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Sorting of Food Waste in Households on Bornholm

Master Thesis
Sustainable Design
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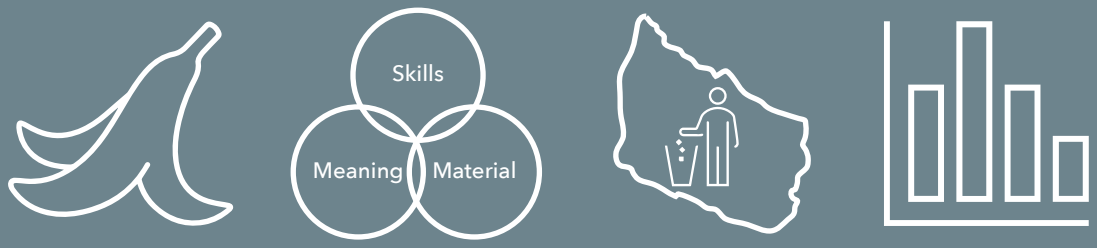

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Sorting of Food Waste in Households on Bornholm
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Abstract

This thesis investigates how decision makers can support households to increase source sorting of food waste. The study is focusing on the specific context of the Danish island Bornholm, with the purpose to work towards a circular economy and a Bornholm without waste.

Bornholm are set to implement source sorting of 12 different waste fractions in the households before the end of 2022. Food waste constitutes almost 50% of the total weight of household residual waste and is therefore an important fraction to separate to recover important nutrients and energy from. Source sorted food waste from Bornholm will be treated in an anaerobic digester, where biogas and fertilizer are produced. However, through the study we identified a lack of focus on the households' role in the system and their crucial responsibility to source sort the food waste, to enable the recovery.

By combining practice theory, ethnographic methods and life cycle assessment in an empirical case study, the thesis shows how the practice of 'sorting food waste' can be established. But also, what barriers might come in the way and what the environmental benefits from recycling the food waste are. The study results in a set of recommendations to the local decision makers (ie. the waste management company) on the island, about how they can support the households to sort food waste.

It was found that from an environmental perspective it does matter to sort food waste and send it to biological treatment, even if it must be transported away from the island to do so. Furthermore, the results showed that information about what can be sorted as food waste, households' willingness to sort and the right equipment (bin, bag, containers), are amongst the vital elements to establish the practice to reach a high sorting rate. Additionally, the study confirms that the combination of practice theory and life cycle assessment shows potential to create solutions that are both environmentally and socially sustainable.

Key-words: *Waste sorting, food waste, Circular economy, life cycle assessment, practice theory, Sustainability, cultural probes*

Preface

This master thesis project is created by three Sustainable Design Engineers in the spring semester of 2022, as our final project of the master study program Sustainable Design at Aalborg University in Copenhagen. The project aims to support the transition towards a Zero Waste Bornholm by focusing on an increased source sorting of food waste. This project was made as a collaborative process with the waste management company on Bornholm, BOFA. We would like to show our gratitude to BOFA and especially David Christensen, who has helped us to get in contact with various actors, but also contributed with important knowledge and insights relevant to the project.

Also, a special thanks to all the people involved in the innovation project 'Much Less Food Waste'. Thanks to Pia Dahlin and Mathias Fallesen from BASF, to Gunhild Nørgaard from Rema 1000 and to Mikkel Dalsgaard from Bacess A/S. Also, a special thanks to Keld Christensen, housing administrator in Bo42. Without his help we would not have been able to get in contact with the households in Bo42. We would also like to show our gratitude to all the participants from Bo42. Thanks to Dorte and Henrik, Eva and Olivia, Troels, Ejvind and Tove, Lene and Brit for taking part in our interviews and to participate in our food waste sorting test. Without their dedication, honesty and hard work this project would not have been possible.
Furthermore, we would like to thank Morten Brøgger Kristensen from Solum and Charlotte Louise Jensen from Concito for spending time to help us learn more about biological treatment of food waste, practice theory and cultural probes.

Additionally, we would like to thank our supervisor Monia Niero, who has guided us in the process and supplied us with relevant feedback, literature and motivation. Thanks for all the dedication and hard work you put into supervising us.

