world leader in recovering energy from waste (Danish Government, 2013).

2.1.1 Sustainability Goals in Denmark

For decades Denmark has been a leader in developing environmentally conscious policies and practices. The energy crisis of the 1970's significantly hampered the economies of a multitude of countries. As a result, Denmark has moved towards becoming fossil fuel independent. In 1973, oil made up 92% of Denmark's energy consumption. Since then, this has plummeted to around 40% as of 2010 (Nordic FolkeCenter, 2010). After the crisis, Danes have actively researched and developed renewable energy resources, with a significant focus on wind turbines and biomass. Currently, more than 20% of Denmark's electricity consumption is supplied by wind power (Lund & Mathiesen, 2009).

In 2012, the Danish Parliament passed the single largest environmental development plan in its entire history; the Danish Energy Agreement. This agreement set in place what are undeniably ambitious goals to move towards a sustainable society. The Agreement lays down some short-term goals to be achieved by 2020, which include supplying at least half of the electrical consumption with wind power alone. Additionally, this agreement plans to have more than 35% of the total energy consumed be produced by renewable energy sources, including organic waste (Ministry of Climate, Energy and Building, 2012). The Danish government hopes to achieve a 7.6% reduction of gross energy consumption compared to what was consumed in 2010, as well as reducing its greenhouse gas emissions by 34%, compared to those levels recorded in 1990 (Ministry of Climate, Energy and Building, 2012). This agreement is unique in that no energy agreement has ever experienced such a large support base within the Danish Parliament, and no energy agreement has ever covered such a long spanning time frame.

Ultimately, Denmark wants to become fossil fuel independent by 2050 (Green Living, n.d.), and they are making good progress so far. One of the key aspects to Denmark's success in establishing large scale sustainable practices is their policy making. Denmark offers compelling

incentives to companies and families who adhere to environmentally friendly practices. A good example of this is Denmark's carbon-negative island Samsø. The Danish government offered an appealing tax exemption policy to families that produce their own electricity. Thus, residents of Samsø started developing wind energy in the area, creating cooperatives through which they could manage their investment. The wind farm in Samsø is entirely owned by locals (Larsen et al, 2005).

Part of the country's energy plan depends on the use of biomass. Using biomass as an energy source allows for flexible electricity production, which is necessary to supply the grid when wind production cannot meet electricity demands at a given time. As of 2002, there were around 20 centralized "large" biogas plants and 35 farm-scale plants in Denmark, producing around 2.6 Petajoules (2.6×10^{15} Joules) of energy (Raven & Gregersen, 2004). Denmark is not new to biogasification, but they aim to significantly expand the amount of waste they recycle into these plants in the near future. The Energy Agreement stresses the importance of ensuring biomass expansion in Denmark, up to triple of what is currently produced now (University of Copenhagen, 2012). This will be accomplished through initiatives such as subsidies for biogas used in the industrial and transportation sectors, and a raise of start-up aid for biogas projects from 20% to 30% (Ministry of Climate, 2012).

2.1.2 History of Organic Waste

The history of waste management in Denmark has slowly developed into the current Danish resource management system. This system has a focus and history of incineration of waste spanning over 100 years with constant development and improvement (Copenhagen Cleantech Cluster, n.d.). Originally, waste was viewed as a health and safety concern and the Dane's primary focus was removing and depositing their garbage in massive landfills outside their major cities. As time has progressed, archaic methods of waste treatment such as landfilling have become less and less popular.

As society started becoming aware of the repercussions of dumping waste in landfills, environmental concerns gradually began to grow into the 1970's and 80's as seen in the below figure. This is when a major shift occurred in which people began to view waste as an environmental issue rather than as a health issue (Kleis, Babcock, Volund & Dalager, 2003). Due to this increased focus and awareness on the negative environmental impacts that were occurring,

Denmark became the first country in the world to pass an environmental protection law in 1973 (State of Green, 2011). With little room for landfilling both physically and politically, waste incineration and composting became the next primary waste treatment solutions. Over the past 35 years, both incineration and landfilling have had numerous improvements in both environmental impacts as well as efficiencies in the capture of heat and energy. With this new focus on incineration, the Danish waste management sector was idealized by two major developments within the 80's and 90's, regulation of waste produced and international involvement. With increased international involvement and the gradual development of comprehensive Danish regulations concerning waste handling, Denmark became one of the first countries to achieve high recycling rates and minimized landfilled waste (Copenhagen Cleantech Cluster, n.d).

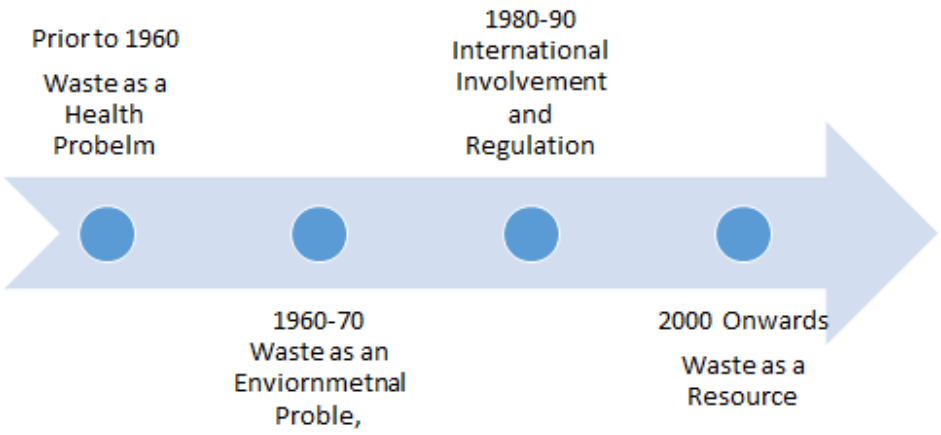

Figure 1: History of Waste Management in Denmark

Until 2004, the Danish government's plan for waste policy was termed 'Waste 21' and focused on the quantitative aspects of waste management, such as minimization and prevention of waste, and increasing recycling throughout the country (Ministry of Environment and Energy, 1999). One of the key principles of Waste 21 is to have more types of waste collected and treated separately to develop new methods of treatment. Additionally, new requirements were implemented to local councils who were responsible for waste management to cooperate across Denmark and internationally to develop new and more efficient waste solutions. Better quality in

waste treatment is now being recognized as necessary to the minimization of the spreading of environmental contaminants and to optimize the utilization of diminishing resources.

