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Increasing Paper and Cardboard Collection for Recycling in Copenhagen, Denmark

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Increasing Paper and Cardboard Collection for Recycling in Denmark

An Interactive Qualifying Project
Final Report

Submitted to

Professor Melissa Malouf Belz
Professor Zhikun Hou
Worcester Polytechnic Institute

Submitted by

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WPI

May 1, 2015

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Abstract

In light of Denmark's goal of increasing municipal recycling rates to 50% by the year 2022, the purpose of this project was to assist the Danish Waste Association in increasing household paper and cardboard collection. To achieve our goal, we analyzed information collected from research, interviews, and on-site visits. By speaking with multinational stakeholders and some of the country's largest waste management companies, we found the impacts that specific collection methods have on recycling, including the collection of mixed paper and cardboard, used beverage cartons, and contaminated cardboard. Finally, we developed three decision matrices which will aid municipalities in increasing their collection and recycling rates.

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Executive Summary

Background and Introduction

Following its long tradition of sustainable development, Denmark has been a frontrunner in recycling and waste management. Denmark Without Waste, the country's resource strategy for the treatment of waste, states the government's goal of increasing the household recycling rate to 50% across seven different categories by the year 2022. However, despite Denmark's high recycling rates, paper and cardboard still represented 23% of the household waste sent for incineration in 2014. Therefore, within the current paper and cardboard recycling system, there is still room for improvement by collecting more of the household paper potential and broadening the number of paper products that can be collected for recycling. Unfortunately, there is no clear-cut process for increasing paper and cardboard recycling: the environment, economics, and service for the citizens must be considered. Environmental impacts, such as transportation and recyclability, are important aspects in the design of a recycling system. In addition, the price at which collected paper is bought and sold depends on the quality and demand of the product. Furthermore, the service aspect of recycling must also be considered; for a recycling system to be successful, it must be convenient for its users. With only seven years left for Denmark to attain its targeted recycling rates, the country must implement changes in the waste management system. Therefore, the goal of this project was to assist the Danish Waste Association in increasing collection and recycling of paper and cardboard.

Methods

To accomplish our goal, we established the following objectives:

1. Understand the current collection and recycling system in Denmark.
2. Recognize the influences of the global paper market on the collection and recycling of paper and cardboard.
3. Identify the elements of different paper and cardboard collection and recycling systems in other countries.
4. Analyze results and formulate the information into a decision matrix.

We achieved these objectives through interviews, site visits, and research. We created three decision matrices stating the advantages and disadvantages of collection methods for paper and cardboard, used beverage cartons (UBCs), and contaminated cardboard, specifically pizza boxes.

To meet our first objective, we conducted several interviews with waste management companies in the municipality of Fredericia, which became the first to collect UBCs in Denmark, and the municipality of Odense, which recently began collecting paper and cardboard together. Furthermore, we interviewed at a local recycling organization as well as at the largest publicly owned waste management company to learn how different sectors handle collected paper and cardboard. To achieve our second objective, we also conducted interviews with paper traders to discuss the paper market. Additionally, we visited the largest international beverage carton producer, Tetra Pak, to assess the possibility of collecting UBCs in Denmark. We also read over reports including Agenda 21 (1992), Denmark Without Waste (2013), and the End-of-Waste Criteria for Waste Paper (2011). To complete our third objective, we analyzed diverse methods of paper and cardboard collection used in other countries throughout Europe.

Findings

Our engagement with local stakeholders provided us with a solid understanding of how waste management works in Denmark and the role of economics in recycling systems. Below, we present the findings extracted from the information gathered during interviews, site visits, and research, in addition to a brief analysis.

Finding 1: The global paper market provides an economic incentive to recycle paper and cardboard.

The global paper market is one of the major driving forces behind the collection of paper and cardboard for recycling, and affects all stakeholders from residents to paper mills. Residents must pay a fee to their local municipality for waste collection services. The waste management company in turn collects the paper and cardboard and sells it to either a paper trader or directly to a paper mill. Municipal waste management officials must consider both the economics of the paper market and the fee residents are willing to pay for the collection of their recyclables. The paper mills convert the recycled paper and cardboard into pulp to produce new paper, which they can sell back to consumers. However, paper fibers will eventually become degraded and shortened until they cannot be recycled any further. The recovered paper cycle is shown in Figure 1 below. Over the past few years, the production of paper has been decreasing, while the production of cardboard has been increasing. Waste collection schemes must be adjusted in order to reflect the current situation.

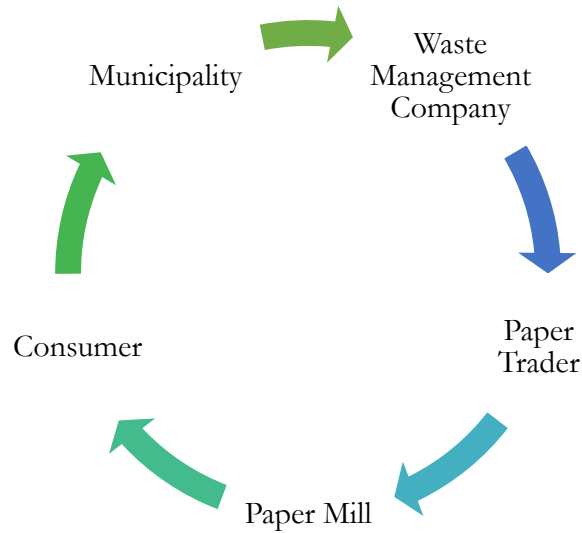


Figure 1: Recovered Paper Cycle (by Authors).

Finding 2: Several municipalities collect paper and cardboard together.

In the year 2014, 23 of the 79 municipalities across Denmark that offer curbside collection of paper and cardboard collected these materials in the same stream. However, most municipalities do not collect a mixed stream for economic reasons. Vestforbrænding explained that mixing the two fractions will lower the quality. DanFiber confirmed this, and explained that a mixture of paper and cardboard is worth approximately 35% less than the separated materials. Nevertheless, in the start of 2015, Odense Renovation implemented a change in their system to collect paper and cardboard in the same bin. Because collecting mixed fractions is more convenient for their residents, Odense Renovation hopes that allowing mixed paper and cardboard will increase the collected volume. Comparing these contrasting opinions shows that unless there is a significant increase in the amount of material collected, there is little economic incentive for municipalities to switch from a separate collection to a mixed collection.

Finding 3: It is feasible to recycle used beverage cartons in Denmark.

Used beverage cartons (UBCs) are widely used throughout Denmark. They contain plastic, metal, and paper, which makes them difficult to recycle, and as a result, they are usually sent to incineration plants. Many studies have shown that recycling UBCs is a better alternative to incineration with respect to energy consumption, because the containers consist of long, high quality fibers that can be recycled up to six times. Despite this, paper traders and waste management companies

throughout Denmark are skeptical about collecting used beverage cartons, as shown in Figure 2 below, because they do not want to lower the quality of the material they are mixed with. However, if enough UBCs are collected, the extra volume in material sold will recoup the losses from the reduced value. In the year 2014, a pilot program performed in Copenhagen showed that it is possible to collect enough material to make UBC collection economically feasible.



Figure 2: UBCs and Pizza Boxes Collected for Recycling (by Authors).

Finding 4: Pizza boxes can be collected in several different streams.

Most municipalities throughout Denmark incinerate pizza boxes and other food-contaminated materials. Nevertheless, it is feasible to recycle these products either in organic waste streams or mixed with UBCs and clean cardboard. In terms of increasing recycling rates, both of these collection methods are better alternatives to incineration. In order to protect quality and avoid contamination of streams, residents can be encouraged to remove dirty portions of the material, so only the clean portions are recycled, similar to what is done in the United Kingdom and Germany.

Finding 5: Residents are willing to recycle as long as it is convenient and the service fee remains the same.

A study conducted by Dare2, a private consulting agency, showed that 88% of the Danish population was willing to recycle more as long as it was convenient and did not cost them more money. According to a study performed by the Danish Ministry of the Environment, household collection is considered the most convenient method as it yields the highest collection rates compared to street

bins. However, the effectiveness of each collection scheme depends on many other factors, which are specific to each municipality. After considering both the cost for their residents and the quality of the collected material, Herstedøster in Albertslund changed their cardboard recycling system from household to street side collection. In addition to the municipality's needs, it is also important to consider convenience and cost when implementing a new system, because paper mills will not take heavily contaminated material and residents will not pay additional fees.

Finding 6: Informing residents about recycling programs can increase rates.

A lack of knowledge is one of the major barriers in increasing recycling rates. As such, various waste management organizations have put resources into teaching the local population how to recycle. After Tetra Pak and the World Wildlife Fund worked together to create a recycling school competition, Sweden saw an increase in used beverage carton recycling rates from 23% to 38% in just two years. In Denmark, Vestforbrænding and the municipality of Fredericia work closely with the local school system to encourage recycling among the younger generation. Other companies, such as Odense Renovation, use newspaper and radio advertisements to reach their adult audience, while the Agenda Center in Albertslund took a more personal approach and went door-to-door to inform their community of their new system. Recycling starts with the residents' cooperation and it is crucial that they remain well-informed on current practices.

Conclusion

In light of Denmark's goal of increasing municipal recycling rates to 50% by the year 2022, current recycling practices must be reviewed and reevaluated. With this in mind, we analyzed two specific approaches that can be taken to increase paper and cardboard recycling rates. The first consisted of investigating methods to collect more of the potential paper and cardboard products in households, and the second was to increase the collection potential by including paper products that are currently not collected for recycling. After our examination, we found there was no single best method, but instead, each municipality must choose a method based on their individual needs. To finalize our project, we developed three decision matrices, which cover the options and impacts of mixed paper and cardboard collection, UBCs in recycling streams, and recycling of contaminated materials. The matrices can be used to aid municipalities in increasing the paper and cardboard recycling in their community.

Authorship

This report represents the equal and combined efforts all of group members. However, the following is a list of the major contributors to each section.

Section	Primary Author(s)	Primary Editor(s)
Abstract	All	All
Executive Summary	De la Fuente and Fargher	All
Chapter 1: Introduction	All	All
Chapter 2: Background	All	All
Chapter 3: Methods	De la Fuente	De la Fuente and Komara
Objective 1	De la Fuente	De la Fuente and Komara
Objective 2	De la Fuente	De la Fuente and Komara
Objective 3	De la Fuente	De la Fuente and Komara
Objective 4	Fargher	De la Fuente and Komara
Chapter 4: Findings	All	Komara
Finding 1	Franklin	Franklin and Komara
Finding 2	Fargher	De la Fuente and Komara
Finding 3	De la Fuente and Fargher	De la Fuente and Komara
Finding 4	Franklin	De la Fuente and Komara
Finding 5	De la Fuente and Franklin	De la Fuente and Komara
Finding 6	Fargher and Komara	De la Fuente and Komara
Chapter 5: Conclusions	De la Fuente and Fargher	De la Fuente and Fargher
Decision Matrices	Fargher and Franklin	Fargher and Komara
References	All	All
Appendices	All	All

Table of Contents

Abstract	i
Acknowledgements.....	ii
Executive Summary	iii
Background and Introduction.....	iii
Methods	iii
Findings.....	iv
Conclusion	vii
Authorship	viii
Table of Contents	ix
List of Figures.....	xi
List of Tables	xii
Chapter 1: Introduction	1
Chapter 2: Background	3
2.1 Waste Disposal	3
2.1.1 Landfilling and Incineration	4
2.1.2 Recycling	4
2.2 Waste Management and Sustainability in Denmark.....	5
2.2.1 European Union Influence.....	6
2.3 Factors Influencing Paper Market	6
2.3.1 Infrastructure for Recycling in Denmark	7
2.3.2 Quality of Recycled Material	8
2.3.3 Composite Paper for Recycling	9
2.4 Recycling Systems of Other Countries.....	9
2.4.1 Germany.....	10
2.4.2 Sweden.....	11
2.4.3 Norway	12
2.4.4 United Kingdom	12
2.5 Efforts from the Danish Waste Association	13
2.5.1 Increasing Recycling Rates	13
Chapter 3: Methods	15
Objective 1: Understand the current collection and recycling system in Denmark.....	16
Objective 2: Recognize the influences of the global paper market on the collection and recycling of paper and cardboard.	17

Objective 3: Identify the elements of different paper and cardboard collection and recycling systems in other countries.....	18
Objective 4: Analyze results and formulate the information into a decision matrix.	19
Chapter 4: Findings	21
Finding 1: The global paper market provides an economic incentive to recycle paper and cardboard.....	21
Material Path	21
The Importance of Quality in the Paper Market	22
Trends in Paper Production and Collection.....	23
Environmental Concerns	25
Finding 2: Several municipalities collect paper and cardboard together.	25
Mixed Fractions	26
Separate Fractions	27
Finding 3: It is feasible to recycle used beverage cartons in Denmark.....	28
Energy Savings.....	29
The Debate on Quality after Adding UBCs	29
Places that Collect UBCs.....	30
The Future of Used Beverage Cartons.....	31
Finding 4: Pizza boxes can be collected in several different streams.....	32
Collection in Organic Streams.....	32
Collection of Cardboard and UBCs.....	33
Finding 5: Residents are willing to recycle as long as it is convenient and the service fee remains the same.	33
Finding 6: Informing residents about recycling programs can increase rates.....	36
Chapter 5: Conclusions	39
References.....	45
Appendix A: Interview with Helene Eskildsen and Signe Landon at Agenda Center Albertslund	49
Appendix B: Interview with Benny Sørensen and Line Falkensten at Vestforbrænding.....	51
Appendix C: Interview with Arne Hansen and Anne Lene at the Municipality of Fredericia	53
Appendix D: Interview with Lars Hansen and Ole Fuglsang at Odense Renovation.....	54
Appendix E: Interview with Niels Søgaard at DanFiber	55
Appendix F: Interview with Brit Schøt-Nielsen and Morten Strandlod at Vestforbrænding	57
Appendix G: Interview with Erik Lindroth at Tetra Pak	59

List of Figures

Figure 1: Recovered Paper Cycle (by Authors).	v
Figure 2: UBCs and Pizza Boxes Collected for Recycling (by Authors).	vi
Figure 3: Distribution of Household Waste in Denmark (by Authors).....	3
Figure 4: Waste Management Hierarchy (by Authors).....	4
Figure 5: Recovered Paper Cycle (by Authors).	7
Figure 6: Tetra Pak Packaging Material (KVDP, 2010).	9
Figure 7: Example of Public Recycling Bin in Hamburg, Germany (by Authors).....	10
Figure 8: Example of Public Recycling Bin in Malmö, Sweden (by Authors).	12
Figure 9: Objectives and Methodology of the Project (by Authors).....	15
Figure 10: The Collection of Paper from 2011 to 2014 in tons per year (Vestforbrænding).	24
Figure 11: The Collection of Cardboard from 2011 to 2014 in tons per year (Vestforbrænding).	24
Figure 12: Odense Household Waste Paper in tons per year (Odense Renovation).....	26
Figure 13: Paper and Cardboard Collection in 2014 versus 2015 (Odense Renovation).....	27
Figure 14: Mixture of UBCs and Pizza Boxes Collected for Recycling (by Authors).	31
Figure 15: Innosort Technology at the Danish Technological Institute (by Authors).....	32
Figure 16: Residents' Attitudes towards Recycling (by Authors based on Dare2, 2014).	34
Figure 17: Miniature Recycling Station used to Educate Children (Vestforbrænding).	37

List of Tables

Table 1: Carbon Savings by Recycling (Behandlingsanlæg, 2013).....	5
Table 2: Seven Week Timeframe (by Authors).....	20
Table 3: Decision Matrix on Collection of Paper and Cardboard (by Authors).....	40
Table 4: Decision Matrix on Collection of Used Beverage Cartons (by Authors).....	41
Table 5: Decision Matrix on Collection of Food Contaminated Cardboard (by Authors).....	42

Chapter 1: Introduction

Denmark has a long tradition of environmental sustainability. In 1973, it became the first country in the world to pass an environmental protection law, which established, among other things, that development should be conducted on a sustainable basis (Sonja, 2012). Ever since, Denmark has been a frontrunner in recycling and waste management with the purpose of attaining sustainable development. In 2013, the Danish Ministry for the Environment published Denmark Without Waste, a resource strategy for the treatment and recycling of waste. Among the goals laid out in the plan, the government is working towards increasing the household recycling rate to 50% across seven different fractions, which are food, paper, cardboard, glass, wood, plastic, and metal waste (Miljøministeriet, 2013). Paper and cardboard, in particular, are widely used household materials that are commonly recycled. By increasing the collection rate of this single fraction, Denmark moves closer to achieving its target.