Table of Contents

Term	Definition
Source sorting	Sorting the waste at its source (e.g. In the household when it is generated). The word "sorting" will be used interchangeably with "source sorting" in the report.
Food waste	Covers all organic waste from the households, both edible (leftovers, food gone bad etc.) and non-edible (peels, bones etc.).
Residual waste	Covers all waste that is not sorted for recycling but is send for incineration or land fill.
Biological treatment	The process of treating biodegradable waste by natural processes driven by microorganisms (e.g. anaerobic digestion).
Anaerobic digestion	The decomposition of organic waste material by anaerobic microorganisms, typically used as a means of waste disposal or energy production.
Sorting rate	The amount of material sent for recycling in opposition to being send to incineration or land fill.
Tender	A tender is an invitation for companies to bid on a specific task that for example the municipality needs to get solved – for example the collection and treatment of different waste fractions.
Bin	Waste container inside the household, for example placed in the kitchen to sort different waste fractions.
Collection container	Waste container outside the household, that is emptied by the waste collection company.

Reading guide

This report is structured in the following sections:

During the report the figure will help the reader to orientate.

We start by setting the scene to explain the background of the thesis project. This is followed by a literature review investigating the existing literature within the field of LCA, practice theory and sorting of food waste.

In the following section the theory and methods that are used to frame the project is presented. Then an explanation of the empirical findings we have made on Bornholm is presented in the section named “Gathering empirical knowledge”. After presenting this the analyses of the empirical knowledge comes.

Based on our findings in the analyses we have created some Recommendations for decision makers on Bornholm. This is followed by a discussion of the project, the contribution we are making to the field of Sustainable Design Engineering and finally the conclusion, including ideas for further work.

Setting the scene

Section 1

1. Setting the Scene

1.1 Waste as a ressource

According to the newest report from the Intergovernmental Panel on Climate Change (IPCC), global temperatures are still on the rise and tipping points are reached. The window for action to stop this development is quickly closing – yet still open (IPCC, 2022). The results are critical and the need for sustainable transitions are urgent. The IPCC, as well as the United Nations (United Nations, 2021), the European Union (European Commision, 2020) and the Danish government (Miljøministeriet, 2021) all mention the circular economy as a strategy to create the sustainable transition needed to mitigate climate change.

One of the main principles of the circular economy is to eliminate the concept of waste and circulate products and materials at their highest value (Ellen MacArthur Foundation, 2022). In the circular economy, waste is seen as a resource and should therefore be kept in the cycle. But currently only 8,6% of the resources we use are being cycled back into the system, creating a circularity gap of more than 90% (Circle Economy, 2022). In the year 2020 the average Danish household generated a staggering 845 kg of waste per person, compared to the European average of 505 kg (Eurostat, 2021). Thereby ranking Denmark as the lead country in Europe generating the highest amount of municipal waste per inhabitant. In 2019 only 42% of the waste from households in Denmark were sent for material recycling of some sort (Miljøministeriet, 2021). Exactly the art of sorting and recycling waste in an efficient way is fundamental to create a more circular use of products and materials (Miljøministeriet, 2021). This not only means that Danish households generate a tremendous amount of waste, the potential for improving recycling rates are huge.

1.2 Tools for sustainable decision making

When transitioning towards more sustainable consumption patterns the influence of policy making and governance cannot be neglected. Decision makers, like politicians and municipalities, have great influence on what solutions are decided to be put in place when for example managing waste in a certain geographical area.
For the decision makers to be able to make justifiable, well-founded and sustainable decisions on behalf of other people, many factors must be considered. Both quantitative and qualitative data concerning the economic, environmental and social impact of the chosen solution should preferably create a solid basis for the best decisions.

To enable the decision makers to complete this task, decision support is needed. Different tools exist to create a solid basis for decisions. For many years financial calculations have been the main determining factor when choosing a solution. But in recent years factors like the environmental impact of the solution is starting to have an influence as well. Examples proving this are when climate footprints or calculations of greenhouse gas emissions become requirements in the construction industry in Denmark (Indenrigs- og boligministeriet, 2021) or when public procurement policies requires all products to be eco-labeled (Finansministeriet, 2020).

One of the preferred tools to measure the potential environmental impact of a product or system is the life cycle assessment (LCA). As it is described in the ISO 14040 standard:

"An LCA can assist in informing decision makers in industry, government or non-government organisations (e.g. for the purpose of strategic planning, priority setting, product or process design or redesign)"

(International Organisation of Standardisation, 2008a, p. 10)

LCAs can be used to create a model of reality to measure the potential environmental impact associated with a specific product or system, including waste management systems. But as with other models of reality, the results are only as good as the data and assumptions put into it and the context which the results are used in. Meaning that the LCA as a decision support tool should be used with caution and the decision makers needs education on what and what not, the LCA can be used for (Hann, 2020). There are simply some limitations to what the LCA can adequately grasp with the existing methodology and thereby a limitation to how truly it reflects reality and how much you can rely on the results for decision support (Ekvall et al., 2007).