2.1.3 "Denmark without Waste" – New Directions in Policy

This new focus on waste is not only a result of the environmental and health safety concerns which are being brought about by the growing waste streams across the globe, but also by a widespread and mounting limitation of resources. Waste can no longer be viewed as an expense or a leftover of production which must be disposed of, but a universal change in view must be considered in which it will become seen as a valuable resource.

This transition from waste to resource, while innovative, still requires basic principles like the harvesting of the energy from the organic waste stream to be efficient and profitable, while simultaneously reintroducing the nutrients that the waste contains back into the agricultural soil for use in food production. When waste companies within Denmark were specifically surveyed about their views on waste, there was a good indication that the companies were in an ongoing transition from waste to resource management. Viewpoints which used to give waste a negative perspective are increasingly moving towards seeing waste as a potential source of profit. This can be seen when the companies were asked to show their expectations for 2012-2017 compared to their performance as of 2006-2011. Their response showed that two-thirds, or 66% of the companies had an increase in turnover, despite the global recession that they were currently experiencing and which continues to this day (Copenhagen Cleantech Cluster, n.d.).

Denmark has been moving towards creating a country without waste including the formation of industrial symbiosis. Industrial symbiosis is the sharing of resources between two companies in which the waste of one becomes the raw materials to be used by the other (Kalendborg Symbiosis, 2014). A few examples of this can be found in the Danish municipality of Kalundborg. This symbiosis not only helps each company involved generate profit, but ensures that all waste is reentered into the industrial cycle as energy, nutrients, or materials for the next generation of production. By closing the loops of different waste streams, companies like Inbicon receive industrial waste from the municipality, and convert it into energy and bioethanol. This ethanol is sold to Statoil, a Norwegian multinational oil and gas company, which exports its waste cooling water to DONG Energy Asnæsværket, which produces heat and energy through incineration of coal and sends its residual fly ash to Gyproc to be used in the production of gypsum (Statoil, 2010. Kalendborg Symbiosis, 2014). By combining the products of one company with the wastes of another, Denmark has been able to create a system wherein energy efficient practices and economics work in harmony.

Figure 2: An example of household organic waste (taken from morgeFile, 1999)

2.2 Waste Management Methods

Throughout history people have come up with different ways of dealing with their waste. Some are simple and involve essentially finding a space where waste can be put out of sight. Other methods have been developed later, in which people try to get the most use out of their waste. This section provides a brief description of the most widely used methods, along with its major benefits and drawbacks.

2.2.1 Landfilling

For many years, landfilling has been the largest waste disposal method in Western Europe, with 57% of solid municipal waste landfilled in 1999 (Giusti, 2009). In 2010, around a dozen European Union countries landfilled more than 60% of their waste (Danish Government, 2013). Landfilling consists of depositing waste in a pre-defined space, usually abandoned quarries or borrow pits. This method is simple and relatively inexpensive, but it has inherent disadvantages. Additionally, if the process becomes mismanaged the landfill has the capacity to have huge negative repercussions for the surrounding population and environment.

Given the mixed composition of the waste placed within them, landfills inevitably release gases such as methane and other greenhouse gases into the atmosphere. Worldwide methane emissions from landfills have been estimated to range from 15 to 20 Teragrams (1Tg=10^12 grams) per year (Spokas et al, 2006). Although methane collection systems have been implemented in a significant amount of landfill sites around the world, this collection system only amounts to around 5 Tg a year (Spokas et al, 2006). Methane is the third greenhouse gas in order of abundance, after water vapor and carbon dioxide, and is responsible for a significant amount of the greenhouse effect (Spokas et al, 2006).

Another significant drawback to landfilling as a method of waste disposal is water accumulation in landfills. Contaminated water accumulated in landfills is called leachate, and if not contained often has detrimental effects in the soil and any nearby water reservoir. This leachate has the capacity to become a major health and safety concern if it begins leaking into a water reservoir used for drinking water as any liquid seepage from a landfill is likely to be contaminated by the waste it encounters due to the mixed nature of the waste itself. Landfilling fails to fulfill the ideal of using waste as a resource. Instead of dealing with rising energy costs and demands as the new Danish objective suggests, landfilling takes up valuable space that could be used for more productive development.

2.2.2 Incineration

Over decades of practice, Danes have become exceedingly proficient at waste incineration. The process consists of placing waste in a furnace, where it is heated and burned. Many incineration facilities use the heat released in the furnace to boil water for a power cycle. Steam generated in a boiler passes through a turbine to power a generator that produces electricity. The steam then goes to a heat exchanger, where it heats up water that is pumped

throughout the city to provide heating. This complete process is called Combined Heat & Power production, or CHP.

Incineration can be highly controlled to maximize its energy output and a large amount of research and effort has gone into the process over the years to make it as efficient as possible. However, a significant amount of effort is required to remove the hazardous byproducts of the incinerated waste. These gases are extremely harmful both to the environment and nearby populations if they are not filtered. Additionally, the leftover ash, which is typically 20-30% of the weight of the MSW, is virtually useless and has to be landfilled, although it is sometimes used as a construction aggregate (Renosyd, 2013).

One of the major drawbacks to using incineration as a method of waste disposal is that a significant amount of municipal solid waste is organic and naturally contains large amounts of water. This kind of waste, which is mostly food waste, will not burn easily due to its high moisture content. This means that incinerators have to spend increased amounts of energy to dry the material before it begins to release energy on its own by burning. Studies have shown that when a large amount of organic waste is collected and treated through incineration, it is less efficient than if it was treated through biogasification (Bolin, 2014). Organic waste has a lot of potential that goes unused when burned, potential that can be utilized through biogasification.

2.2.3 Biogasification

Biogasification is a process by which methane is harvested from decomposing organic material. The waste is placed in sealed containers where it is heated and left for two weeks. Bacteria gradually decompose the waste, which produces a methane-rich gas mix. The biogas can be then purified from its natural 50-70% methane concentration to a 95% concentration (Al Seadi, 2010). At this point, the gas is exceedingly versatile, as it can be stored, transported, or pumped into the gas grid. The gas can now be referred to as biomethane due to its nature as a synthetic natural gas and can be burned with CHP to produce electricity and heat, or it can be used to power gas cars.