Today, Denmark has a respectable paper and cardboard recycling rate. However, a study by the Ministry of the Environment showed that paper and cardboard still represent 23% of the household waste that ends up in incineration streams (Mere genanvendelse af affald fra husholdninger og servicesektoren, 2014). This demonstrates that despite high participation in recycling, there is still an opportunity to increase the collection of these materials. Furthermore, there is a large number of paper and cardboard products that are not collected for recycling, which means that there is also a chance to broaden the collection potential. The majority of municipalities in Denmark do not collect used beverage cartons (UBCs), such as milk cartons, or contaminated cardboard, such as pizza boxes. These materials make up 8% of the household waste that is sent for incineration (Miljøstyrelsen, 2012). The Danish Waste Association, a leading waste management lobbying company, is making an effort to increase the recycling rates of these materials and increase Denmark's overall recycling rates.

Unfortunately, there is no clear-cut process for increasing recycling: there are various factors which need to be taken into account, including the environment, economics, and service for the citizens. Environmental impacts, such as transportation and recyclability, are important aspects in the design of a system. In addition, the recycling method must be economically feasible; if infrastructure costs become too high, or if there is not enough revenue from selling the collected paper, then municipalities and waste management companies are unlikely to use that particular approach. Beyond the economics, the service aspect of recycling must also be considered. In order for a recycling system to be successful, it must be accepted by the community. Environmental, economic, and service

constraints vary between municipalities, which is why there is no single solution to increasing recycling rates.

Moreover, although there is a large amount of research on paper and cardboard recycling, there is still data that has not been collected, compared, nor analyzed. Assembling this information and making it available to stakeholders will aid the municipalities in making an educated choice on the best paper and cardboard recycling system for their community.

The Danish Waste Association asked us to assist them in addressing this issue. The main goal of our project was to increase the collection and recycling of waste paper and cardboard by developing a decision matrix to present the advantages and disadvantages of the various solutions. To do this, we learned about the current recycling system in Denmark, studied the global paper market and its influence on the collection of paper and cardboard, and examined recycling systems in other countries. We interviewed figures of authority in the waste management sector and supplemented this information with research from previously written papers. We compiled the data from these sources and analyzed our results in order to create a decision matrix to help municipalities develop the best recycling system for their community.

In Chapter 2, we discuss the background of the environmental, economic, and social aspects of the current recycling system in Denmark. We then explain our goals and objectives and the procedures we used to achieve them in Chapter 3. Our methods are followed by a discussion of our findings in Chapter 4, as well as the effects of each paper and cardboard collection system on various aspects of the entire recycling process in Chapter 5.

Chapter 2: Background

Every country in the world produces a lot of waste; Denmark is no exception. In 2009, Denmark was one of the top producers of waste per person in the European Union (European Environment Agency, 2011). A significant amount of the waste is generated at home. In fact, in 2011, over the course of the year, the average Danish household produced 447 kg of waste per person, which means that the average Dane throws away about 8 kg of waste every week (Miljøministeriet, 2013). All of the household waste adds up, and accounts for one-fourth of the waste generated from all sources in Denmark (Miljøministeriet, 2013). The disposed material goes into three main sectors: recycling, incineration, and landfilling. In 2012, 43% of all household waste was recycled, 53% was incinerated, and 4% was landfilled, as shown in Figure 3 below (Affaldsstatistik 2012, 2014).

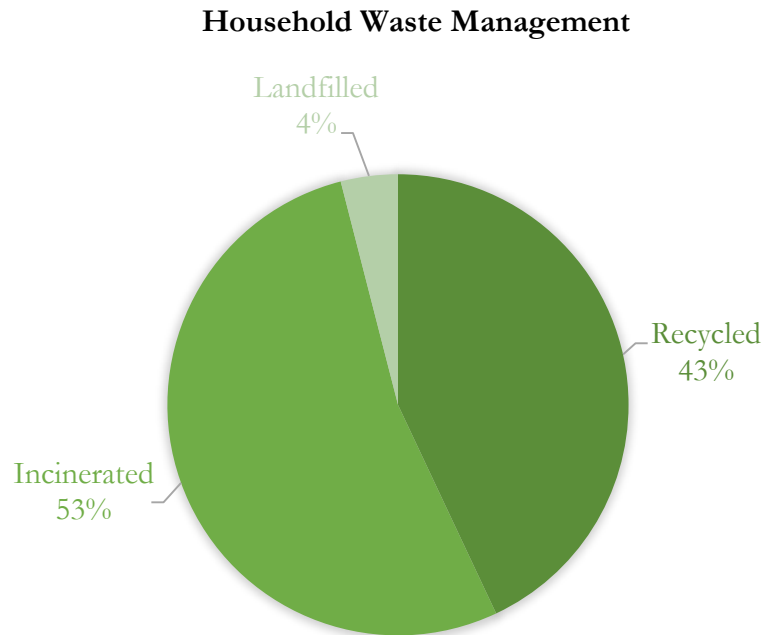


Figure 3: Distribution of Household Waste in Denmark (by Authors).

2.1 Waste Disposal

With the production of so much waste, it has become a priority for Denmark to find the best disposal method. The European Union's 2008 Waste Framework Directive (WFD) builds the foundation for fundamental waste management principles, and has developed the waste management hierarchy shown in Figure 4 below. Since categories higher up on the inverted pyramid are preferable,

it is evident that recycling is more sustainable than incineration or landfilling. Of the household waste sent for incineration, 6% was recyclable paper products, not including UBCs and pizza boxes (Miljøstyrelsen, 2012). As such, there is still a great potential for increasing the collection of paper and cardboard for recycling. In this paper, we will explore different approaches Denmark can take to increase these rates.

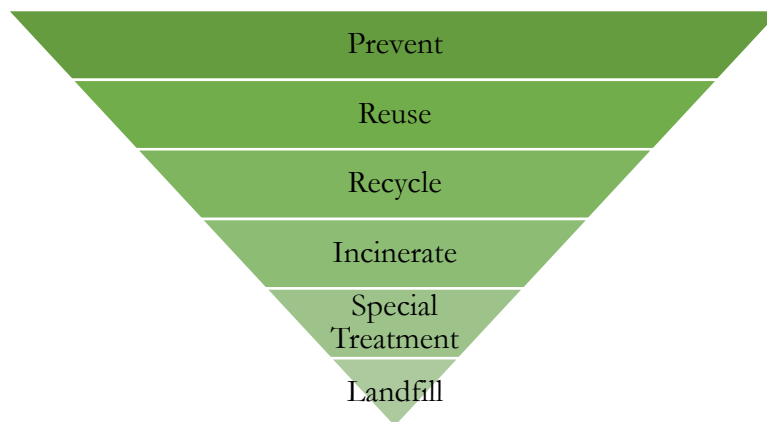


Figure 4: Waste Management Hierarchy (by Authors).

2.1.1 Landfilling and Incineration

Landfilling is the least effective method of paper and cardboard disposal, therefore it is rarely used. Of the 3% of household waste that is deposited into landfills, only a very insignificant portion is paper and cardboard (Winkler, 2014).

Paper and cardboard waste are also burned in incineration plants. Denmark incinerates a large portion of its household waste because the energy produced is used for electricity and district heating (Miljøministeriet, 2013). District heating is a system used to distribute heat that is generated at a central location, and is widely used across Denmark. Paper and cardboard that are not recycled end up in incineration streams (Danfoss Co., 2015). Incineration is a much better alternative to landfilling because the waste is reused in order to produce green energy. However, recycling is still the preferred method for waste disposal, as shown in the waste management hierarchy in Figure 4 above.

2.1.2 Recycling

Right now, Denmark recycles 700,000 tons of paper per year, yet is working to increase paper and cardboard recycling rates (Affaldsstatistik 2012, 2014). Paper products can be recycled about six

to seven times before the material is too degraded to be used again (U.S. Environmental Protection Agency, 2012), and the energy recovered from burning virgin paper is less than the energy saved from recycling paper (Villanueva and Wenzel, 2007). Recycling also produces less carbon emissions and protects trees as a natural resource. The Danish Ministry of the Environment estimates that approximately 2800 kg of carbon dioxide is saved per ton of recycled paper produced and approximately 1500 kg of carbon dioxide is saved per ton of recycled cardboard produced, as shown in Table 1 below (Behandlingsanlæg, 2013). Since recycling is the most environmentally friendly and economically feasible method of disposing a large amount of paper waste, Denmark has made a commitment to increase recycling rates.

Reuse Of	CO₂ Saving (kg/ton)
Paper	2800
Cardboard	1500

Table 1: Carbon Savings by Recycling (Behandlingsanlæg, 2013).

2.2 Waste Management and Sustainability in Denmark

In response to the negative environmental impacts of the 1973 oil crisis, Denmark became the first country in the world to pass an environmental protection law, which ensures that “people, nature and the environmental interests of Denmark and other countries are protected against pollution, and that development is conducted on a sustainable basis” (Sonja, 2012, p.1). Denmark has strongly committed to this law, and has since worked hard towards attaining sustainable development. In order to do so, the government has created new innovative policies and plans in different sectors to help the country increase sustainability.

Denmark is one of the frontrunners in paper and cardboard recycling. In 1987, the country first began to collect paper for recycling and in 1990, placed a tax on landfilling and incineration in order to encourage recycling (Winkler, 2014). Since then, Denmark has been working towards increasing its paper and cardboard recycling rates.

One of the recent plans Denmark has developed regarding waste management is Denmark Without Waste, which aspires to make Denmark even better at recycling and reusing materials. Ida Auken, the Danish Minister of the Environment, claimed that “We must move towards perceiving waste as a resource which can be reused and recycled, and away from considering it as just something

to throw away” (Miljøministeriet, 2013, p.1). The goal of the plan is to more than double the recycling rate by 2022, in an environmentally and economically efficient manner, to achieve a 50% recycling rate of seven different fractions of household waste, which are: organic, paper, cardboard, glass, wood, plastic, and metal (Miljøministeriet, 2013, p.11).

2.2.1 European Union Influence

The European Union (EU) has been a motivating factor for Denmark to continue its efforts in reducing waste. The EU introduced a zero waste policy, which states that waste will be reduced to the minimum volume possible and that discarded materials can be used as new resources. To achieve this policy, it is imperative to diminish material disposal and increase recycling rates (Zero Waste Europe, 2012).

In 2008, the European Union released the Directive 2008/98/EC, also known as the Waste Framework Directive (WFD), which lays out the basic waste management principles that member states are expected to follow. Denmark’s goal of achieving a 50% household recycling rate by 2022 (Astrup, Christensen, and Fruergaard, 2010) will meet the WFD requirement, which also looks to achieve a 50% recycling rate of municipal waste; however, the rates are measured differently.

2.3 Factors Influencing Paper Market

Protection of the environment is not the only factor that encourages collection and recycling of paper. Recycling paper also offers an economic incentive for paper mills, paper traders, municipalities, and even residents themselves. Residents pay their municipality for a collection system for paper and cardboard, whether it is collection at home or at a nearby recycling station. The amount residents have to pay for their waste disposal depends on the price that can be obtained by selling their collected paper and the cost for the collection.

As shown in Figure 5 below, municipalities can own waste management companies such as Vestforbrænding, for example, which is Denmark’s largest nonprofit municipal waste management company, to collect and dispose of their waste. Paper traders, such as DanFiber, for example, buy paper in bulk from waste management companies and sell it to paper mills, ensuring that municipalities can dispose of all their waste and that paper mills receive a steady supply of paper. The price at which paper is bought and sold depends on the quality and demand of the collected paper, which must be taken into account when designing a collection system.

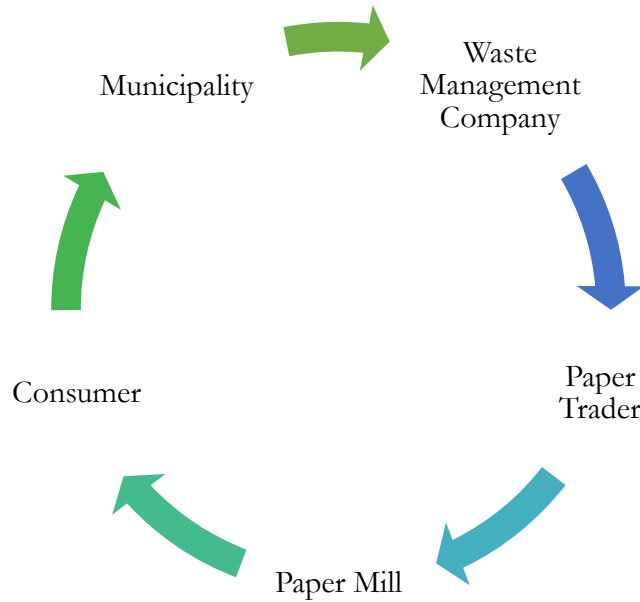


Figure 5: Recovered Paper Cycle (by Authors).