Literature suggests complimenting the technical LCA as a decision support tool with other methods from other fields of science (Polizzi di Sorrentino, Woelbert and Sala, 2016; Niero et al., 2021). By combining methods from social science and engineering in a socio-technical approach, we expect that the assumptions and the context of which the LCA is based on, can provide a closer reflection of reality in the model.

Another aspect where we expect the social science to support the LCA is to create action plans to reach a certain desired future. Often results from LCA gives a static picture of a potential environmental impact based on a certain set of assumptions in a specific setting (Ekvall et al., 2007). But the LCA is falling short on its ability to inspire or give insight to how the modelled scenario can be obtained in reality. In other words, it could be said that the LCA provides a "what" to reach, but not a "how" to reach the desired scenario with a lower potential environmental impact. This is also where the insights from social science can complement to create actionable decision support for decision makers wanting to create sustainable change.

1.3 Targets for source sorting in the households

Decision makers around the world have already taken many decisions to create sustainable change in a plethora of different operational areas. One of these areas is concerned with waste and how the value of the resources can be kept in the system at its highest quality. But how do we know what is best in terms of treating the waste? Here the "waste hierarchy" (The European Commission, 2008) can be useful to visualise the most preferable way to treat the waste to keep the value of the resources, see **figure 1**.

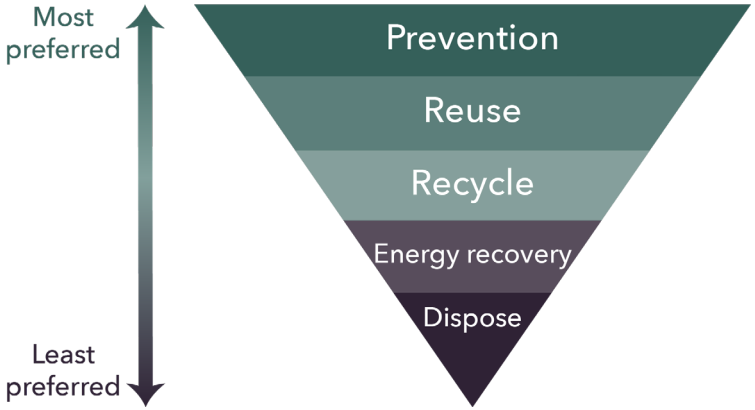


Figure 1: Waste hierarchy

The work in this thesis is focusing on the area of recycling and recovering. One of the main conditions to enable recycling is the correct source sorting of waste fractions in the households. Source sorting is a term used to describe the sorting of waste at the source i.e. where it is generated, in this case in the household. In EU's Circular Economy Action Plan, the importance of waste sorting is stressed if we are to transition towards a circular economy:

"High quality recycling relies on effective separate collection of waste."

(European Commision, 2020, p. 13)

In line with this EU has set targets for the source sorting of municipal waste in the member states, including Denmark. By 2025, the preparing for re-use and the recycling of municipal waste shall be increased to a minimum of 55 % by weight, by 2030 the target is 60% and in 2035 it is 65% (European Parliament and European Council, 2018).

On this basis the Danish Government has created their own action plan for a circular economy. A national plan to prevent and manage waste. The national targets in Denmark are set to reach the targets from EU. By July 1st 2021, all Danish municipalities were obliged to establish collection schemes for source sorted household waste in the following fractions: food, paper, cardboard, metal, glass, plastic, cartons from food and beverage and dangerous waste. In July 2023 textile is added to the scheme. Furthermore, the recommendation is to collect small electronics and batteries together with the dangerous waste (Miljøministeriet, 2021).

Until now all municipalities have had their own individual rules for waste sorting and management, meaning that the potential of recycling the fractions has been challenged due to differences in material composition and amounts in the collected waste fractions (Etwil-Meyland, 2019). The purpose of aligning the waste management systems across all municipalities is to increase the potential of recycling the waste and to reduce confusion about how to sort among citizens. This is an example where results from LCAs could have been used to argue for the benefit of investing in the streamlining of the municipal waste sorting systems across municipalities.

But due to challenges of establishing the infrastructure for the collection schemes, 74 out of 98 municipalities got dispensation to postpone the establishment of collection schemes until December 31st 2022 (Miljøministeriet, 2021).