It is important to understand that biogasification does not eliminate the need for other waste management methods due to its limitations to strictly using organic and food wastes. Still, it is a much cleaner and more efficient method of treating organic waste than incineration or composting. Using this method, all the methane produced is contained and made available for

use. The solid remainder after biogasification is completed is rich in phosphorus, which makes it usable and sellable as fertilizer increasing the profit from the system even further.

Currently, Denmark lacks an infrastructure to supply enough material to support the planned expansion of biogasification facilities. Still, there is a significant potential in households that can hopefully lead to biogas becoming one of Denmark's main sources of heat and electricity. With the participation of a majority of Denmark's citizens in a new program of sorting and collection organic waste separately from the MSW stream, a new era of green energy and independence from fossil fuels could be seen.

2.3 New Issues and Methods of Organic Waste Sorting

In the words of Ida Auken, the former Danish Minister of the Environment, "Today we incinerate food scraps that could become biogas. We incinerate sludge from wastewater that could be used as fertilizer. And we incinerate electronics that contain noble metals. We have become too good at incinerating and too bad at recycling. And that is why a lot of value is lost. It is bad for the environment and makes no sense in a world where demand for resources increases every day. (Lauritsen, 2013)" This section delves into the current Danish waste model, as well as the barriers to the future improvement of the organic waste sector in Denmark.

Figure 3: An example system for sorting different household wastes (morgueFile, 2000)

2.3.1 The Danish Waste Model

When the "Danish Waste Model" was first developed in 1980, the responsibility for the treatment of all waste, with the exception of recyclable business waste, was placed upon the municipalities rather than the government. This in turn obliges private companies to use the

facilities allotted by the municipalities. This mutual dependence has not only created a system of efficient collaboration but has the potential to create a local collaboration between different companies where the waste of one company is the valuable resource for another.

It can be seen that the transition from waste to resource management not only requires novel techniques and methods of sorting waste, but also requires strong political backing and leadership. To this end, in March 2012 a new Energy Agreement was reached which brings Denmark even closer to its goals of being 100% renewable energy by 2050. The Danish Government is encouraging biomass initiatives by increasing the startup aid for new projects from 20 to 30% (Ministry of Climate, 2012). Even though the Danish biomass market is relatively small in comparison to other European countries, the presence of the world's biggest biogasification test facility in the University of Aarhus and the biggest biomass production facility, Maabjerg Biomass have kept Denmark at the fifth highest biogas energy producer per inhabitant (Andersen & Mortensen, 2014).

As of 2011, Denmark produced approximately 13 million tons of waste, of which 60% was recycled (State of Green, 2011). Of the total waste, 1 million tons was organic household waste and was incinerated. Instead this could have been used in either a biogasification or compositing process, returning the nutrients back to the environment (Copenhagen Cleantech Cluster, n.d.). It is due to this widespread misuse of the organic waste potential that the Danish resource strategy, implemented by the Minister of the Environment, plans to recycle six times as much organic waste from households by 2022 (Lauritsen, 2011).

One of the major challenges facing the creation of biogasification plants is the separation of the organic and biodegradable waste streams from the rest of the ordinary waste supply. In most European countries, biodegradable and organic kitchen and garden wastes are still the biggest fraction of the municipal solid waste stream (DONGenergy, 2011). "When we mix potato peels, paper, shampoo bottles and empty beer cans in the trash bin, it is incinerated and valuable resources end up in smoke. Denmark can reuse twice as much household trash in 2022 through better means of sorting trash" (Lauristen, 2013).

2.3.2 Overcoming Costs Associated with Biogasification

In Denmark, there is a general state tax on waste, differentiated such that it is most expensive to landfill, cheaper to incinerate, and tax exempt to recycle the waste. Municipal

councils can also charge fees to finance their waste management as well, but optimize it to suit their needs. Due to this Denmark enjoys some of the cheapest waste disposal fees in Europe.

Prior to 2003, capital, operation and maintenance costs associated with the normal operation of biogasification systems did not compare well to other alternatives. This was due to the fact that biogasification systems were typically several times smaller than their incineration counterparts. The small sizes of these plants led to higher capital cost per kilowatt and higher operating costs due to the fact that fewer kilowatt hours were produced per employee (Sieger, 2002). These factors, combined with the inexperience of the technicians operating the biogasification systems, made the process as a whole appear remarkably inefficient. However, as with any system, the economies of scale will eventually begin to take over as the system becomes increasingly popular and prices will eventually decrease.

When three biogasification plants were compared to their incineration counterparts in Singapore, the results clearly showed that the net production of electricity was much greater in the biogasification plants. This is extremely important due to electricity being the main profit of the waste treatment plants, with incineration averaging 2/3 Mwh (Megawatt hours) electricity and 2 Mwh heat produced per ton of waste (Copenhagen Cleantech Cluster. n.d.). However, in this study on Singapore, a large biogasification plant was able to produce nearly 450 kWh (Kilowatt hours) of electricity compared to the 175 kWh produced by incineration plants. Additionally from this study, it can be seen that as biogasification plants increase in size, they increase in the efficiency of net electricity produced as well as heat recaptured through CHP (Bolin, 2009).

Given Denmark's goals to become fossil fuel independent by 2050 and its current reliance upon incineration to provide 2 million MWh of heat and 2/3 of a million MWh of electricity, it is imperative that the biogasification systems become as efficient as possible. The net output of electricity from incineration of organic waste is only 40% of that from a large or medium scale biogasification plant. Therefore, a large or medium scale facility seems to be preferable to several small scale facilities scattered throughout the country (Bolin, 2009). Creating a system where organic waste is not only sorted but can be transported to a central large scale facility will create more clean energy than is currently being produced by the

incineration facilities. Additionally this will reduce Denmark's overall dependence upon fossil fuels for heating and energy.