2.3.1 Infrastructure for Recycling in Denmark

Collecting recyclables as a public service requires a certain level of infrastructure. The type of collection system varies greatly between municipalities (Levlin, J.-E., & Grossmann, H., et al., 2010). Despite the large number of different systems, they can be described by two categories: collection and separation methods. Collection methods are the ways that waste is gathered before it is recycled, whereas separation methods are how the different recyclables are separated from each other.

Household, or curbside collection and separation methods in Denmark are carried out by each municipality. Recyclables must be separated from residual waste. Some municipalities have implemented street containers to collect recyclables such as paper, cardboard, plastic, and glass. Residents are welcome to bring their waste to these locations at any time, or they can wait for the garbage truck to collect it from their homes on a particular day. People can also drop off their waste at recycling stations. These are generally open every day of the week, sometimes including holidays. However, getting to the centers often requires further travel, which makes it difficult for residents without private transportation. Depending on the collection and separation methods used within the municipality, both the infrastructure and the quality of the product can be affected (Levlin, J.-E., & Grossmann, H., et al., 2010).

Waste must be separated into pure fraction streams in order to prevent the mixing of distinct materials during the recycling process. Separation processes can be divided in two categories, which are centralized sorting and source separation.

Centralized sorting is the separation of recyclable material after collection and transportation (Hill, A., Dall, O. and Andersen, F., 2014). Within this method, the organization managing the collection process is responsible for the sorting. The main advantage of centralized sorting is that waste collection becomes much simpler for both homeowners and garbage collectors, and fewer vehicles are needed. When recyclables are mixed, the likelihood of contamination increases.

On the other hand, within the source separation method, the residents are responsible for the sorting of recyclables. Multiple containers and collection vehicles are used in order to keep the different materials separated from each other throughout collection and transportation, which can increase the infrastructure cost (Hill, A., Dall, O. and Andersen, F., 2014). Source separation produces material that is of higher quality and thus worth more. As a result, the paper industry prefers separated collection (European Commission Joint Research Centre, 2011).

2.3.2 Quality of Recycled Material

Quality plays an important role in the use of recycled paper. Higher quality paper, such as graphic paper and stationery, often consists of higher grade material and does not contain much recycled material. More common, lower grade paper, such as newspaper, paper napkins, and toilet paper, can easily be made with recycled paper (U.S. Environmental Protection Agency, 2012).

Contamination will greatly lower the quality and value of recycled paper. Oil and grease from food residue are not easily separated from paper fibers and damage the final product (U.S. Environmental Protection Agency, 2012). Collecting used beverage cartons (UBCs), such as milk or juice cartons, and cardboard contaminated by food and water could increase the collection potential. However, if these materials are collected with other paper products such as clean cardboard, they will also lower the quality of the recyclables. Paper mills not equipped to remove oil and grease will return any collected paper with too much contamination. Mixing higher grade paper, such as office paper, with lower grade material, such as corrugated cardboard, may be easier for residents to gather, but will lower the overall quality of the recycled paper. Municipalities can sell a mixture of newspapers and magazines containing a minimum of 60% newspapers (European List of Standard Grades of Paper and Board for Recycling, 2013). As such, they must keep in mind the quality of the collected paper and cardboard when they develop a system for recycling.

2.3.3 Composite Paper for Recycling

Paper products that are made of several materials require special equipment to be recycled. These products are mostly food and beverage packaging, and include UBCs. Tetra Pak is a Swedish company that makes containers for milk, juice, and other food packaging, made up of layers of paper board, polyethylene, and aluminum (Tetra Pak, 2015) as shown in Figure 6 below. Since paper, plastic, and metal each have different recycling processes, they must be separated from each other in order to recycle the materials. Most Danish municipalities do not recycle Tetra Pak products and UBCs, but send the waste directly to incineration streams instead.

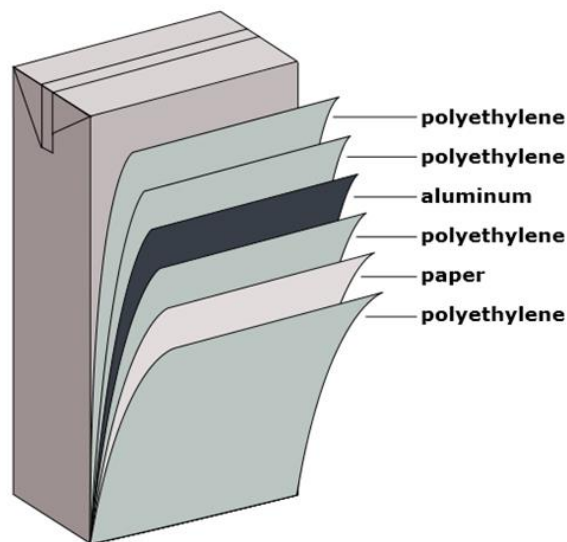


Figure 6: Tetra Pak Packaging Material (KVDP, 2010).

Denmark's neighbor, Sweden, has the technology to recycle UBCs in its Fiskeby plant, where they are broken down into their three separated components: fibers, plastic and aluminum. The recovered paper fibers are recycled and the separated plastic and aluminum are burned in Fiskeby's own incineration plant to offset energy costs. In fact, 40% of the mill's electricity is generated from steam (Fiskeby, 2011).

2.4 Recycling Systems of Other Countries

It is important to look into recycling systems of other countries to explore different options used in waste management. Other effective systems can be used as an example for Denmark to increase the potential of paper and cardboard collection and recycling.

2.4.1 Germany

Germany has a complex, yet effective recycling system. In homes and apartments throughout Germany, there are at least four types of recycling bins, each color-coded according to the type of waste (Moore, T., & Foulkes, I., 2005). Individual buildings have a blue bin for paper and cardboard that will accept a wide range of material as long as they do not contain any plastic, oil, grease, food residue, or metal pieces larger than a paperclip. Large cardboard boxes must be disassembled and left flat. Contaminants must be removed from waste before it is placed in the recycling container. Pizza boxes can be recycled as long as they do not contain large remains of food or oil stains (Directorate of Public Works of Schweinfurt, 2014). Paper and cardboard are picked up once a month throughout Germany, but if the recycle bin fills up before then, people can take it to the nearest recycling station. Used beverage cartons are not accepted in the paper and cardboard recycling bins. Instead, Germany uses the Green Dot system, which requires companies to pay a fee in order to place a Green Dot symbol on their products, so they can later be placed in a special bag by consumers. The products in this special bag are then recycled or destroyed depending on the material. Approximately 90% of Germans sort out their trash into the corresponding bin (Moore, T., & Foulkes, I., 2005), while the remaining 10% rely heavily on their general non-recyclable bin.



Figure 7: Example of Public Recycling Bin in Hamburg, Germany (by Authors).

2.4.2 Sweden

Sweden ranks as one of the best paper and cardboard recycling countries in the world, with more than 90% of all paper recycled (PappersKretsen, 2015). In 1999, Sweden implemented the Swedish Environmental Code which enforced the “Polluter Pays” principle (Ministry of the Environment and Energy, 2000). This legislation served to legally put the responsibility of recycling paper on the producer and the consumer, rather than the municipality (Ministry of the Environment and Energy, 2000). Paper and cardboard companies have since then formed the joint organization Packaging and Newspaper Collection, or FTI, which is responsible for the collection and recycling of paper waste.

The residents of Sweden are accustomed to sorting their waste into various different categories, including newspaper and recycled paper, paper packaging, plastic packaging, and metal packaging (FTI, n.d.). These divisions can be picked up by a curbside collection, taken to one of Sweden’s 6,000 street collection sites (FTI, n.d.), or brought to a nearby recycling station.

Sweden’s high paper and cardboard recycling rate can be attributed to the various materials collected. UBCs can be placed in the paper packaging waste stream, which includes other paper products such as paper cups, paper plates, wrapping paper, and packaging similar to cereal boxes (FTI, n.d.). These collected materials are recycled at plants such as Sweden’s Fiskeby plant, which are equipped to recycle composite materials (Tetra Pak, 2015). In 2012, Sweden was encouraged by Tetra Pak and the World Wildlife Fund to increase the recycling of composite materials, such as milk and juice cartons. In three years, recycled UBCs increased from 23% to achieve a recycling rate of 38% (Tetra Pak, 2015). Sweden also allows for the collection of paper and cardboard that has been contaminated by food waste, such as pizza boxes, which can go into the paper packaging recycling stream (FTI, n.d.). Corrugated cardboard, which is too big to go into the paper packaging recycling stream, is collected as bulky waste (Stockholms Stad, 2015). Another major contributor to Sweden’s high paper and cardboard recycling rate is newspaper, which is collected as a separate, clean fraction, and can also include magazines, office paper, and flyers (Stockholms Stad, 2015). A survey conducted by United Minds on behalf of Pressretur and the FTI showed that Sweden’s newspaper recycling system is convenient and easy to use, with 91% of survey participants responding that it was easy to recycle newspapers, and eight out of ten saying that newspaper collection bins were close by (PappersKretsen, 2015).



Figure 8: Example of Public Recycling Bin in Malmö, Sweden (by Authors).

2.4.3 Norway

Norway takes a different approach in paper and cardboard recycling. In 2010, the country recycled less municipal waste than Denmark (European Environment Agency, 2011); however, they have widened their collection potential to include both UBCs and carton, such as cereal boxes. Similar to Germany and Sweden, Norway also utilizes the producer responsibility system in which companies are required to pay a fee for their products to be recycled. According to Norway's Retursamarbeidet, which manages recycling, some municipalities require residents to sort out the individual paper and cardboard fractions, while other municipalities collect it all together. In this case, UBCs, carton, paper, newspaper, and cardboard, including dirty pizza boxes, can be combined for collection (Sortere, 2015). The waste is later sorted by the Swedish company IL Recycling, and then sent to paper mills. This system resulted in households recycling 63% of UBCs, 84% of paper, and 64% of carton in 2013 (Ljøstad, K.-I., 2014).

2.4.4 United Kingdom

Although the United Kingdom has a 67% recycling rate of paper and cardboard (Recycle, 2015), the recycling system varies between municipalities. Some municipalities require only one recycling bin, while others require up to nine different containers, which takes up a lot of space and can cause confusion due to the complexity of the system (BBC Magazine, 2011). Nevertheless, used paper products can usually be deposited in home recycling bins, which are provided by the local council. In the city of Canterbury, for example, a red bin is used to collect paper, cardboard,

newspapers, and magazines (Recycling Guide: How to use your new bin and boxes, 2015). Soiled paper, or paper fibers that are contaminated with food, cannot be recycled. For example, the greasy portion of a pizza box should be torn out and put into the main rubbish, while the remaining contents that are not contaminated should be recycled.

Unlike Denmark, 91% of municipalities throughout the United Kingdom collect UBCs for recycling (ACE UK, 2014). In Canterbury, a blue bin is used to collect UBCs along with glass, tins, cans, and all plastics (Recycling Guide: How to use your new bin and boxes, 2015). To reduce contamination and to improve recycling efficiency, the UK council recommends scraping out any food remains, pouring away excess liquid, and rinsing the UBC prior to recycling. In addition to recycling bins at home, there are numerous recycling banks located in public areas throughout the UK, which contribute to the recycling rate above.

2.5 Efforts from the Danish Waste Association

Dansk Affaldsforening, or the Danish Waste Association, is a politically oriented member organization which represents municipalities and several publicly owned waste management companies throughout the country. With Denmark's ambitious goals for waste reduction in the upcoming years, the organization has focused on researching better waste management methods, distributing information to their members, and lobbying the government on behalf of their members (Dansk Affaldsforening, 2014).

The municipalities play a very important role in the plan to achieve waste reduction; it is through their efforts that the government will be able to create a new and more effective waste management policy (Miljøministeriet, 2013). Since the Danish Waste Association has members in all 98 of the municipalities throughout Denmark, the ideas they promote can influence the renovation and improvement of the country's waste management.

2.5.1 Increasing Recycling Rates

Since Denmark has one of the highest per capita waste production rates in the European Union, recycling rates of each of the seven waste fractions must increase significantly in order for the country to achieve its goal of recycling 50% of household waste by 2022 (Hill, A., Dall, O. and Andersen, F., 2014). The Danish Waste Association has invited us to work with them to increase the potential of recycling paper and cardboard and to analyze the possibility of collecting UBCs and

contaminated cardboard, such as pizza boxes. They asked us to create a decision matrix comparing methods of paper and cardboard collection for recycling based on current Danish infrastructure, economics, residents' attitudes towards recycling, and the best practices from other countries. The details of how we accomplished the objectives are explained in the next chapter.

Chapter 3: Methods

The goal of this project was to assist the Danish Waste Association in increasing collection and recycling of paper and cardboard. In order to accomplish this, we developed a decision guide that presented the advantages and disadvantages associated with different recycling options.

A wide variety of factors influence the success of a recycling system, including economic constraints, social acceptance, and infrastructure requirements. Taking into account all of these elements, we established the following objectives:

1. Understand the current collection and recycling system in Denmark.
2. Recognize the influences of the global paper market on the collection and recycling of paper and cardboard.
3. Identify the elements of different paper and cardboard collection and recycling systems in other countries.
4. Analyze results and formulate the information into a decision matrix.

This chapter explains the above objectives and the methodology we followed to achieve our goal of increasing the collection and recycling of paper and cardboard in Denmark, as illustrated in Figure 9 below.