Source sorting of waste on the "Bright Green Island"

One of the municipalities that have postponed the requirement of establishing collection schemes before July 2021 is the Danish island Bornholm, located in the Baltic sea. In the beginning of 2022 very few types of waste are source sorted and collected at the households on Bornholm (paper/cardboard/textile, glass, small electronics and batteries).

As other municipalities the Bornholm municipality is working to establish the collection schemes to be ready at the end of 2022.

Many decisions are to be made to create the most environmentally and practically viable solutions (**Figure 2**).

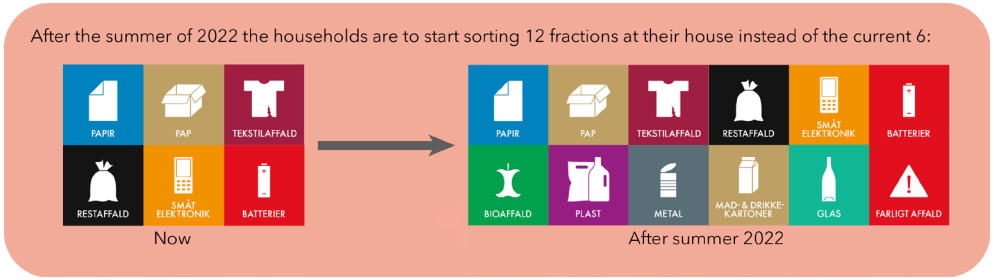


Figure 2: The current and future waste sorting scheme

Bornholm is a place where the "green" agenda has been in focus for several years under the project name "Bright Green Island". The vision is to create a Zero Waste Bornholm (ZWB) in 2032, where the local incineration plant will be closed. The goal is to prevent as much waste as possible and enable recycling for everything else (Christensen et al., 2021), (**Figure 3**). But there is still some road to travel before the vision can become reality. Therefore, the local waste management actor, BOFA and the Regional municipality, Bornholms Regionskommune, are working with different innovative projects and collaborations to support the agenda to become a "Bright Green Island" (Bornholms Regionskommune, 2018).

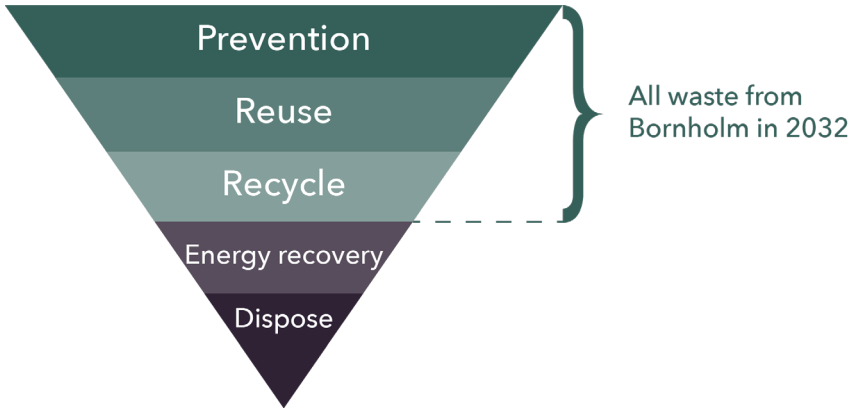


Figure 3: Vision for Zero Waste Bornholm in 2032

Project "Much Less Food Waste"

The work for this thesis started together with one of BOFA's ZWB innovation projects, namely the project "Much Less Food Waste" (in Danish "Meget Mindre Madspild"). A project made in collaboration between BOFA, Rema 1000, BASF, Bo42 and BACESS A/S (see **appendix 1: Project Much Less Food Waste**). It is a pilot project investigating the potential of a specific biodegradable bag, both used to store and prolong the lifetime of fruits and vegetables, but also to collect food waste from the households to be composted locally on the island. All to ensure less food waste and the correct sorting and treatment for the food waste. In line with this innovation project

the focus of the thesis became the source sorting of food waste in households on Bornholm, specifically focusing on the households in the collaborating housing association, Bo42, in Rønne. Both with the agenda to support the project "Much Less Food Waste", but also to provide valuable knowledge for BOFA to create a successful transition to the upcoming change in the waste sorting habits for the inhabitants on Bornholm.

Very early in the process of interacting with the project partners we discovered a lack of insight and focus on what is going on in the household in regard to waste sorting. Attention were given to technical aspects of the biodegradable bag and the treatment of the waste in a composting facility. Therefore, we saw a gap where we could contribute with knowledge on the social practices in the households. Social practice is a term describing "what and why people do as they do" and will be elaborated later in the report.