2.3.3 Site Visit to Clark University

Recently, Clark University, a college located in Massachusetts within the United States, began to implement a "If it was ever alive, you can compost it!" campaign. By placing small waste receptacles in three freshman housing dorms, Clark University sought to collect and divert all compostable items in these halls. Previously landfilled items like food and paper towels are now composted through the use of a system wherein students are motivated to participate through the ease of use.

Figure 4: Small bin found next to the sink

Figure 5: The larger bin found outside the dormitories

By creating small composting bins that could be placed atop the kitchen counters of these dorms, students are encouraged to participate in the system due to the ease with which the food waste can be placed within the receptacle. In order to overcome concerns on smell and bugs infesting the dorms, these small bins are moved, every day, to a larger barrel that is kept further away from the rest of the housing. Once the waste is collected in the larger barrel it is allowed to accumulate for two to three days before being removed to an offsite location where it is kept until a bi-weekly collection company moves the waste to an industrial composter. By working in this manner, Clark University has been able to keep the compost sorting area clean of all

negative connotations, as well as removing any bugs or negative connotations that are typically associated with the sorting of organic waste from the rest of the MSW (Clark University, 2014).

2.3.4 Recognized Systems of Sorting

Although creating systems of sorting is extremely important and related to our project, there does not seemed to be a large amount of information available. One of the methods of treating this organic waste once it is sorted is REnescience technology. In this system, the unsorted MSW is treated with water and warmed to 37^0C. Through the addition of enzymes and bacteria the biodegradable materials are liquefied and separated from the non-organic solids. Once the bio liquid is separated is separated from the rest of the MSW, it can be transported to be used in a variety of purposes, including biogas production (DONGenergy, 2011). Through the completion of this project, recognized systems of sorting will be expanded upon through the methodology.

2.4 Social Implications

Within the proposal of any societal change, public psychologies and influences must be addressed. As iterated earlier, one of the Danish government's goals is to be fossil fuel neutral and be running on 100% renewable energy by 2050 (Andersen, 11). This section will discuss the science behind recycling participation. It will then describe how this relates to Denmark specifically and conclude with key factors that will aid in increasing participation rates.

2.4.1 Stages of Change

There have been numerous studies to determine what factors contribute to successful behavioral change. In this case, getting people to participate in a recycling program may prove to be difficult task. When people are deciding to make a change they go through a process known as the spiral model of change (Bourge, 2012).

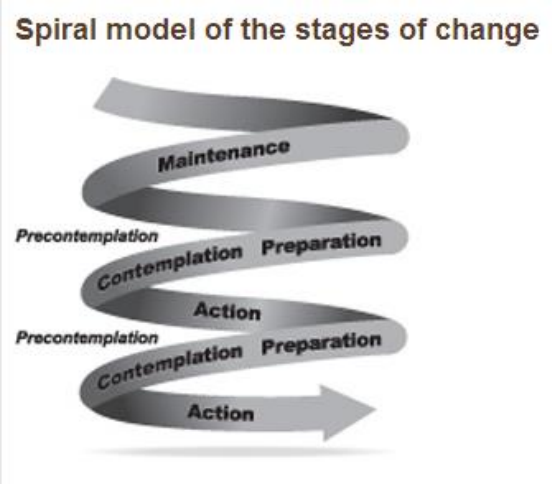

Figure 6: Spiral Model of Change. (Bourge, 2012)

As illustrated above, figure 6 shows the spiral model of change. There are five stages of this process: pre-contemplation, contemplation, preparation, action and maintenance. Pre-contemplation is the stage when the person is not aware of wanting to make a behavioral change. The contemplation stage occurs when the person becomes aware change is needed, but has no commitment to act upon that desire. Some people may remain in the contemplation stage indefinitely and not make a change. For those who take the next step, the preparation stage is experienced and occurs when a person begins to create plans to enact the desired change. After preparation is completed, the action plan is the next stage to be completed, and is where the plan is finally put into motion. After 6 months of this change, there is a maintenance phase where the new behavior will hopefully become habit. There will be relapse into old habits throughout this process which is to be expected. (Berens 2010, Bourge, 2012). The maintenance stage is key in creating a long term recycling behavior and if sustained will soon become a habit; a behavior that is no longer thought about.

To increase recycling participation, the ultimate goal would be to make recycling a personal habit for people. A habit is considered a learned action that soon becomes an automatic response during trigger situations (Knussen & Yule, 2008). However, recycling is an action more difficult to instill good habits into people because it takes a couple of steps to accomplish. For example, to recycle a bottle one needs to wash it, store it, and then put it out to be collected at a later time. Some people find that process to be too much effort. Knussen & Yule's study (2008) in which they surveyed Scottish residents in an effort to determine why residents failed to recycle. The top reasons were lack of recycling habit, facilities were not easily available, and no

local curbside collections were in place (Knussen & Yule, 2008). The study also showed that the lack of recycling habit was due to the lack of recycling in the past. This corroborates with the idea that the frequency of past behavior is a good indicator for future behavior (Oullete & Wendy, 1988). The frequency of past behavior can be used to create a favorable attitude towards that behavior (Eagly & Chaiken, 1993). People are more likely to form favorable intentions about acts they have frequently performed in the past.

2.4.2 Recycling Behaviors in Denmark

In order to increase recycling behavior, it is important to study the psychological factors of behavior and learn the motives of Danish citizens. RenoSyd I/S, a municipality company that has done a past study on the typical recycling behavior of its consumers within its municipalities. These results are a compilation of data from focus groups, interviews at home, and observations of large groups at recycling centers. The parameters RenoSyd I/S judged on were: proactivity, experience, knowledge, interest in learning more, focus on the environment, focus on self, aesthetics, convenience, waste is a problem and willingness to sort waste. Through these parameters seven typical consumers emerged.