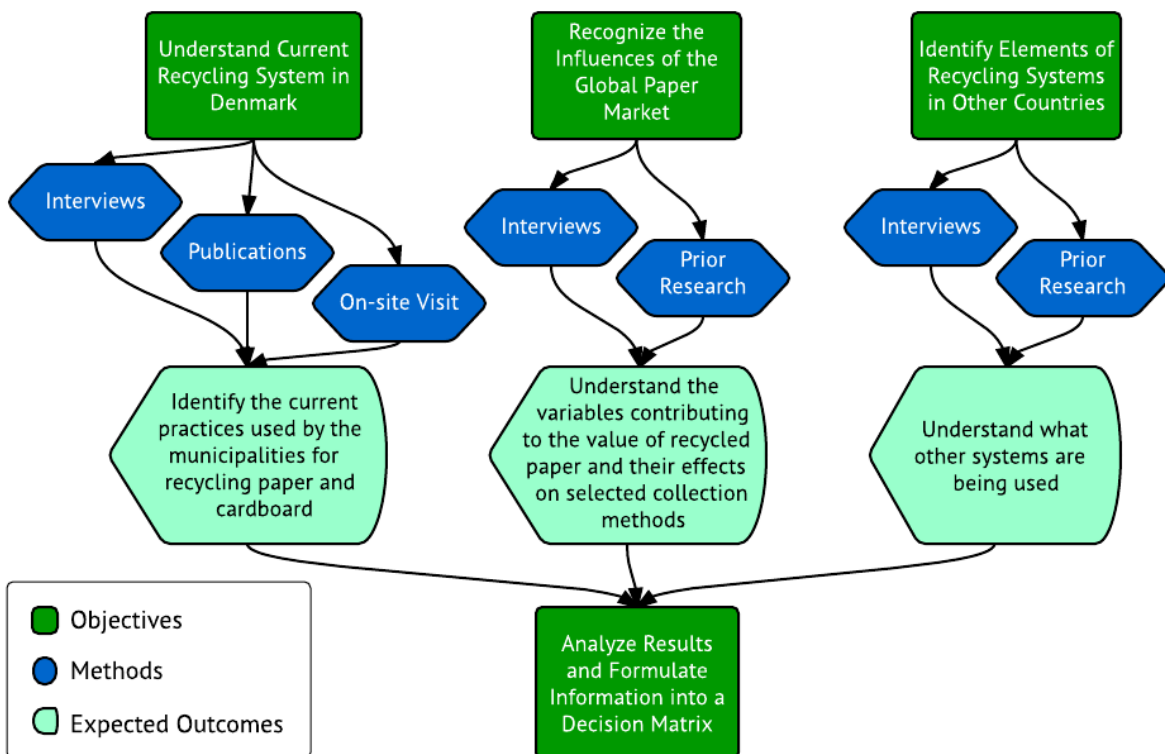


Figure 9: Objectives and Methodology of the Project (by Authors).

Objective 1: Understand the current collection and recycling system in Denmark.

In order to make any changes to the current paper and cardboard household recycling system, defined as the separation, collection, and treatment of paper and cardboard, we needed to gain knowledge of how waste management works in Denmark. To meet our first objective, we conducted semi-structured interviews and studied various documents provided by the Danish Waste Association. We chose to perform semi-structured interviews because this approach gave the interviewee more freedom to discuss the topics that they considered most relevant and also allowed us to have more flexibility with the questions (Berg, P.E.O., 1993). The questions were prepared prior to the interviews, however, were adjusted depending on the direction of the dialogue. A shift from the original plan was sometimes needed in order to obtain more detailed information about the topics that were discussed.

On Wednesday, March 18, 2015, we conducted an interview with Helene Eskildsen and Signe Landon. They are Environmental Consultants at Agenda Center Albertslund, a nonprofit organization that provides advice and information to residents about sustainable development. The purpose of this interview was to identify the reasons why the cardboard collection system in Herstedøster was recently altered, and to learn about the process of implementing the new system and residents' behaviors towards the change in recycling. Notes were taken throughout the interview, which were later discussed and analyzed. A list of the questions asked can be found in Appendix A.

After interviewing Eskildsen and Landon, we visited the local recycling station of Albertslund to gain a better understanding of the collection system. This visit provided us with a clear idea of how waste management works in Denmark and allowed us to see the different categories Denmark uses to separate waste.

To further our research on Denmark's collection system, we visited Vestforbrænding's recycling center in Frederikssund on Thursday, March 26, 2015. Vestforbrænding is the largest publicly owned waste management company in Denmark and represents nineteen municipalities. There we took a facilities tour and were able to see how the collected paper and cardboard from local recycling centers and households are treated before being placed in the paper market. This visit was crucial to gain insight on the actual quality of the paper and cardboard and to recognize the challenges waste management companies face when dealing with contaminants. We also conducted an interview with the Operations Leader, Benny Sørensen, and the Accountant, Line Falkensten. During this interview, we focused on the legislation and laws Vestforbrænding follows for collecting and selling waste, the

technologies used to separate it, and how the company maintains a high quality of collected paper. A portion of the discussion deviated from the recycling system towards the paper market, which helped us fill gaps in our second objective: to recognize the influences of the global paper market on the collection and recycling of paper and cardboard. A list of our interview questions can be found in Appendix B.

To understand how municipalities deal with waste management, we interviewed Arne Hansen, Plant Manager, and Anne Lene, Engineer, of the municipality of Fredericia on Tuesday, April 14, 2015. During this interview, we obtained specific information about the way municipalities decide which waste management system will be implemented in their area. Since each municipality in Denmark has an independent collection and recycling system, it was crucial for us to comprehend the reasoning behind choosing a specific system. We asked questions regarding the collection system of specific materials and the quality of paper and cardboard they are receiving. An overview of the questions asked can be found in Appendix C.

On Tuesday, April 14, 2015, we visited Odense Renovation, the company that manages all the waste throughout the municipality of Odense, and interviewed Lars Hansen, the Transport Manager, and Ole Fuglsang, the Environmental Expert. The municipality of Odense recently decided to combine paper and cardboard into one single stream for recycling, as opposed to the rest of the municipalities throughout Denmark which keep them separate. We conducted this interview to understand the reasons behind this change and to look into the effects they have seen thus far. A list of the interview questions can be found in Appendix D.

In addition to conducting interviews and visiting plants, we reviewed several documents, including Agenda 21 (1992), Denmark Without Waste (2013), and the End of Waste Proposal for Paper (2011). These reports helped us further understand the policies regarding the collection and recycling system in Denmark, which was useful in developing the final decision matrix.

Objective 2: Recognize the influences of the global paper market on the collection and recycling of paper and cardboard.

The paper market dictates the economic feasibility of different collection and sorting methods. No system can be proposed without first gaining knowledge of stakeholders and evaluating the economics of recycling, which include the cost of separation, collection, transportation, processing, and the value of the final product.

In order to accomplish our second objective, we performed semi-structured interviews with leading stakeholders of the industry. Before doing so, we designed specific questions for each interviewee, depending on their area of expertise.

On Thursday, March 19, 2015, we conducted an interview with Niels Søgaard, the Managing Director of DanFiber. DanFiber is a well-known paper trading company which acts as the link between the paper collectors and the paper recycling mills. We conducted this interview in order to gather information about the paper market throughout the European Union, including Denmark, and to focus on the importance of the quality of the collected paper. An overview of the interview questions can be found in Appendix E. To gain another perspective, we conducted an impromptu phone interview on Wednesday, April 22, 2015. We spoke with Jan Højberg, a Consultant at Marius Pedersen, a private waste management company, to discuss the economy of selling and sorting mixed paper and cardboard.

To further understand the economics of paper trading, we visited the Vestforbrænding plant in Glostrup on Wednesday, March 25, 2015. In conjunction with this visit, we interviewed Brit Schøt-Nielsen and Morten Strandlod, each Heads of Section at Vestforbrænding. The main purpose of this interview was to gain specific knowledge of the collection system in Denmark, as well as any associated challenges. We also discussed several possible solutions in order to increase recycling rates and Vestforbrænding's economic feasibilities. A list of the questions asked can be found in Appendix F.

On Friday, April 10, 2015, we interviewed Erik Lindroth, the Environmental Director of Tetra Pak in Lund, Sweden. The main purpose of this visit was to look into the feasibility of collecting used beverage cartons (UBCs) in order to increase Denmark's recycling rates. Our interview questions focused on the economics of recycling UBCs, and how other countries around the world recycle their products. Erik's responses helped in gathering information for our third objective: to identify elements of paper and cardboard collection and recycling systems in other countries. The interview questions can be found in Appendix G.

Objective 3: Identify the elements of different paper and cardboard collection and recycling systems in other countries.

The European Union has established paper and cardboard recycling goals for all of their members, and each country has come up with regulations and waste management systems to meet the required recycling rates. Our third objective was to identify the elements of different paper and

cardboard collection and recycling systems in other countries. By analyzing diverse methods of paper and cardboard collection, we developed a better idea of how Denmark could increase its recycling rate.

In order to achieve this objective, we first chose to research recycling systems of European countries that have achieved high recycling rates. After looking at several recycling systems from around the world, we decided to take a closer look at those used in Germany, Norway, Sweden, and the United Kingdom, since their recycling systems have shown positive results. We looked into the way these countries separate and collect both paper and cardboard, specifically focusing on their collection methods of UBCs and contaminated cardboard.

We supplemented our research on waste management outside of Denmark with our visit to Tetra Pak in Sweden, as mentioned in Objective 2. Prior to our interview with Erik, we divided our questions into two categories: the first focusing on the paper market and the second focusing on the way Sweden and other countries throughout the European Union dispose of their UBCs. Following the interview, we discussed the initiatives Tetra Pak is taking in order to educate residents and to incorporate their products into the paper and cardboard market.

Furthermore, when we traveled through Germany, Sweden, and Norway, we gained a better understanding of the different sorting systems throughout the European Union. While taking a closer look at the distinctive recycling bins used to collect municipal waste in each country, we were able to compare the systems firsthand. Some examples of the different bins can be seen in Chapter 2.

Objective 4: Analyze results and formulate the information into a decision matrix.

Once our first three objectives were concluded, we analyzed the collected material in order to synthesize the data into an appropriate decision matrix for the Danish Waste Association as our final objective. In order to accomplish this, we organized all the information we gathered from research, observations, and interviews, and designed decision matrices which identify the different approaches Denmark can take to increase their recycling rate of paper and cardboard. We looked for trends within the interviews, as well the consequences of various recycling methods. During each interview, the discussion covered the two possible approaches to increase paper and cardboard recycling, which are collecting more of the current paper fractions and increasing the variety of paper products that can be collected. By analyzing the interviews, we were able to identify the advantages and disadvantages of

each recycling system considered, as well as the effects on increasing paper and cardboard recycling. We then presented our decision matrix to the Danish Waste Association for their feedback and approval.

In the next chapter, we discuss the findings that became evident from completing our objectives through interviews, site visits, and research. Our objectives described above were achieved within a seven week timeframe, which is laid out in Table 2 below.

Weekly Timeline								
Task	Week							
	Prep	1	2	3	4	5	6	7
Orientation and Background								
Understanding Current Recycling System								
Recognize Influence of the Global Paper Market								
Identify Elements of Collection & Recycling Systems in other Countries								
Analyze Results and Create a Decision Matrix								
Present Findings								

Table 2: Seven Week Timeframe (by Authors).

Chapter 4: Findings

Our engagement with local stakeholders provided us with a solid understanding of how waste management works in Denmark and the role of the economics in recycling systems. Overall, we learned that: even though Denmark has a high recycling rate, there is still room to increase the collection of paper and cardboard; that the paper market plays a key role in the selection of a recycling system; and that the Danish population is willing to cooperate with recycling as long as it is convenient for them. Given that Denmark is committed to promoting sustainable development, municipalities emphasize the following three pillars: environment, economics, and service, which are considered to be the base of increasing sustainability. Therefore, our research and interviews were built upon the three pillars, in order to recognize the effects of each collection and recycling system on the environmental, economic, and service sectors. In this chapter, we present the findings we extracted from interviews, site visits, and research, in addition to the analysis and discussion on each finding.

Finding 1: The global paper market provides an economic incentive to recycle paper and cardboard.

Through interviews with waste management companies and paper traders we were able to accomplish our first and second objectives, which were to understand the current collection and recycling system in Denmark and to recognize the influences of the global paper market on the collection and recycling of paper and cardboard. By speaking with several experts, we learned that the global paper market is one of the major driving forces behind the collection of paper and cardboard for recycling in municipalities. Once a waste management company has collected used paper and cardboard, they can then sell the material in order to recuperate their collection expenses. As the data we collected points out, the paper market is very complex; whenever a contract for used paper is made, there are price negotiations, and prices vary constantly. However, we found out that there are a number of general concepts that can be discussed with relative certainty and we will explain them in the next paragraphs.

Material Path

There are stakeholders all throughout the paper market, from residents to paper mills. Residents at home must pay a fee to their local municipality or utility company for waste collection services. These collection services can include local recycling stations, recycling bins on the streets,

and curbside, or at home collection. A municipality can own a waste management company, such as Odense Renovation, which is the waste management company for the municipality of Odense. Alternatively, several municipalities can work together to create a waste management company, such as Vestforbrænding, which is Denmark's largest waste management company and serves 19 municipalities. The fee which residents pay the municipalities is determined by the cost needed to keep the waste plan and management running.

Once the waste management company has collected the paper and cardboard, the material may be sorted and baled prior to recycling. The waste management company sells their paper either to a paper trader such as DanFiber, who will navigate the paper market, or directly to a paper mill. The paper mill turns the paper and cardboard back into pulp, produces new paper, and sells the paper to consumers. Once the paper is back on the market, the cycle can restart. However, the paper fibers will become degraded and shortened over time, until they cannot be recycled any further. Refer back to Figure 5 in Chapter 2 for a visual of the collected paper cycle.

The Importance of Quality in the Paper Market

The price for which the paper and cardboard is bought and sold is affected by many factors throughout this cycle. Stakeholders from each sector must decide what level of quality paper they need, and the price at which they are willing to buy and sell paper. Paper mills determine which materials they are willing to buy and handle, while municipal waste management officials decide which quality they are willing to collect and sell. According to Vestforbrænding, the paper that is collected by them is of very high quality, and they try to avoid collecting material that could contaminate their streams.

The type of paper that a paper mill can produce, depends very much on the quality of paper and cardboard that they receive. To make higher quality paper such as office paper or stationery, the mills must use a clean stream of paper with long fibers. Paper mills are often specialized to produce a particular product, which narrows down the quality of used material they are willing to accept. For example, a paper mill that makes newspaper will accept recycled paper, but will not accept cardboard due to the differences in material. Higher quality products have higher prices associated with them. Niels Søgaard, Managing Director of DanFiber, reported that in April of 2015, old corrugated cardboard cost around 100 euros per ton, while used newspapers cost around 125 euros per ton. He also stated that materials that have been mixed have even less value, as mixed paper and cardboard cost around 70 euros per ton.

Erik Lindroth, Environmental Director of Tetra Pak, explained that some mills, such as the Fiskeby plant in Sweden, may be capable of dealing with contaminated cardboard, while other plants can only accept clean, unsold newspaper print due to the high quality materials that they make. Niels Sogaard of DanFiber stated that the price that a company is willing to pay for recycled material varies. The value of certain types of paper will change frequently, making it very difficult to determine how much a particular quality of paper is worth. Additionally, changes in pricing can occur over long periods of time. From our visit to Odense Renovations, we learned that the difference in price between clean paper and clean cardboard decreased, which was part of the reason Odense changed the quality of the material they were collecting throughout the municipality.