Aligned with the focus of the innovation project, the thesis is focusing specifically on the food waste fraction (**figure 4**). Even though we look at one type of waste we acknowledge that no households only have to deal with food waste seen in isolation. In all households, there will also be other types of waste fractions like plastic, paper, metal, glass etc. If food waste is to be source sorted it is most likely that other waste fractions are source sorted as well. We argue that zooming in on the source sorting of one type of waste can generate some general learnings, that are also applicable to other types of waste fractions, even though obviously different kinds of challenges will arise when learning to sort food waste compared to e.g. plastic waste. We kindly ask the reader to have this in mind when reading the report.

Figure 5 provides the reader with an overview of the related projects and targets that are relevant for the understanding of the thesis project and where the knowledge produced can contribute.

Figure 4: The focus of the project will be on food waste

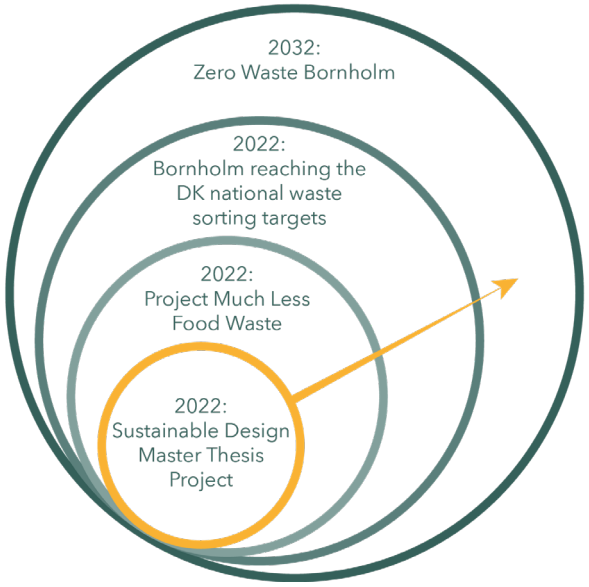


Figure 5: The contribution of the master thesis project

1.4 Research question

This master thesis is based on what is called a socio-technical approach, shortly described it means we take both humans and technology into consideration when answering our research questions. We will investigate how a combination of methods from technical and sociological fields of knowledge can be combined, to provide a solid basis for decision makers on Bornholm to create a more sustainable waste management system. The purpose is to ensure an increase in resource recovery from the island, as it is a crucial component in the transition to a circular economy and a Zero Waste Bornholm.

The research question and the accompanying sub-questions which are used to answer the main question, are the following:

How can decision makers support source sorting of food waste in households on Bornholm, to encourage the transition to a circular economy and thereby towards a Zero Waste Bornholm?

- *How does source sorting of food waste in the household affect the total environmental performance of the food waste manag ment system?*
- *What is the practice of source sorting food waste in households on Bornholm?*
- *What kind of support should decision makers provide to households, to help them increase source sorting of food waste?*

The sub-questions are addressing different aspects of the overall research question.
NB: The words “source sorting” and “sorting” will be used interchangeably throughout the report.

To evaluate the environmental performance of the food waste management system we conducted a life cycle assessment (LCA) (Hauschild, Rosenbaum and Olsen, 2017). The food waste management system includes all processes from source sorting in the household, collection, transport, treatment and the benefits gained from recycling the waste. The purpose of the LCA is to understand what impact an increase of the sorting rate (i.e. amount of material send to recycling) has on the overall environmental performance of the waste management system. We compare scenarios with different amounts of source sorted food waste that is send from the households to either anaerobic digestion (biological treatment) or incineration.

By making a practice theoretical analysis of source sorting in the household, we want to address the social aspect of sorting food waste. We look at materials, competences and meanings that together comprise a practice (Pantzar and Shove, 2010). This is done to understand how and why people behave as they do. We both analyse the current practice of sorting waste in the household and the future practice of sorting food waste specifically. The future practice of sorting food waste is still not very widespread on Bornholm and we therefore term it as a “proto-practice”, meaning a practice that is not yet fully established and stabilised by actors (Pantzar and Shove, 2010).

We will do this by using ethnographic methods like interviews, observations, cultural probes and a survey.

The final sub-question is where the different analyses from different fields of study are combined into recommendations for the decision makers on Bornholm. This is done by making an analysis of the relevant actors and their relations, to understand how the recommendations should be formed and translated to the right people.