The consumers ranged from Anders Ansvar (Anders Responsibility), who is the ideal recycling guy who sorts almost all his waste, to Lief Ligelglad (Leif Indifferent), who just wants his waste to go away and does not care what method is utilized. In between these extremes were consumers who were motivated by aspects like convenience and willingness to sort. (Biener, et al., 2013)

Dansk Affaldsforening has recently published a similar study. The consumers that emerged with respective percentages were: Ida and Ivan Idealist: 30%, Cristina and Claus Convenience: 23%, Paul and Pamilla Pragmatiker (Pragmatist): 36%, and finally Lasse and Linda Ligeglad (Care): 12% (Dansk Affaldsforening, 2013). These identified personas are similar to the ones identified earlier by RenoSyd I/S. The analyses factors used were: idealism, price focus, convenience, aesthetics, other motivators, and satisfaction. As with the RenoSyd I/S study, there were idealists whose goal is to make a difference in the environment. In contrast to that, Christina and Clause convenience were characterized by the idea that sorting should be as easy as possible and they want to make a difference, but sorting itself is a barrier. Paul and Pamilla pragmatist will sort if they must because there are rules, but they do not have any extra

motivation beyond that. Lastly, are Lasse and Linda Ligegland who represent a small population who just do not care about sorting and just cannot be bothered to put in the effort to recycle (Dansk Affaldsforening, 2013). These studies give insight into what the motivations are of the Danish population to sort.

2.4.3 Elements of Successful Campaigns: Learning from the Recycling Change

Successful information campaigns have effective education components that inform and engage the consumer. Traditionally, information campaigns have dealt with recycling by listing off statistics and facts in order to convince the consumer to recycle through the use of logical persuasions. However, limiting the persuasive arguments to this one aspect would be a massive flaw in the multifaceted aspects of convincing consumers to sort their organic waste out of the MSW stream. In 1988, a researcher investigating the motivations behind participation in household recycling practices conducted a pilot study with 200 households and identified the homes as either recyclers or non-recyclers. After the pilot study was conducted, the households were contacted and asked to answer a series of questions in which 91 responded. The conclusions from de Young's study proposed it was not that people were unaware of the environmental benefits behind recycling, but instead that they lacked the knowledge or motivation to even begin. Information campaigns have traditionally attempted to convince the consumer into sorting through negative reinforcement concerning the pitfalls of not participating in the recycling, but do not cover the details on where to begin. From de Young's study (2008), the non-recycler scored highly on the perceived difficulty scaling of recycling indicating that the reason the process seemed to be so difficult was due to a lack of knowledge concerning how the local recycling system functioned. These findings seem to be shared by a wide variety of studies indicating that this is a psychological phenomenon which can be relied to continue into the future.

In the Metropolitan Area of Lisbon (MAL), a study was conducted by Vicente (2008) whose goal was to gain insight into the local household recycling practices. The study showed that households were more likely to participate in recycling programs if the information on recycling was present within the household, as well as if the recycling area's hygiene and areas of location were being improved. Another factor that was included in this study was the presence of children within the home, a factor which typically was not included in the scope of the psychological studies before it. Typically, children tend to be more open towards the creation

and maintenance of creating a recycling system and can often be used to bring a new mindset into a home which otherwise would not be willing to participate (Vicente, 2008).

The idea of viewing children as "a powerful agent of change at home" was proposed by Chen (2009, p.838) as a factor to encourage adults to actively participate in a recycling program. The study extrapolates on this point, discussing that as children grow older, they will become adults who continue the recycling behavior and teach the methods to their children in turn. An overall recommendation that could be taken from the two studies would be to increase the amount and quality of existing recycling information to citizens as well as creating an information campaign to introduce recycling into classrooms and encourage the students to bring the practice home. This will make non-recyclers feel more confident about their recycling and veteran recyclers more informed by providing more detailed instructions on what can be recycled and where. Although these studies focus on recycling rather than the sorting methods needed for organic waste, the two concepts are intrinsically linked, and successes in one are likely to be transferrable to the other.

Creating the right form of information distribution and advertisement is just as important, if not more important than the actual information itself. There are a plethora of avenues through which education programs could continue, including television, radio and social media. However, Vicente's study in 2008 indicated that direct media campaigns would likely be much more successful than those marketed to the masses, due to their ability to be more personalized to the target citizens. By creating a more personal, communal feel which encouraged people to participate, these campaigns could create systems of sorting which could be sustainable and efficient.

2.4.4 Successful Organic Waste Sorting Campaigns

Each year, throwing away food costs Danish households an average of 16 billion dollars, with an estimated 20% of all food bought thrown out (Stop Spild Af Mad, 2014). The majority of younger Danes agree that if they could clearly see a personal financial savings from reducing their daily food waste they would participate, while those aged 60-75 are among those who indicate that they were unable to reduce their food waste any further. These findings are in keeping with the conclusions of the studies, indicating that the creation of any new organic sorting system should focus on changing the habits and established tendencies of the younger

generations who will in turn perpetuate a cycle of recycling and sorting within their own households and with their children (Stop Spild af Mad, 2014).

In Sweden there currently exists a program called "Tak for Maten", or "Thanks for the Food!" wherein the hope lies that 40% of the food waste in Burlöv and Malmö will be sorted out from the municipal waste stream for use in biogasification plants. With the average Swedish household throwing out 5.6 kg of food waste every day, 33,000 tons of food waste end up in the municipal waste stream annually. By initializing the system within the singular municipality of Husie, before moving onto the next municipality in a systematic manner, Sweden was able to ensure participation from all individuals. The project began in May of 2012, and it will conclude in September of 2014 after visiting 11 different municipalities. By providing 9 liter paper bags within brown waste receptacles free of charge, Sweden was able to effectively provide enough infrastructure to make the entire project feasible and easy for the different companies to participate in effectively (Tack for Maten, 2011).

Lastly there is a system of sorting referred to as "Mission Mulig 2" or Mission Possible 2 within Denmark. In this, students and children are encouraged to support the changing perception of waste to value. Additionally, it works to develop both games and teaching materials to facilitate these new perceptions. Although they have not specifically posted anything upon their website as of May 2, 2014, the creators of Mission Mulig 2 have linked several different websites where these teaching materials can be accessed. By focusing their projects upon changing the perceptions of the children rather than upon the adults, this mission hopes to revitalize and invigorate significant change in the sorting practices of the households through the methods listed in the studies above. Although this is a new movement in Denmark, it is obvious that there is great potential behind systems like these (Renosyd, 2014).

3.0 METHODOLOGY

The goal of this project is to assist Dansk Affaldsforening in its goal of maximizing the use of organic waste as a resource through assessing the sorting psychology behind sorting organic waste at the household level and presenting our findings and those of pertinent investigations.