Waste management companies must determine the quality of paper they wish to collect. The standard published by the Confederation of European Paper Industries, also known as CEPI, is used by the European Union to define the grade of the collected paper, which is determined by composition of material. For instance, grade 2.02 is defined as “Unsold daily newspapers, free from additional inserts or illustrated material colored in the mass” (European Committee for Standardization, 2014). Additional requirements can be included when a contract is made. For example, the quality used by Vestforbrænding for read newspapers is based on grade 1.09, but contains additional specifications. The quality of paper product that a company wants to collect often affects the infrastructure and transportation costs, the volume of paper and cardboard collected, and the convenience for citizens. A company must therefore decide on a collection method that is balanced among these categories. The overall revenue of a waste management company after collecting, selling, and transporting their paper determines the fee that residents must pay to their local municipality for waste collection services on paper and cardboard.

Trends in Paper Production and Collection

Over the past few years, the production of paper has been decreasing, while the production of cardboard has been increasing. A report from CEPI for the year 2013 indicates that production of graphic paper, such as white office paper, fell by 5%, while production of packaging paper, such as cardboard, increased by 2% (Confederation of European Paper Industries, 2014). Of total paper and cardboard production in the EU in 2013, 41.8% consisted of newsprint and other graphic paper, and 45.9% was composed of packaging material (Confederation of European Paper Industries, 2014). Similar statistics exist for the year 2012, and the progression is expected to continue.

This tendency is reflected in Denmark and can be observed in the graphs provided by Vestforbrænding below. Figure 10 represents the collection of paper from 2011 to 2014 and displays a steady decrease in the amount of tons that were collected per year.¹ Figure 11 represents the collection of cardboard, also from 2011 to 2014, but instead demonstrates an increase in the amount of tons that were collected within the last three years shown.² Although the amount of paper and cardboard that was collected may reflect changes in the collection system, there were no major changes to the system within the years shown below.

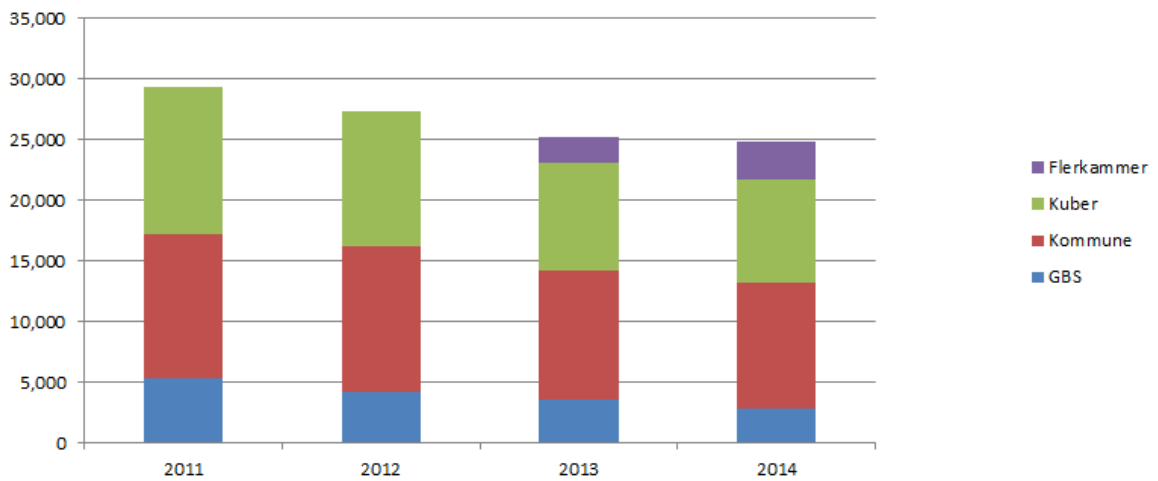


Figure 10: The Collection of Paper from 2011 to 2014 in tons per year (Vestforbrænding).

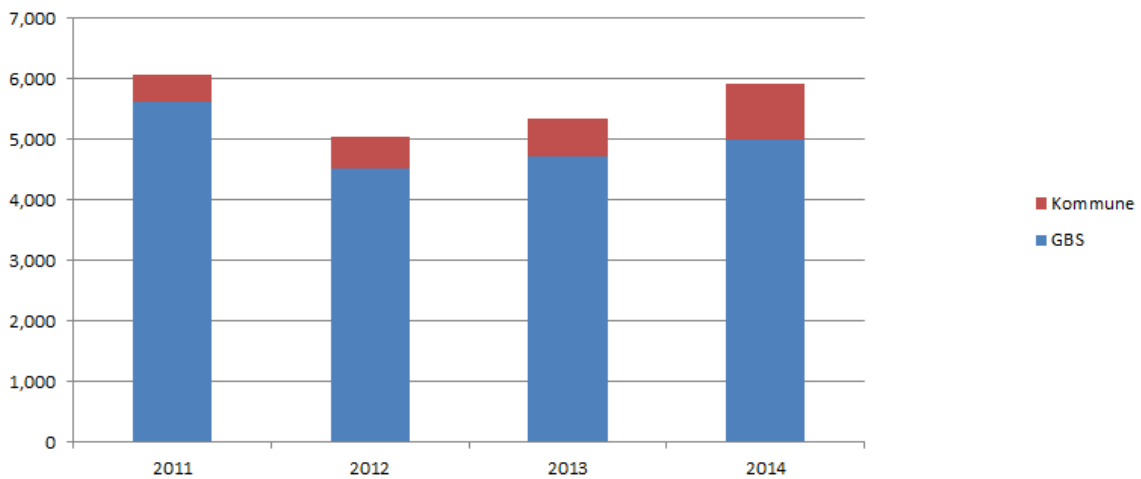


Figure 11: The Collection of Cardboard from 2011 to 2014 in tons per year (Vestforbrænding).

¹ Flerkammer translates to multi-chamber containers, Kuber translates to street containers, Kommune translates to collections by the municipalities, and GBS translates to recycling stations.

² Kommune translates to collections by the municipalities and GBS translates to recycling stations.

Both Benny Sørensen, Operations Leader of Vestforbrænding, and Niels Søgaard, Managing Director of DanFiber, attributed this trend to the increase in internet usage for news, reading, and online shopping. In addition, Post Denmark, the country's leading mail provider, created a mailbox sticker that reads "Advertisements No, thanks" as a way to opt-out of the delivery of advertisements and complimentary newspapers (Reklamer Nej tak, 2014), which has also contributed to the decrease in the consumption of paper. While Denmark has a strong paper recycling system, packaging is the largest component of the paper product found in incineration streams (Mere genanvendelse af affald fra husholdninger og servicesektoren, 2014), and thus presents an opportunity for increasing the recycling rate of paper and cardboard.

Environmental Concerns

Beyond economic considerations, municipalities and paper traders must also take environmental influences into consideration. Brit Schøt-Nielsen and Morten Strandlod of Vestforbrænding and Niels Søgaard of DanFiber explained that the Asian paper market will buy almost any quality of paper, making it attractive from a purely economic standpoint. However, they generally have lower standards for environmental and social safety. For instance, during the paper reclamation process, there is some amount of material that is not reusable; what happens to this waste material is regulated within the EU, but is often subject to many fewer restrictions in Asia, if any. As a result, Vestforbrænding and DanFiber both avoid selling recovered paper to the Asian market.

Overall, although the paper market provides an incentive to collect and recycle paper material, the value of the collected waste varies based on a number of factors. These elements, as well as their environmental and social impacts, must be considered in order to create a recycling system that is economically sustainable.

Finding 2: Several municipalities collect paper and cardboard together.

In the year 2014, 23 of the 79 municipalities across Denmark that offer household, or curbside, collection of paper and cardboard collected these materials in the same stream (Affaldskontoret ApS, 2014). While most municipalities choose to collect their paper and cardboard separately, there are also benefits to mixing these two fractions. In fact, Odense Renovation evaluated both the advantages and disadvantages of each method and decided to change their recycling system. In January of 2015, the

municipality of Odense implemented a change in their collection system of paper and cardboard, from a separate collection to a mixed collection.

Mixed Fractions

A major consideration for waste management companies is that the collection of recyclables is both easy and convenient for their residents. Mixing of paper and cardboard can make collection user-friendly by reducing the amount of waste sorting that has to be done in the homes, as well as reducing the number of bins and collection schedules to keep track of. When we spoke with Lars Hansen, the Transport Manager of Odense Renovation, he mentioned that residents had been requesting to mix their paper and cardboard together, and that their paper stream already consisted of between 2% and 3% cardboard. Ole Fuglsang, the Environmental Expert of Odense Renovation, added that since the change, residents had been very happy with the new system.

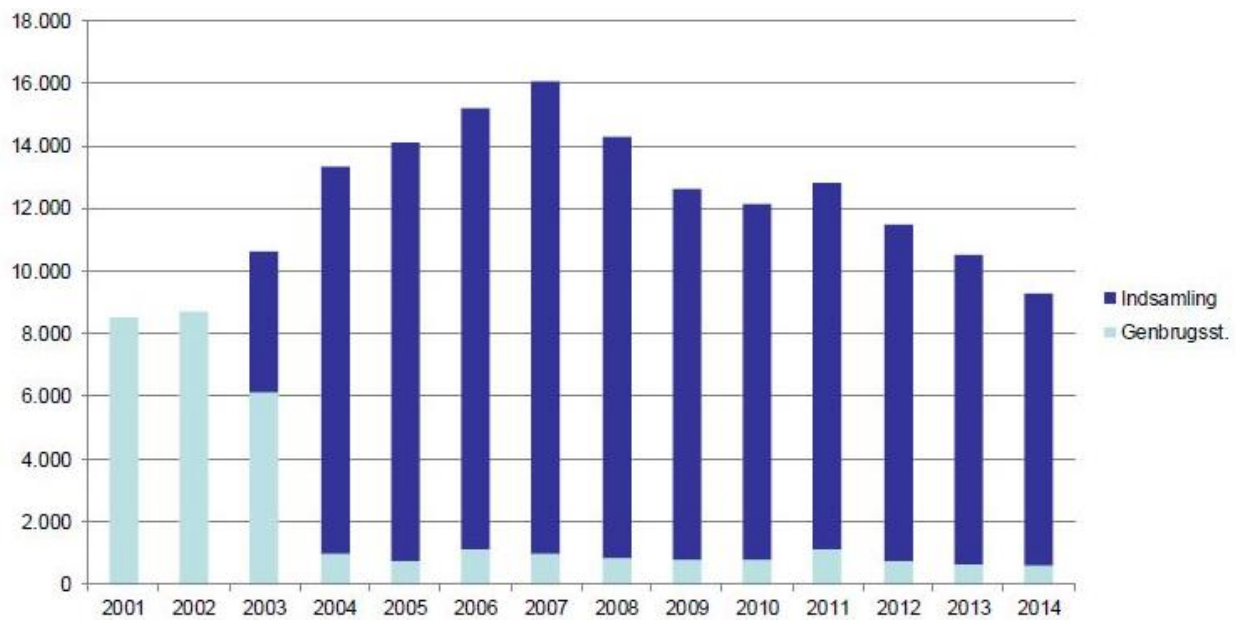


Figure 12: Odense Household Waste Paper in tons per year (Odense Renovation).

Due partly to its increased convenience for residents, mixing the fractions can also help to increase the collection of paper and cardboard. Many municipalities have experienced a decrease in paper waste in the past few years. As displayed in Figure 12 above,³ the municipality of Odense experienced a general decrease in paper collection from 2007 to 2012, with a difference of

³ Indsamling translates to door-to-door collection and Genbrugsstation translates to recycling stations.

approximately 10,000 tons of household waste paper per year. The graph provided by Odense Renovation also shows that paper collection continues to fall. Both Hansen and Fuglsang explained that as a result, paper bins were almost never completely filled when their waste disposal trucks came to pick up the waste each month.

Not much time has passed since the municipality of Odense implemented the change in their recycling system, so they cannot say whether or not collection has increased. However, Figure 13 displays preliminary results of the amount of paper and cardboard collected in January and February of 2014 compared to the amount collected in January and February of 2015. As shown, whether the collection is door-to-door or at a recycling station, there is a continual decrease in paper and cardboard collection for recycling. However, anecdotal results from garbage truck drivers report that there has been less cardboard in incineration streams since the change in Odense’s collection system. Hansen and Fuglsang also pointed out that the new paper and cardboard collection bins were usually full at the time of pick up each month, as opposed to before the change.

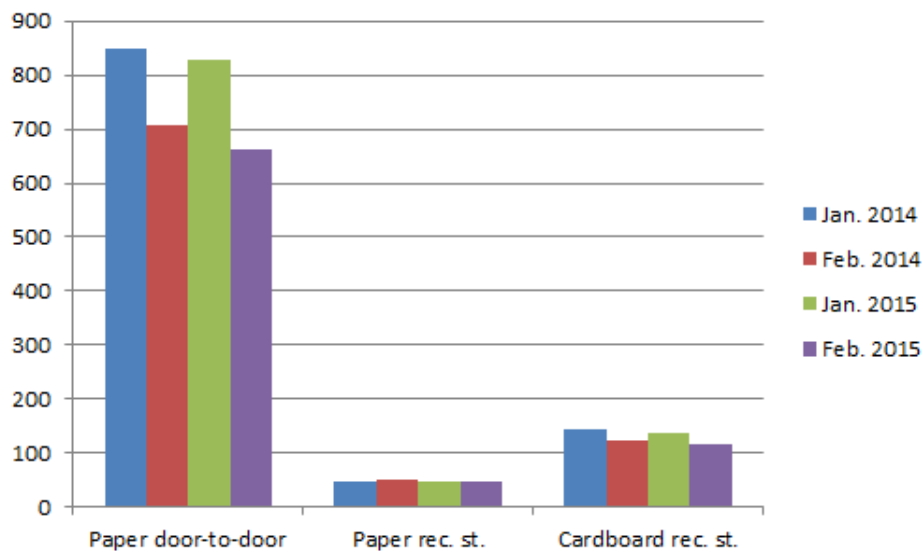


Figure 13: Paper and Cardboard Collection in 2014 versus 2015 (Odense Renovation).

Separate Fractions

On the other hand, 56 of the 79 municipalities across Denmark that offer curbside collection of paper and cardboard do not collect mixed paper and cardboard (Affaldskontoret ApS, 2014), due to the many disadvantages of mixing. Vestforbrænding, for example, stated that they do not collect mixed paper and cardboard in any of their nineteen affiliated municipalities. The main concern of

mixing the two fractions is the reduction in quality, which leads to a reduction in price, of the sold paper and cardboard. When we interviewed Brit Schøt-Nielsen and Morten Strandlod, both Heads of Section at Vestforbrænding, they explained that the company collects very clean, high quality streams of separated paper and cardboard, which they can sell at a high price. According to Niels Søgaard of DanFiber, clean paper including newspapers, magazines, and office paper, can be sold at a price between approximately 120 to 123 euros per ton, while clean corrugated cardboard can be sold at a price between approximately 107 to 110 euros per ton. However, when the paper and cardboard are sold as a mixed fraction, the price decreases to approximately 70 to 75 euros per ton, as stated by Søgaard. Unless there is a significant increase in collection by switching from separate collection to mixed paper and cardboard collection, there is little economic incentive to do so.