We will be working on this project from March 17, 2014 until May 7, 2014. We hope that our work with Dansk Affaldsforening will influence and educate the citizens and householders of both Copenhagen and the entirety of Denmark about the benefits of sorting and collecting

organic waste at the household level for use in biogasification systems. We plan to accomplish our goal through the fulfilment of the following objectives:

- Understanding organic waste sorting techniques and practices
- Investigate perceptions of householders concerning organic waste
- Learning from other waste management awareness programs
- Identify key factors and report findings

Our project plans to accomplish these objectives within the seven week time frame allotted through the following Gantt chart. Note that this is a preliminary itinerary and will be changed as the situation develops upon our arrival on-site.

Task	Week							
	Prep	1	2	3	4	5	6	7
Understanding organic waste sorting techniques and practices								
Investigate perceptions concerning organic waste								
Learning from other waste management awareness programs								
Analyze data and report findings								
Presentations to Dansk Affaldsforening								

Figure 7: Proposed Gantt chart

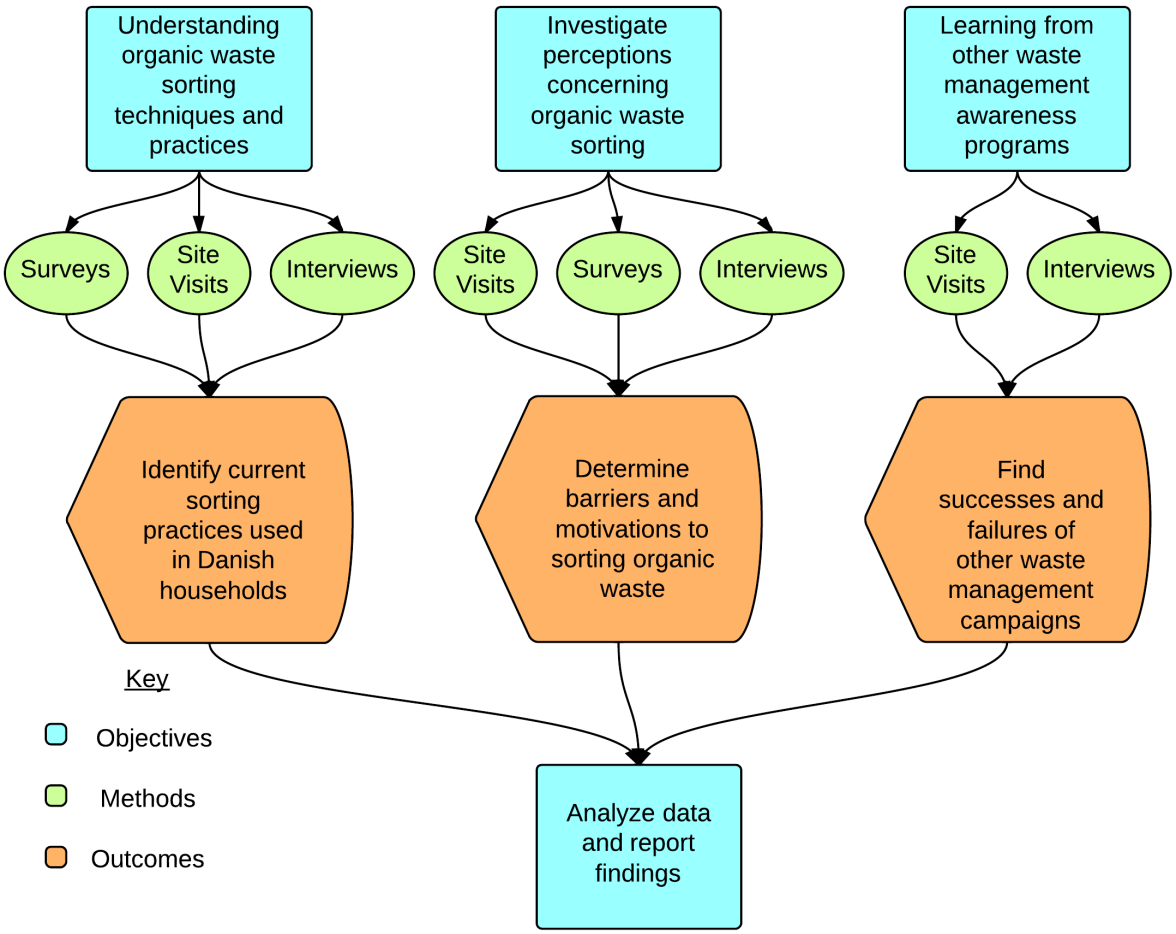

Figure 8: Project Flow Chart

3.1 Understanding Organic Waste Management Techniques and Practices

In order to effectively evaluate the psychology of sorting organic waste in the household, an understanding and examination of the current organic waste sorting practices must be performed. Currently, 98 distinct municipalities exist within Denmark and each contains a unique waste management system. In order to best understand how improvements can be made, a well-rounded and in depth knowledge of the current organic waste management systems must be formulated, with a focus on the specific sorting practices implemented in households. Key factors that we will consider in the acquiring of this knowledge are:

- Location of bins
- Type and style of bins
- Frequency that organic waste receptacles are changed

- Interface to Collection- methodology applied to the disposal of organic waste

The team plans to visit the municipality of Holbæk, unique in that it is one of the few in which organic waste is sorted at the household level already. By visiting Holbæk we plan on gaining experience with successful systems and the methods through which these systems of sorting were implemented. We will accomplish this through surveying the householders of Holbæk. Additionally, site visits will extend to the Biovækst biogas plant located near Holbæk to gain a practical understanding of the methods through which sorted organic waste is converted into usable biogas. Upon arrival at the plant, interviews will be staged by the project team with a facility manager with the purpose being to uncover the specific requirements native to Denmark required in the conversion of organic waste to energy. Some questions we expect to ask are:

- Since the initialization how frequently do organic waste deficits occur?
- When did this facility become fully functional and begin to process organic waste?
- How did this company impact the creation of a collection pathway?
- What was involved in securing a constant input of organic waste?
- What was the timeline for the completion of the facility? (i.e. construction completed first or the securing of an infrastructure concerning collection)?

From the interviews and site visits performed, the team hopes to gain insight into the biogasification process, including specifics not available in the literature review. This insight will include the personal experiences of the biogasification companies as well as the citizens regarding difficulties with the collected waste. This knowledge will allow the team to better understand how organic waste should be sorted in order to optimize its usage at biogasification plants, as well as the methods by which the citizens of Holbæk implemented successful organic waste sorting practices at the household level.

One difficulty that may arise is determining the common household waste sorting practices used by Holbæk. As previously mentioned, there is no uniform waste sorting method throughout Denmark and asking to see people's kitchens would likely have a low success rate due to low probability of people letting the team into their homes. In order to overcome this obstacle our team plans to utilize a movement called NulSkrald or "Zero Waste" which has enjoyed increased popularity as of late. This movement has a highly followed Facebook page called "NulSkrald"

that could be used to distribute a survey asking citizens of Holbæk what methods are used in the household sorting of organic waste. By contacting the facilitators of this Facebook page, permission could be granted to perform a "Show us how you sort" survey, asking people to take a photograph of their kitchen sorting set up and to give a brief explanation. Along with the picture request, there would be a demographic survey component asking questions concerning age, gender, and type of housing situation in order to better organize the results gained from this survey. Through the use of social media, we expect to reach a wider range of households than would be normally possible through physically traveling to these sites. Specifically, we will be looking for a minimum of 15-25 responses to this survey in order to gain a basic understanding of the different organic waste sorting methods employed in Danish households. Photographs of different sorting practices will be the most useful type of response for this survey due to their creation of a visual aid for how each household sorts their organic waste. Lastly, the team will compile a list of common household sorting methods from the results of this survey. The overarching purpose of this will be to gain an understanding of the successful organic waste sorting practices implemented across Denmark.

We also plan to conduct an interview with the leaders of the NulSkrald movement to utilize their experience and opinions on effective organic waste sorting practices. Some questions that we might ask during this interview are:

- Do you give people specific guidelines on how to sort their waste, or are they free to develop their own sorting systems?
- How much participation are you getting from the citizens in your waste sorting system?
- Do citizens raise any major complaints about the current waste sorting system?

The team hopes to gain insight into the thought process of people who have created a system of household sorting. This will provide the team with valuable knowledge on how household waste sorting system can be implemented.

3.2 Identifying the perceptions concerning organic waste sorting

In addition to understanding successful organic waste management techniques, the perceptions concerning participation in an organic waste sorting system must also be explored. By exploring studies detailing significant factors in increasing participation, an in depth knowledge of the psychological aspects of motivation must be gathered. In order for the whole of

Denmark to participate in a national organic waste sorting practice, there are several key factors which must be understood. These factors include the following:

- The motivations to participating in recycling and organic waste sorting
- The negative factors, barriers and challenges keeping householders from recycling and sorting

To explore the motivations concerning participation, the team plans to visit the town of Tversted, which in 2014 was appointed the first "Nulskrald Village" or "Zero Waste Village". In conjunction with the zero waste movement mentioned in section 3.1, Tversted is a pilot study on the success of sorting waste that began in January 2014. For the year spanning 2014 to 2015, this village will participate in Nulskrald, or zero waste, methods, meaning that every aspect of waste production will be monitored and improved upon, offering significant opportunities to identify the methods and motivations which influenced the citizens desire to participate in Nulskrald.

This would be an insightful place to visit since it is a working experimental model on how organic waste sorting systems could be implemented into households. Specifically, the team hopes to personally interview at least 10 people from the village to garner opinions on organic waste and to discover their concerns on its sorting. During these interviews, we plan on posing questions similar to the following:

- What were your initial concerns about organic waste?
- How has this program changed your view on organic waste sorting?
- What do you think is preventing others from sorting?
- What unforeseen difficulties have arisen since you began this process?

Another avenue of surveying the team would be contacting IKEA. This is an international furniture store that would give the team the chance to see what sorting options are commercially available to consumers. Also the customers would be great candidates to ask what the negative connotations to organic waste are. This survey would include questions such as:

- What factors prevent you from sorting your organic waste?
- What would it take to get you to begin sorting your organic waste?

- Out of the following choices, which sorting method would you be most likely to use?

While positive factors are key to the successful implementation of an organic waste sorting system, negative factors associated with sorting must be considered as well. It is important to understand how these factors affect people's habits and their opinions towards organic waste sorting. One of the negative elements that we propose to investigate is the smell of the organic waste in the receptacles that they are sorted in. Other negative factors include cost, convenience, hygiene, and infestation of bugs. These are factors that need to be considered in the design of any organic waste sorting system as well as in the collection of this waste. For this portion of our project, our team will gather information through online and in-person surveys by traveling to municipalities where organic waste is currently sorted. We will survey areas that represent the different living situations found throughout Denmark such as rural areas, urban areas, and suburban areas. These locations all have unique needs and concerns that need to be taken into consideration during this project and should provide us with representative samples to account for the different residential areas in Denmark.

The ultimate result of these surveys and analysis of the needs of the municipalities with organic waste sorting is the creation of a weighted listing, detailing the needs that face the municipalities as well as the weight with which they influence the citizens. An example of this weighted table is a pairwise comparison chart (PCC) table shown below where the ranking system is 1 if the leftmost column is more important, ½ if equally important and 0 if less important. The purpose of this objective is to understand how to best motivate the population of Denmark to sort their food waste and to understand the current obstacles which prevent them from participating in this program.

Table 1: PCC table detailing difference in importance between different needs

Need	Smell	Sanitation	Insects	Etc.	Total Score
Smell	X	1	1	1	3
Sanitation	0	X	0.5	1	1.5
Insects	0	0.5	X	1	1.5
Etc.	0	0	0	X	0

3.3 International Comparative Study- Assessing the Success of Other Campaigns

By exploring the successes of other campaigns, both local and international, key aspects can be transplanted from useful studies which may not have focused on the more recent focus of utilizing organic waste as a resource. Currently Miljøpunkts within Copenhagen have written and studied upon the environmental impacts as they influence humans, an important focus which could be shared between these studies as well as our own. Additionally foreign bodies such as Germany and Sweden have utilized biogasification and organic waste sorting for years, meaning that research within those countries will likely focus more upon the optimization, rather than creation of sorting and collection pathways.