However, both Hansen and Fuglsang from Odense had a different opinion on the economic disincentive. They stated that mixing the two fractions only resulted in a 10 to 15 euro difference with their paper trader, Marius Pedersen. According to the Odense experts, this minor loss in price was less important than the improved convenience for their residents and a potential increase in paper and cardboard recycling. Jan Højberg, Consultant at Marius Pedersen, also explained that the mixed paper and cardboard can either be sorted at a sorting facility or sold as a different grade, depending on the market price, although sorting is generally preferred.

Finding 3: It is feasible to recycle used beverage cartons in Denmark.

Used beverage cartons (UBCs) are widely used in Denmark as almost all milk, yogurt, and juice products are packed in this material. Søgaard stated that every year, 25,000 tons of UBCs are released onto the Danish market; yet, the majority of the municipalities in Denmark do not collect UBCs for recycling. Used beverage cartons are made of composite material and therefore require specialized equipment to recycle, which only 29 paper mills throughout the European Union possess. Additionally, UBCs are often traded as a mixed fraction and are combined with clean cardboard, which lowers the value of the collected material. Furthermore, waste management companies send UBCs to incineration streams in order to generate energy. According to Niels Søgaard, incineration plants provide most of the district heating, as well as electricity through hot water, for households in Denmark. Many municipalities we spoke with were concerned with these issues, however there are also benefits of recycling used beverage cartons, including energy savings and increasing recycling rates.

Energy Savings

A study conducted by the Swedish Environmental Institute and Tetra Pak showed that recycling used beverage cartons saves more energy than what can be produced by incineration (Bengtsson, 2013). According to this study, recycling one ton of milk cartons offers energy savings of 27,000 mega joules, which is equivalent to 7,000 mega joules more than if cartons are burned and utilized as energy (Bengtsson, 2013). In addition, Erik Lindroth, Environmental Director at Tetra Pak in Lund, Sweden pointed out that burning UBCs reduces the valuable resources that could be obtained by recycling UBCs. Used beverage cartons are made out of high quality virgin paper fibers that can be recycled at least 6 times, and can easily produce more packaging or paper pulp (Erhardsen, 2013). Lindroth also stated that recycling UBCs such as Tetra Pak will not lower the material available for incineration. After several uses, this product will eventually end up in the incineration stream; however, it will be recycled a few times before becoming waste. To support Lindroth's claim, a life cycle analysis (LCA) conducted for Tetra Pak, by Lisa Hallberg and Hanna Ljungkvist, proves that recycling of UBCs with either none, 50%, or 100% of the plastic and aluminum recycled, consistently show more energy savings than incineration of the UBCs (Hallberg, L., & Ljungkvist, H., 2013).

The Debate on Quality after Adding UBCs

Despite the benefits of including UBCs in collection schemes, paper traders and waste management companies throughout Denmark are skeptical about collecting UBCs. Brit Schøt-Nielsen and Morten Strandlod of Vestforbrænding and Niels Søgaard of DanFiber all agree that the collection of used beverage cartons with cardboard would change the quality of cardboard they collect. UBCs can be collected separately from other cardboard, however, this increases infrastructure and transportation costs. If collected separately, paper traders often request the UBCs to be mixed with clean cardboard before being sent to paper mills, which makes the selling process simpler, more frequent, and more profitable. Arne Hansen from the municipality of Fredericia, for example, is considering sending a mixture of UBCs and clean cardboard to a paper mill in Germany. Søgaard and Schøt-Nielsen also pointed out that even though collecting this material will result in an increase in volume of cardboard to sell, it does not necessarily mean there will be an increase in revenue for the waste management company. Benny Sørensen, Brit Schøt-Nielsen, and Morten Strandlod all stressed that it is very important to Vestforbrænding to have clean fractions, as they receive a higher price on the paper market. Furthermore, Schøt-Nielsen and Strandlod emphasized that they are not interested in recycling UBCs at the moment because the material they receive is of a very high quality, and they

want to avoid diminishing its value. In addition, Schøt-Nielsen mentioned that since Denmark does not have producer responsibility, municipalities must pay a lot of money in order to recycle these materials, and therefore she is concerned that the process is too expensive.

Erik Lindroth, however, has a different point of view on this circumstance. According to him, a 25% recycling rate of the total potential UBCs is the breakeven point for recycling. Anders Faber, Project Supervisor at Copenhagen Engineering and Environmental Management Department, agrees with Lindroth in regards to economic feasibility of collecting UBCs. Moreover, after both Faber and Lindroth conducted a pilot project to collect UBCs in Copenhagen, Denmark, Faber said that the citizens will have to pay less in renovation tax when they produce less waste, meaning if the experiment shows that revenues in cardboard become larger, the overall economy in the municipal waste schemes will be better (Erhardtsen, H., 2013, p.1).

Places that Collect UBCs

The municipality of Fredericia recently became the first in Denmark to begin collecting UBCs. According to Arne Hansen, Plant Manager of the municipality of Fredericia, the first shipment allowed them to achieve a zero cost economy, or experience no net profit or loss, while still increasing recycling rates. It took the municipality of Fredericia about six months to collect enough UBCs to fill a single truckload to be shipped, and when the load was shipped, transportation costs were high. Hansen explained that the money earned from selling UBCs to Fiskeby was just enough to cover the transportation costs to the plant in Sweden. Additionally, Fredericia traded UBCs without any mixture of clean cardboard, which was not what paper mills typically look for. Although the paper mills can take the clean UBCs, their paper trader instead requested Fredericia to send a mixture of materials in the future. Taking many factors into account, the municipality is considering selling mixtures of 30% UBCs and 70% clean cardboard to a closer paper mill in Germany for the future.

Despite difficulties in recycling UBCs, the process has been successful in other countries throughout the European Union. For example, Germany, Norway, and Sweden include used beverage cartons in their recycling systems and have shown consistently high recycling rates. Additionally, to protect quality, Germany and the United Kingdom encourage their residents to remove contaminated sections from UBCs and cardboard, and to recycle the remaining clean areas into the appropriate stream. For example, they are encouraged to cut out oily portions of pizza boxes, rinse out yogurt containers, and more, prior to recycling. Although more inconvenient for residents, Denmark could

consider mixing UBCs with pizza boxes, which is addressed in the following finding and shown below in Figure 14.



Figure 14: Mixture of UBCs and Pizza Boxes Collected for Recycling (by Authors).

The Future of Used Beverage Cartons

Advancing technology also has the potential to provide more incentives to recycle UBCs. Tetra Pak has set the goal of increasing its global recycling rates to 40% by 2020 (Tetra Pak, 2015). As a result, Tetra Pak has invested time and resources in both educating the public about their products and researching new recycling technologies (Tetra Pak, 2015). In our interview at Tetra Pak, Lindroth spoke of research into improving the recycling of the plastic found in UBCs. Recycling plants would then have more products that they would be able to sell, and would therefore be able to offer a higher price for collected UBCs from municipalities.

The Danish Technological Institute is also developing technology which could encourage municipalities to begin collecting their UBCs. Innosort, as shown in Figure 15 below, has the potential to identify and remove used beverage cartons from paper products on a conveyor belt. Although the system is still in the development stage, the implementation of Innosort technology would allow a municipality to collect paper products and UBCs in the same collection stream and still have sorted fractions, making it easier and more convenient to collect used beverage cartons. Municipalities must make sure that their decisions on collection methods reflect advancing technologies.



Figure 15: Innosort Technology at the Danish Technological Institute (by Authors).

Finding 4: Pizza boxes can be collected in several different streams.

Despite numerous possibilities for the collection and recycling of food contaminated cardboard, in particular pizza boxes, these products are currently incinerated in most municipalities. This is due to the reduced quality caused by food contamination, as oils and grease cannot be made into new paper, and thus need to be removed from the paper fibers before they can be recycled. The lower quality reduces the price per ton of the collected paper. Nonetheless, it is possible to recover paper and cardboard with food contaminants, which can result in increased collection rates.

Collection in Organic Streams

Some municipalities throughout Denmark, such as Gribskov, instruct residents to place pizza boxes and other paper products contaminated by food in the organic waste stream for composting (Gribskov.dk: Biosortering. n.d.). This method will leave clean cardboard streams uncontaminated. Strictly speaking, the paper fibers in the pizza boxes are not recycled into new paper products, but since organic material is part of the Danish waste plan, it would count towards the 50% recycling target.

Collection of Cardboard and UBCs

It is possible to collect pizza boxes with clean cardboard as well as with UBCs. For example, both Sweden's and Norway's paper packaging streams allow for pizza boxes to be placed with the rest of the recyclables. During our interview, Niels Søgaard mentioned that there were a number of paper mills willing to accept mixed cardboard and UBCs, albeit at a lower price. Vestforbrænding also told us that they were not interested in adding food contaminated cardboard into their clean cardboard streams because they currently sell their clean cardboard for a very high price.

In the United Kingdom, pizza boxes can be recycled with the remainder of the cardboard once the dirty portions are removed and only the clean portions of the container remain. Although implementing this system only involves informing residents about the desired process, it can be inconvenient for them as an additional step is required. Additionally, failure to properly remove dirty portions of the materials will leave the cardboard stream contaminated.

Finding 5: Residents are willing to recycle as long as it is convenient and the service fee remains the same.

Participation from Danish residents is critical to increase recycling as they are responsible for sorting and delivering recyclables. In a study conducted by Dare2, a private consulting agency, for the Danish Waste Association, the Danish population can be divided into four categories: Ida and Ivan Idealist, who will always recycle; Christina and Claus Convenience, who will recycle only when it is convenient; Poul and Pernille Pragmatiker, who will follow recycling rules; and Lasse and Linda Lige glad, who will only recycle if it is easier than simply disposing of the waste (Dare2, 2014). As shown in Figure 16 below, only 12% of the population are not willing to recycle. The remaining population is willing to start sorting more of their recycling, but only if it is easy and convenient to do so and does not cost them more money (Dare2, 2014). Barriers to household separation and recycling stem from a lack of knowledge of the recycling system and of recycling opportunities, rather than a lack of motivation (Dare2, 2014). It is clear that the majority of the population in Denmark will be willing to accept a change towards increasing household recycling as long as the system remains simple, convenient, and inexpensive.

Residents' Attitudes towards Recycling

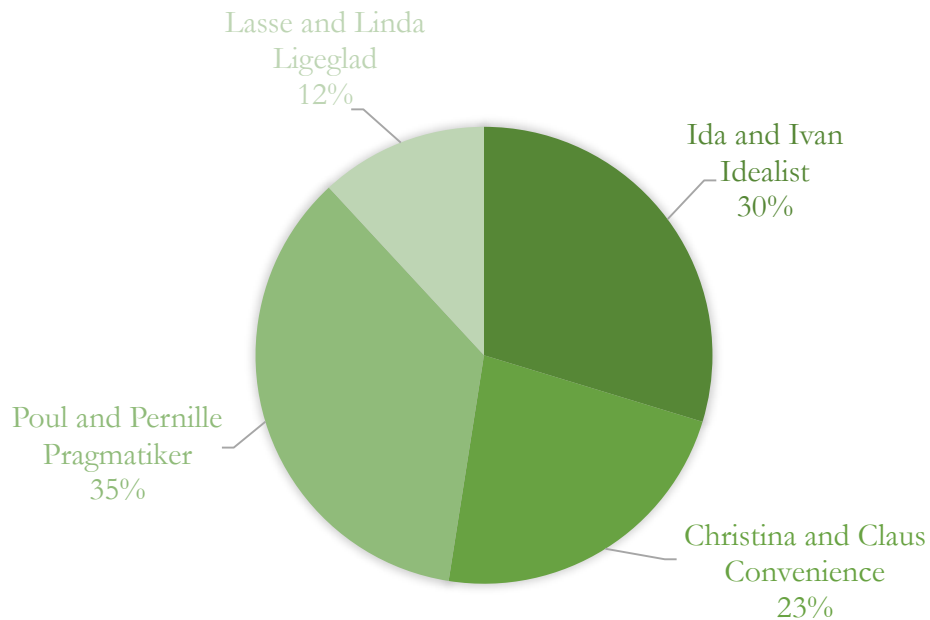


Figure 16: Residents' Attitudes towards Recycling (by Authors based on Dare2, 2014).

Waste management companies need to make sure that whatever system they chose to implement remains easy and accessible to the public. As discussed in the next finding, it is also important that residents are well informed on how the waste management system works and what materials can be recycled.

Convenience for residents is greatly affected by the method of collection of recyclables. Household collection is generally preferred over street containers and recycling centers; according to all of the waste management companies we interviewed, more material is gathered by collecting closer to the source of the waste, because it is more convenient for people to separate from the comfort of their home. Odense Renovations, for example, indicated during our interview that their collection rate nearly doubled after implementing a household collection system, which was accompanied by a significant decrease in the use of their recycling station. This can be seen in Figure 12 of Finding 2 above. However, the number of fractions that can be collected is limited by the number of bins people can keep at their homes.

A report conducted by the Danish Ministry of the Environment also shows that household collection results in the highest collection rate. For single family housing, it is estimated that 90% of the paper and cardboard potential will be collected at the household, as opposed to the 58% that will be collected at street side containers and recycling stations. For multi-family housing, household

collection results in 70% collection rate compared to 52%, respectively. However, the report only gives a broad overview of the different methods without taking into account local situations.

The effectiveness of each collection scheme depends on many other factors that are particular to each municipality. For example, in Herstedøster, a neighborhood in the municipality of Albertslund, the local Agenda Center is installing a street side cube for cardboard recycling which will replace their current household collection for cardboard, where cardboard is collected along with residents' bulky waste. The reasoning behind this is that the bulky waste collection for cardboard is too infrequent and thus leads to more cardboard in the incineration stream. To make it more convenient for residents, the container is being installed at the entrance to Herstedøster, where all traffic in and out of the village must pass. Since the system was only installed in March of 2015, there are no conclusive results that show whether this move from household collection to street side containers has a positive, negative, or neutral effect. Even when there is data regarding the effectiveness of the change, it is important to note that the situation surrounding Herstedøster is different from many other locations in Denmark, because it is a small residential area with only 400 people living in it, and the collecting chamber is only 200 meters away from the farthest household.

Recycling centers provide a centralized location to bring waste, however, they do not tend to be the preferred collection system of residents. As shown in Figure 12 of Finding 2 above, once household collection was implemented in Odense, use of the recycling station dropped dramatically. Figure 10 of Finding 1 above also shows that paper collection by Vestforbrænding is mostly from other sources. However, recycling stations collect many other materials besides paper and cardboard, and are often the only location where substances such as hazardous waste or large equipment can be recycled. There is no reason that paper and cardboard cannot be collected alongside these other materials. In addition, recycling centers may be one of the only locations in a municipality for collection of cardboard. Figure 11 of Finding 1 above, provided by Vestforbrænding, shows that cardboard collection occurs mostly at the recycling station.

The question of economics is much more difficult than that of collection efficiency. Residents will not be willing to accept a change in the recycling system if the service fee is increased. Nevertheless, when the economics of selling cardboard changes, residents might experience a change in the fee they are paying for the collection of their waste. Collecting from the household requires a vehicle that will go to each home. In addition, these vehicles need to be able to keep separated material apart from each other during transit. This can either be done with multiple vehicles, or specialized vehicles that contain multiple compartments. Residents often need to pay for their containers, as well.

Street side containers have an initial installation cost; after they are installed, vehicles are needed to unload the containers. Recycling stations generally have employees at them to maintain the station.

Additionally, it is important to notice that collection methods affect the quality of the material; according to Arne Hansen, curbside collection generally yields higher quality as people tend to recycle better when they are able to see what is inside the container. This quality affects the price a waste company can receive for their collect material, which is passed on to the residents in the fees they pay to the municipality. Each municipality should take into consideration where the expenses go in each collection method and select the one that is more suitable for their needs.

Finding 6: Informing residents about recycling programs can increase rates.

The success of a recycling system depends on the cooperation of the people. Residents themselves are the most powerful driving force to increase collection of recyclable material. However, according to the Dare2 report explained under Finding 5, a lack of knowledge is one of the major barriers to increasing recycling rates. Because of this, many waste management organizations have spent time and resources on teaching the population how to recycle.

The packaging company Tetra Pak in Sweden, for example, has had success in increasing recycling rates through working with residents. Erik Lindroth commented during our interview, that in 2011 the company found Sweden only had a 23% recycling rate of UBCs. Since this rate was lower than expected, the company worked with the World Wildlife Fund to create a school competition which encouraged children to take responsibility of recycling in their own home. The program was very successful and managed to have the participation of 61,234 school pupils (Tetra Pak, 2013). After this education initiative and other programs, Lindroth confirmed that Tetra Pak saw a 38% increase in the recycling of UBC.

Waste management organizations in Denmark have recognized the impact informing residents can have and therefore are putting resources into instructing people, and children in particular. Vestforbrænding, for example, has created a miniature recycling station, as shown below in Figure 17, as well as a “Waste Lab”, where they can educate children of all ages on sorting, recycling, and incineration processes. Brit Schøt-Nielsen and Morten Strandlod explained at our interview that schools bring children to the Waste Lab so they can learn about waste management in a didactic way. The Municipality of Fredericia also works closely with children to help increase recycling of UBCs and pizza boxes. Arne Hanson commented that elementary schools were implementing new recycling bins to collect used milk cartons. To encourage recycling in the schoolyard, one pupil is given the task

of carrying the waste to the recycling bin, which gives the children a sense of responsibility and encourages them to recycle.



Figure 17: Miniature Recycling Station used to Educate Children (Vestforbrænding).

However, learning about recycling can happen at all ages. Helene Eskildsen and Signe Landon, collaborators in the recycling center at Herstedøster, a community in Albertslund that just changed their cardboard collection method, mentioned that in order to inform their 400 residents of the change, they went door-to-door to speak to community members. They hoped this personal approach would motivate residents to use the new system and it would provide the opportunity to ask questions or get clarification on any doubts. However, since the project was still underway, there are no results yet on the effectiveness of the door-to-door approach to education. Moreover, Odense Renovation also had to invest in resources, like an annual newsletter, radio and newspaper advertisements, to inform people about the change in their collection scheme. Hansen and Fuglsang stressed that teaching people the new recycling system was just as important as carrying it out.

In spite of all the effectiveness of keeping residents informed, there is a limitation regarding how many times you can expect the people to learn certain methods. Several of our interviewees mentioned one of the difficulties of changing recycling systems is that once you implement a method and teach the community how to use it, it becomes impossible to take it back. As Brit Schøt-Nielsen and Morten Strandlod mentioned, “when changing fractions or co-mingling, it’s difficult to go halfway and then go back on that decision” – meaning that once you teach people to recycle certain material, it is very difficult to re-educate them and ask them not to recycle it anymore. In general, keeping

people informed on how the recycling systems works is important to maintain high rates, therefore municipalities must include the cost and impact of teaching the society when implementing a new system.

Chapter 5: Conclusions

With only seven years left to attain its goal of increasing municipal recycling rates to 50% by the year 2022, it is imperative that Denmark begins making changes to its recycling system as soon as possible. With this in mind, we gathered and analyzed all of the information we obtained during this project and developed three decision matrices which will aid the Danish Waste Association and municipalities in increasing paper and cardboard recycling rates. Our matrices assume that recycling directly benefits the environment and therefore only evaluates the impacts implementing different techniques will have on the economic and the service pillars. Table 3 below looks at the options for the collection of mixed paper and cardboard, while Tables 4 and 5 look at the possibilities of including UBCs and contaminated cardboard in collection streams, respectively.

There are some gaps open in our decision matrices that call for further research. We suggest the Danish Waste Association complete the missing information by further exploring into the following topics:

- Demand from paper mills for certain quality paper
- How much paper product is actually recycled in paper mills
- Results from the Agenda Center Albertslund street container project
- The economics of the sorting system of the municipality of Fredericia
- Results from the change in recycling systems in the municipality of Odense
- Possibility of creating a paper packaging fraction in which includes UBCs
- Clarifying the effects and difficulties in collecting carton
- Follow up on Copenhagen's decision on introducing UBC collection in 2016

Each of the 98 municipalities throughout Denmark is in charge of deciding its own method of waste collection. Because of this, achieving Denmark's goal of collecting 50% of seven fractions of household waste will require participation from every municipality. Waste management authorities must research which paper and cardboard collection will best serve their community. The decision matrices we presented to the Danish Waste Association will serve as a starting point for every municipality who is looking to increase their recycling rate of paper and cardboard.

Paper and Cardboard	Collection Method	Municipalities that use method	Quality	Market Price (€/ton)	Collection Rate (%)	Collection Price (DKK)	Demand/Tradability	Cost/household (DKK)	Convenience	Notes
Separate	Curbside Collection of Paper	56	Good – protected from the elements	120-123	90	12 (140 L)	Good		High	
	Street Container for Paper	67	Good – have not had an issue with incorrect sorting or contamination	120-123	58	100	Good		Low	
	Curbside Collection of Cardboard Bulky Waste	46	Can be wet from the rain	107-110	Lower – carton not collected; people forget to leave it out for collection; used in own woodstove	Higher	Good		Low – located in the house	
	Street Container for Cardboard	26	Good – protected from the elements	107-110	Agenda Center Albertslund project – predict they might collect more	145	Good	20-25	High	
Mixed	Curbside (Unsorted)	23	Mixed quality	70-75	Highest – convenient for residents; collects carton fraction	Lower – less fractions to collect separate	Lower		Highest	Municipalities sort depending on the market price and access to a sorting facility
	Street Containers (Unsorted)		Mixed quality	70-75	Medium	Lower – less fractions to collect separate	Lower		Low	
	Curbside (Sorted)	23	Greater chance of contamination from other materials	95-98 (for paper); 82-85 (for cardboard)*	Highest – convenient for residents; collects carton fraction	Lower – less fractions to collect				*Calculated by subtracting 25 €/ton (the cost of sorting mixed material) from market prices of separated material
	Street Containers (Sorted)		Greater chance of contamination from other materials	95-98 (for paper); 82-85 (for cardboard)*	Medium	Lower – less fractions to collect				*Calculated by subtracting 25 €/ton (the cost of sorting mixed material) from market prices of separated material
Mixed with UBCs and food contaminated cardboard	Curbside	0		75-80	High	Higher	Very low			
	Street Containers	0		75-80	High	Low	Very low			

Table 3: Decision Matrix on Collection of Paper and Cardboard (by Authors).

Used Beverage Cartons (UBCs)	Collection Method	Municipalities that use method	Quality	Market Price (€/ton)	Collection Rate (%)	Collection Price (DKK)	Demand/Tradability	Cost/household (DKK)	Convenience	Notes
UBCs by themselves	Curbside	0	Can be dirty with food waste	40-50	Low		Limited			Paper mills prefer to buy a mixture of UBCs and cardboard
	Recycling Station	0	Clean – must be taken into car	40-50	Lower		Limited			
UBCs with clean cardboard	Curbside	0		75-80	High		Limited			
	Street Containers	0	Clean	75-80	Medium		Limited			
UBCs with food contaminated cardboard	Curbside	2*		75-80	Medium		Limited			*Only the municipality of Fredericia collects UBCs, however Copenhagen might begin collecting in 2016. Faxe Forsyning ran trials.
	Street Containers	1*		75-80			Limited			*Only AVV ran trials.
	Recycling Station	2*		75-80			Limited			*Only the municipality of Fredericia collects UBCs, however Copenhagen might begin collecting in 2016. AVV ran trials.
UBCs with paper packaging	Curbside	0		75-80			Limited		Easy to decide which fraction to recycle in	System in Sweden with a 37.8% recycling rate of UBCs
	Street Containers	0	Material protected from elements	75-80	Lower		Limited		Easy to decide which fraction to recycle in	System in Sweden with a 37.8% recycling rate of UBCs
UBCs with plastic packaging	Curbside	0		Requires sorting						Germany adopted this system within the green dot system and has one of the highest recycling rates of UBCs
	Street Containers	0		Requires sorting						

Table 4: Decision Matrix on Collection of Used Beverage Cartons (by Authors).

Food Contaminated Cardboard (Pizza Boxes)	Collection Method	Quality	Market Price (€/ton)	Collection Rate (%)	Collection Price (DKK)	Demand/Tradability	Cost/household (DKK)	Convenience	Notes
Bio-Waste	Curbside	N/A	N/A	High	Same as the price to collect bio waste	N/A		High	Will count towards the 50% household recycling rate, however, the paper fibers are not actually being recycled
Recycle with clean cardboard, where food contamination is removed	Curbside with Bulky Waste	Good – however not protected from the elements	107-110*	Lower – inconvenience	145	Good – may be same as clean, separated cardboard fraction		Low – remove contaminated portions	*Potentially less, depending on contract
	Street Containers	Good – protected from the elements	107-110*	Lower – inconvenience	145	Good – may be same as clean, separated cardboard fraction		Low – remove contaminated portions	*Potentially less, depending on contract
Recycle with paper packaging	Curbside	Poor – food contamination	Lower than cardboard	High				High	Used in Sweden with producer responsibility
	Street Containers	Poor – food contamination	Lower than cardboard						

Table 5: Decision Matrix on Collection of Food Contaminated Cardboard (by Authors).

Note: The information presented within the matrices above was gathered from our research, interviews, and site-visits.

In light of Denmark's recycling targets, current recycling practices need to be reviewed and reevaluated. Since so much paper and cardboard is used in the household, it has become an important fraction in the recycling stream and collecting more of this material will put Denmark one step closer to reaching its overall goal. Even though Denmark has a well-established paper recycling system, there is still room for improvement. Unfortunately, recycling is not a clear cut process and many factors must be considered in order to implement a change within the system. Throughout this project, we analyzed two specific approaches that can be taken to increase recycling rates. The first approach consisted of investigating methods to collect more of the potential paper and cardboard products in the households, and the second was to increase the collection potential by including paper products that are currently not collected for recycling. Throughout our investigation, we found that there was no single best method, but rather each municipality, or even the country as a whole, must choose a method based on their individual needs.

Recycling systems can be improved to collect more of the paper and cardboard products that are in the households. According to a Danish EPA report, about 23% of the waste going for incineration is paper products. Collection methods should be improved so that more of paper and cardboard potential is recycled. One approach is to begin collecting paper and cardboard in the same stream. As discussed in Chapter 4, the municipality of Odense changed their recycling system in 2015 to collect paper and cardboard together. Although mixed paper and cardboard is of a different quality than separate streams and is sold for a lower price on the paper market, Odense Renovation believed the convenience for residents and the expected increase in collection were more important than the decrease in value. Because the change was so recently adopted, Odense Renovation did not have any conclusive data on an increase in volume collected.

Some paper and cardboard products still end up in incineration streams because they are not allowed in the current collection for recycling. To take full advantage of paper and cardboard waste resources and to increase municipal recycling rates, systems can incorporate these products into the collection pool. Both pizza boxes and UBCs represent a significant amount of these non-collected material. Denmark utilizes around 25,000 tons of used beverage cartons per year, and today only one out of the 98 municipalities recycles them. One major concern with collecting UBCs is that if collected with other paper products, the current high quality of the recycled paper and cardboard will be reduced and therefore the value of the material will be lowered, making the process undesirable. However, the loss in price can be compensated by a potential increase in volume collected. Other countries within

the European Union, such as Germany and Sweden, have been collecting UBCs for several years and they have been able to reach some of the highest recycling rates in Europe.

Throughout the investigation, paper quality has been a recurring concern from stakeholders. The effect on quality with different collection methods must be considered, and municipalities must be sure that there is a market for their collected product. When determining the best collection method to increase paper and cardboard recycling in local communities, municipalities must research the advantages and disadvantages of each method and its effect on quality, volume, cost, and convenience for users. The Danish Waste Association and municipalities can use our decision matrices as a starting point to this process.

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Appendix A: Interview with Helene Eskildsen and Signe Landon at Agenda Center Albertslund

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling plant, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Introduction

Tell us a bit about your new recycling system.

Goals & Objectives

1. What are your reasons behind implementing a new recycling system?
2. What are you hoping to achieve with the new recycling system?

Old System

3. Why did you change the old recycling system?
4. What were the faults in the old recycling system?
5. How much paper and cardboard recycling are you currently receiving? *Per day/week/etc.*
6. How much contaminated paper do you receive in the recycling streams? *Per day/week/etc.*
7. How clean is the paper and cardboard that comes in for recycling?