On the local scale the team plans on meeting with the nearby Miljøpunkts like Nørrebro and Amager to gain an understanding of the recycling, pollution and human-impact studies which they have performed in recent years to gain an understanding of what factors must be considered in the creation of any new system which impacts such a wide range of people . Also the team will interview with municipalities that are just implementing a sorting system, in order to ascertain knowledge of the difficulties and concerns which have arisen as a result of implementing a new and drastic change such as this. The team would ask questions such as:

- How long has it taken for this sorting system to be created?
- What was stopping the government from creating a sorting system?
- What were the issues that made creating a sorting system difficult?
- What factors did the municipality determine to be most important in motivating people to sort?

Aside from exploring the techniques, practices and motivations which have been successful in Denmark, an important step in increasing the participation of household sorting of organic waste is the investigation of acknowledged methods implemented in foreign countries. In cooperation with Dansk Affaldsforening, the team has arranged to travel to both Germany and Sweden. These countries are locations where waste policies have been based on the utilization of all natural resources to the greatest extent possible. By traveling to these countries the team plans to investigate successful campaigns that have been used and garner a better description of methods which could be transplanted into Denmark. Key areas of interest in our examination of these foreign countries are:

- Successful aspects of previous campaigns
- Aspects of campaigns that could be improved

Within Germany there exists a well-established biogasification plant which will be used in conjunction with the Biovækst biogas plant located near Holbæk described in section 3.1 to gather even more information pertaining to the methods by which sorted organic waste is converted to usable biogas. Additionally interviews will be implemented in conjunction with the site visit to investigate the campaigns that were accomplished to encourage organic waste sorting. Questions posed during the interview with the facility managers of the German biogasification plant will be very similar to those posed in section 3.1, however by gaining a broader base of information our data will become more credible and applicable to a wider population base.

In Sweden there currently exists an extensive organic waste system which has been established for years. By utilizing the Swedish experiences with issues that have undoubtedly arisen over the course of the creation and maintenance of this system the team can design a Danish system which could prevent these issues from ever arising. Additionally, during this site visit the team can learn about the successful aspects of their information campaign that had to be created in order to encourage people to follow the new methods. During this site visit to Sweden, we hope to interview or survey an individual who was heavily involved in the creation or maintenance of this system. Key points of interest that the team wants to pursue are:

- What was involved in the original implementation of this system?
- What improvements or difficulties have been made since its implementation?

These on-site visits will give a hands on experience to the team as well as give the team the opportunity to observe a successful organic waste sorting system. By interviewing head officials we will gain knowledge in the inner workings of a successful sorting system. Overall with the gathered information the team will analyze what factors made the foreign sorting programs successful. Our full interview questions can be seen in Appendix A.

3.4 Analyses of Findings

The analysis of our findings will likely utilize the methods described in the text above, including site visits to different locations, interviews with key individuals and surveys spanning a

wide population base. Additionally the use of a PCC table shown previously in Table 1, as well as a numerical evaluation matrix will be implemented to identify a system with aspects best suited to the constraints and objectives unique to our project. A numerical evaluation matrix is one where the constraints are compared between all the different methods available in order to remove those systems which are not applicable to our project. Once these inappropriate methods have been removed, they are compared using our objected in a value of between 0-100 based on how appropriate they appear to be suited for each objective. An example numerical evaluation matrix is shown below:

Design Constraints and Objectives	Method 1	Method 2	Method 3	Method 4
C: Must sort organic waste			X	
C: Must be located within the household				
O: Limit Smell	100	80		50
O: No Bugs	70	60		50
O: Hygienic	40	90		60
Total	210	230		160

Figure 6: Numerical Evaluation Matrix Example

After determining the most effective organic waste sorting practices currently in place in Denmark, we must systematically evaluate and contrast the different methods versus the specific needs that we have identified above by gathering and categorizing the information available. We plan to accomplish this through comparing the methods with the needs as shown in table 2 below. This will help us to determine what method of sorting organic waste best addresses each of the concerns listed in the table. We plan gathering our results for this table by evaluating the results of our surveys and interviews that were obtained during the first few weeks from our visits to the municipalities in which organic waste is already sorted and to Germany and Sweden.

Table 2: Comparison of Methods with Needs

	Smell	Hygiene	Convenience	Cost	Handling	Insects/bugs	Notes
Method 1							
Method 2							

3.5 Conclusion

The purpose of this project is to assist in the maximization of utilizing waste as a resource through the determination of factors that prevent citizens and householders of Denmark from participating in the sorting of organic waste produced within the home and to present these findings along with a review of the successes and failures of organic waste management campaigns. Once the barriers to the Danish people participating in the sorting of organic waste separate from the rest of the municipal solid waste stream is identified, a collection pathway can be implemented to bring this waste to a biogasification facility to best extract the natural resources from it. The research and methodology above best allow us to assist Dansk Affaldsforening and the Danish Government in their goals of reducing incineration of waste which could be utilized more efficiently through biogasification.

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Appendix A: Interview Questions

Interview Questions for Municipalities that sort organic waste

- How long have you been sorting organic waste?
- Is the current sorting system working?
- Is there anything you want to change about the current system?
- How much waste is your municipality currently sorting?
- What, if any, technology is being used to make sorting easier for the residents?
- Where does the sorted organic waste go after it is collected?
- How is the organic waste collected?
- How do you advertise and market organic waste sorting?

Interview Questions for Municipalities that are just beginning to sort

- What was preventing you from sorting organic waste before?
- What are the issues that made creating a sorting system difficult?
- How do you plan on motivating people to begin sorting their waste?
- What made you decide to start a new sorting system?

IKEA questions

- Do you currently sort your organic waste?
- If not, what is preventing you from sorting organic waste?
- Would you consider organic waste a useful resource?
- What are the options available for consumers who wish to sort their organic waste?

Interview Questions for trip to Germany & Sweden

- How long have organic waste sorting systems been in place in your country?
- What changes have been made to the system throughout the years?
- Where does the sorted organic waste go after it is collected?
- How is the organic waste collected?
- How much citizen participation are you getting through this system?