New System

8. How will the new system work?
 - a. If residents collect paper and plastic in the same container to be collected, where will that be sorted?
 - b. In your new system, how important is the separation of paper and cardboard?
9. What types of obstacles do you expect to face within your recycling system? *Technical details on problems the facility faces.*
10. How do you plan to overcome these obstacles? *Are these solvable problems, or inevitable?*
11. Will this system be easier than the previous system for residents?
12. How will you dispose of contaminated paper and cardboard such as dirty pizza boxes?
13. What do you expect to work well within the new system? *Could this be implemented elsewhere?*
14. Are you interested in recycling multi-composite material such as used beverage cartons (UBCs)?
15. Have you found that source separation showed an increase in recycling over central sorting?

Economic Effects

16. Is there an increase in cost for the municipality with the new system, especially now that the number of bins will increase? *Transportation of trash*

17. How do you plan on not raising waste fees for residents if you have to collect the sorted waste both at homes and at the new recycling receptacles?
18. Where is the highest cost within your system?

People & Transition

19. How do you plan to inform residents about the new system? Do you have plans for educating children about recycling?
20. How will the transition between recycling systems be carried out?

Appendix B: Interview with Benny Sørensen and Line Falkensten at Vestforbrænding

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling system, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Background Questions

1. Can you tell us a bit about your division, and in particular how you help your member municipalities recycle?
2. What do you think of the goal of achieving a 50% household fraction recycling rate by 2020?
3. We read that Vestforbrænding works hard to recycle as much waste as possible, and we are impressed by your 70% overall recycling rate. However, we have some questions on this.
 - a. Do you know the current paper and cardboard recycling rate?
 - b. Is it feasible to go beyond the current recycling rate of paper and cardboard?
 - c. What will need to change in order to recycle more? (Collection, citizen's awareness, etc.)
4. How much paper do you receive for recycling?
 - a. How do you think we could increase this?
 - b. Which collection scheme gives the most amount of paper to be recycled? What about cardboard?
5. How much paper goes into incineration streams?
 - a. What is the main reason why paper ends up in incineration streams? Contaminants?
 - b. What is the most common contaminant found in paper and cardboard?
 - c. Is there a way to reduce this contamination?
 - i. How?
 - d. How much contamination can treatment plants tolerate?
 - e. If bad quality paper is obtained from contaminated paper, can this still be reused for purposes where high quality paper is not needed? Will this be convenient?
 - f. How much of the paper and cardboard that you collect actually gets recycled? How much is too contaminated to get recycled and has to be incinerated? What do you do if a load of paper waste is rejected?
6. How high is the quality of the paper that you receive?
 - a. Is there something that could be changed in the collection system to improve the quality?
 - b. When/how do you determine the grade of the paper bales?
 - c. What kind of collection methods give the highest quality paper?
 - i. Paper from recycling centers, paper collected from homes, paper collected from collection bins in the street
7. What do you think of sorting in the facility vs. source sorting?

8. How do you determine which paper mills to send your paper to?

UBCs (Used Beverage Cartons) and Dirty Cardboard

9. How often do you see UBCs with paper recycling?

a. Does that lower the quality of the paper you receive?

10. Do you collect UBCs?

11. Can you recycle UBCs with dirty cardboard?

12. What do you do with pizza boxes you receive?

a. How would recycling these with the rest of the cardboard affect the quality of the paper product?

Appendix C: Interview with Arne Hansen and Anne Lene at the Municipality of Fredericia

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling system, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Topics to Discuss

- Collection system of milk, juice, and gravy cartons
- Collection system of dirty cardboard, for example pizza boxes
- Quality and price of collected paper and cardboard

Questions

1. Can you tell us a little bit about your recycling system, in particular in regards to paper and cardboard collection?
2. When did you start to collect UBCs (used beverage cartons) and Tetra Pak products?
 - a. Why did you decide to start collecting UBCs?
3. When did you start collecting contaminated cardboard, such as pizza boxes?
 - a. Why did you decide to start collecting contaminated cardboard?
4. What other paper products, if any, are the UBCs collected with?
5. What other paper products, if any, is the contaminated cardboard collected with?
6. Have you seen an increase in paper and cardboard collected for recycling?
 - a. If so, by about how much?
7. What is the quality of paper and cardboard you are now receiving?
8. Have you seen a decrease in price for the paper and cardboard you are selling?
9. How have you educated people on the new recycling system?
 - a. How did the society feel about the change in the collection? Have you faced any opposition?
 - b. How quick did residents respond to the new system?
 - c. How much participation do you get? Has it increased over the past few years?

Appendix D: Interview with Lars Hansen and Ole Fuglsang at Odense Renovation

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling system, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Questions

1. Can you give us a brief overview of your company and what you do?
2. Why did you decide to start collecting paper and cardboard together?
3. What kind of research and resources did you look into to inform your decision?
4. What was your previous recycling system for paper and cardboard?
 - a. How well was it working?
 - b. Why did you decide to change it?
5. So far, how successful has your new system of collecting paper and cardboard together been?
6. What is the quality of paper you are receiving?
7. We have heard that mixing paper and cardboard together can have an impact on the quality, and therefore makes it hard to sell. Do you believe it will be harder to place your combined products in the paper market?
8. Have you had to change contracts or sell paper to different paper mills?
9. Have you seen a decrease in the amount of money you are receiving for each ton of paper and cardboard collected?
 - a. If so, by how much?
10. Have you seen an increase in the volume of paper and cardboard collected?
 - a. If so, is it enough to compensate for the lower price you are receiving for your paper?
11. Do you know the paper and cardboard recycling rate of Odense?
12. About how much paper and cardboard do you collect each day?
13. Have you considered collecting UBCs (used beverage cartons), such as Tetra Pak containers, in your paper and cardboard streams?
14. Have you considered collecting contaminated pizza boxes in your paper and cardboard streams?
15. How have you educated people on the new recycling system?
 - a. How did the society feel about the change in the collection? Have you faced any opposition?
 - b. How quick did residents respond to the new system?
 - c. How much participation do you get? Has it increased over the past few years?

Appendix E: Interview with Niels Søgaard at DanFiber

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling plant, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Opening & Background Questions

1. From our understanding, DanFiber is the link between collecting recyclable paper from Danish municipalities and sending it to paper mills. Can you tell us more about your company's role in the paper and cardboard market?

Paper Market

2. What are the major factors in determining the price of paper resources?
3. Do you buy and sell cardboard that's contaminated by food?
 - a. How much contaminated cardboard does a paper mill usually receive?
 - b. Is there much of a market for it?
 - c. What can it be used for? Is it much of a problem?
 - d. Do you see a lot of contaminated cardboard? Is this something that the public needs more education on?
4. Is the paper market generally stable?
5. How will an increase of paper and cardboard recycling affect the paper market?

Paper Mill

6. What are some challenges that paper mills face and how could you improve the current system?
7. What costs paper mills the most when recycling paper and cardboard?
8. Of the material going into the mill, how much is recycled and how much is new?
9. What is the quality of the recycled paper compared to new paper?
10. Can paper and cardboard be recycled together?
 - a. Why is it better to recycle them separately?
 - i. Is cardboard a lower grade / have shorter fibers?
11. How well can a plant cope with contamination?
 - a. Are there ways of removing contamination?
 - b. Is there a certain amount of contamination allowed that won't harm the final product?

Danish & International Paper Mills

12. Why has Denmark reduced the number of paper mills over the last years?
13. How does transportation to paper mills in other countries affect prices?

Fiskeby Plant

14. Is it worth to transport milk cartons (economically and conveniently) all the way to Sweden?
Will it be convenient to have a used beverage carton (UBC) recycling plant in Denmark?
15. Do you believe the UBC recycling system in the Fiskeby Plant could be implemented in Denmark? If so, what challenges will be faced?
 - a. Why is Denmark still looking to burn UBCs rather than recycle them?
16. How much of the entire UBC is paper that's recycled?
17. How do other countries collect and dispose of UBCs?

Technical Questions

18. About how much paper fiber has to be discarded because the fibers are too short?
 - a. Can this be improved by educating the public about the quality of paper that should be recycled?
 - i. or, better just to separate it at the plant
19. How are paper fibers separated?
20. When pulp contains fibers that are too short to use, do you throw the whole batch out, or can you separate out the fibers that are too short?

General Questions

21. Have you seen a decrease in the amount of paper you receive for recycling?
22. Have you seen an increase in the amount of cardboard you receive for recycling?
23. We heard that you have done some consulting for municipalities on different methods of collecting paper. In your opinion, what is the best method?
 - a. What about for cardboard?

Appendix F: Interview with Brit Schøt-Nielsen and Morten Strandlod at Vestforbrænding

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling system, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Background Questions

1. Can you tell us a little bit about your company, and in particular how you help your member municipalities recycle?
2. Is your company involved in working towards meeting the European Union's Waste Framework Directive's goal of achieving a 50% household recycling rate by 2022?
3. We read that you work hard to recycle as much waste as possible, and we are impressed by your 70% overall recycling rate. However, we have some questions on this.
 - a. Do you know the current paper and cardboard recycling rate?
 - b. Is it feasible to go beyond the current recycling rate of paper and cardboard?
 - c. What will need to change in order to recycle more? (Collection, citizen's awareness, etc.)
4. How much paper goes into incineration streams?
 - a. What is the main reason why paper ends up in incineration streams? Contaminants?
 - b. What is the most common contaminant found in paper and cardboard?
 - c. Is there a way to reduce this contamination?
 - i. How?
 - d. How much contamination can treatment plants tolerate?
 - e. If bad quality paper is obtained from contaminated paper, can this still be reused for purposes where high quality paper is not needed? Will this be convenient?
 - f. Are any of your municipalities considering recycling dirty cardboard?
 - g. How much of the paper and cardboard that you collect actually gets recycled? How much is too contaminated to get recycled and has to be incinerated? What do you do if a load of paper waste is rejected?
5. How high is the quality of the paper that you receive?
 - a. Is there something that could be changed in the collection system to increase it?

Incineration

6. How will an increase in paper and cardboard recycling affect incineration plants?
 - a. How will you continue to heat so many people's homes without the same amount of waste to burn?

Municipalities

7. What are the economic incentives for residents to recycle their paper and cardboard?

8. Which collection scheme gives the most amount of paper to be recycled? What about cardboard?
9. How much are the street paper recycling bins used?
 - a. About how often do you have to collect the paper and cardboard?
 - b. Where are the recycling bins generally located? How far apart from each other?
 - c. What is the quality of the paper and cardboard you collect from them?
 - i. Is there any deterioration or mold from damp conditions?
 - ii. Do you find people putting the wrong materials into the paper and cardboard bins? Is there a way to prevent this from happening?

UBCs (Used Beverage Cartons)

10. Do any of your municipalities recycle UBC's?
 - a. Are any of your municipalities considering recycling UBC's? Why or why not?
 - b. Could you recycle UBC's with dirty cardboard?
 - i. By how much would this increase cardboard recycling?
11. Are there any negative effects associated with incineration?
 - a. What happens with the contaminants that are filtered out of the steam?

Education and Projects

12. Do you have any educational programs for the general public about recycling?
 - a. How much success have you had with these?
 - i. Have you seen an increase in recycling since starting these educational programs?
13. How much awareness is there among the general public about paper and cardboard recycling?
14. Is Vestforbrænding currently involved with any projects on increasing paper or cardboard recycling?
 - a. Could you tell us more about these projects?
 - b. Have you worked on any similar projects in the past?
 - i. How much success have you had with these?

Appendix G: Interview with Erik Lindroth at Tetra Pak

We are a group of students from Worcester Polytechnic Institute in Massachusetts, USA. We are conducting interviews with waste companies to learn more about their experiences with the collection and recycling of paper and cardboard. This is a project for Dansk Affaldsforening, and your participation is greatly appreciated. Our ultimate goal is to get a better understanding of the recycling system, including any strengths and weaknesses, and your insights will be extremely useful.

This interview should take no more than one hour, and your participation is completely voluntary, meaning you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would be useful for readers to understand how the recycling process works in specific plants.

If you have any questions, please don't hesitate to contact us at DAF-D15@wpi.edu.

Background Questions

1. Can you tell us a little bit about your company?
2. How are used beverage cartons (UBCs) treated in the waste streams in other countries throughout the EU? Which method do you think is the most successful? Why?

UBCs and Collection for Recycling

3. What do you think the largest difficulty in recycling UBCs is?
 - a. Do some municipalities find it difficult to collect enough UBCs to sell for recycling?
4. How do you support municipalities that want to start recycling UBCs?
 - a. In your opinion, what are the best practices to start collecting UBCs for recycling?
 - b. Are there any areas that are planning to collect UBCs in the near future?
5. Do you know about any UBC recycling initiatives currently in Denmark?
6. Do you think Copenhagen should start collecting its UBCs for recycling in 2016?
 - a. Do you think this is a feasible goal for the rest of Denmark?
 - b. What do you think the quality of this paper stream would be?
7. From 2011 to 2013, Sweden saw an increase in beverage carton recycling of about 10%. What kind of changes did Sweden have to make to see this increase?
 - a. How are UBCs collected in Sweden?
 - b. How much does Tetra Pak pay for producer responsibility?
 - i. How do they finance the collection and recycling of their products?
 - c. Does the cost depend on the type of product collected?

Tetra Pak Products and Recycling Process

8. How does the recycling process of Tetra Pak products differ from paper packaging without plastic?
 - a. Tetra Pak has a large number of different products. Is the recycling process different for each of them?
 - b. Do you produce any products that can be recycled at paper mills that are not equipped to recycle Tetra Pak products?
9. What proportions of aluminum, plastic, and paper are in Tetra Pak products?
10. What is the process for separating the cardboard, plastic, and aluminum from Tetra Pak products?
 - a. Are the plastic and aluminum recycled?
11. Which foods require packaging with aluminum foil?

12. What is the quality of the paper fibers that are extracted from recycling?
 - a. What kind of products are made from recycled Tetra Pak products?
13. Is it possible to create Tetra Pak products from recycled material?
14. Is food contamination a big problem for recycling Tetra Pak products?
15. Is there any research into making your products more easily recycled?
 - a. Are there any plans of reducing the amount of plastic in your product?
 - b. Are there other areas for improvement? What direction are you heading in?

Paper Market and Sales

16. How much demand is there for UBCs in the recycled paper market?
 - a. Is the market for recycling UBCs growing?
17. Are the sales of UBCs growing in comparison to glass or aluminum packaging?
 - a. If so, do you know why?
18. How many facilities are there for recycling UBCs?
 - a. How would an increase in the collection of UBCs affect these facilities?
 - b. Can current paper mills be renovated to recycle UBCs?
19. How much money would a municipality from Denmark receive for one ton of collected UBCs?

Packaging

20. Do you know how many of the UBCs sold are collected for recycling?
 - a. Do you have any data on the collection efficiency in Sweden?
21. How much of household waste is made up of UBCs?
22. Are UBCs part of the EU packaging legislation?
23. How does the EU packaging legislation affect Tetra Pak?