Process

To provide the reader with an overview of the interactions we have had with relevant actors and how these have shaped the focus of the project, **figure 6** shows a timeline of the project. The things mentioned in the timeline will be elaborated during the report.

As **figure 6** describes, the thesis project started with one focus for the empirical case study but ended up with a slightly different focus. Going from being closely connected to the pilot project "Much Less Food Waste", to looking more broadly on the practice of source sorting of food waste in households on Bornholm and how to support decision makers in this process. During the entire project the academic focus has continuously been to combine practice theory and life cycle assessment.

The process of the thesis has been very iterative. Every time we explored new fields and obtained new knowledge or met challenges; the project adapted to it. Through this explorative and problem-based approach the report you are about to continue reading came to life.

Date	Activity	How it shaped the project
18/1	First contact to David - Project manager at BOFA	Collaboration established to support the project "Much Less Food Waste".
23/2	Meeting with Bacess A/S	Learning about the compost facility to treat the food waste from the pilot project.
25/2	Meeting with the project group "Much Less Food Waste"	Learning that the pilot project is mainly focusing on the functions of the biodegradable bag and the compost facility, and not so much the social practice of source sorting food waste or the future waste sorting system on Bornholm. Understanding the interests of the different actors.
8/3	Visit to BOFA + Talking to David	Seeing the incineration facility on Bornholm. Learning about the upcoming waste sorting systems on the island. There is a lack of focus on what happens inside the households regarding source sorting.
	Visit to Bo42 (housing association participating in the pilot project)	Seeing the current waste facilities. Learning there are currently limited options for source sorting.
	Interview with Keld (housing administrator at Bo42)	Learning that Bo42 are willing to invest in the project to create better conditions for their inhabitants to sort waste.
8-9/3	Interviews with test persons in Bo42, before test period	Learning about different opinions and habits towards source sorting. Interesting them to be part of our test.
10/3	Food waste sorting kits delivered to 5 test households	Test period start. Participants sort their food waste and note down their thoughts and concerns.

Date	Activity	How it shaped the project
10/3 - 1/4	Text message interaction with test persons	Learning that all participants have integrated their new food waste sorting in their daily routines.
30/3	Survey distributed in relevant Facebook groups to get answers from all over Bornholm	Acknowledging that we need more empirical knowledge to generalise about food waste sorting practices.
1/4	Second meeting with project group "Much Less Food Waste"	Pilot project has been postponed and focus of the thesis can no longer mainly be based on the project collaboration. Focus of the thesis changes to the upcoming implementation of food waste sorting on Bornholm.
5/4	Food waste sorting kits and notebooks collected from test households	Learning that most people found it easy to sort their food waste, but with certain challenges.
	Interviews with test persons on Bornholm, after test period	
6/5	Third meeting with the project "Much Less Food Waste"	Declaring our independence , from the pilot project - they can benefit from the learnings we made on the practices in the household.
10/5	Visit to Biovækst A/S (biological treatment facility)	Helping us to understand the treatment process to strenghten assumptions made in the LCA.
	Meeting with David (BOFA)	Learning more about the upcoming waste sorting systems on Bornholm and how to support decision makers on the island.
14/6	Workshop in "The Waste Tower" on Bornholm.	Handover of recommendations, findings and thesis report to BOFA.

Figure 6: Timeline of the project

Literature Review

Section 2

2. Literature review

This section will outline recent and relevant research identified within; the field of LCA modelling of food waste management, the practice of source sorting waste in households and how results from LCA and practice theory can be combined, in the context of supporting decision makers to create sustainable change. The methodology for the literature review is elaborated in **section 4** and in **appendix 2: Search strings.**

In the previous section life cycle assessment (LCA) is mentioned as a tool that can help support the transition to a circular economy. The tool is used to quantitatively assess the potential environmental impact of different products and systems. This is done to help support decision makers to identify and promote the right solutions to create a circular economy (International Organisation of Standardisation, 2008; Laurent et al., 2014; Slorach et al., 2019). The decision makers can be different actors like policy makers, municipalities, companies or governments. Because of the increasing waste challenges that our world is faced with, by Salemdeeb et al. described as a global pandemic (Salemdeeb et al., 2022), it is important for decision makers to identify the most relevant, economically and environmentally reasonable waste management strategies to implement (Laurent et al., 2014). Therefore LCA, often combined with a life cycle cost analysis (LCC) is used to create decision support (Iqbal, Liu and Chen, 2020; Xiao et al., 2022).

In the field of LCA there are international standards (ISO 14044 and ISO 14040) for how to model certain products or systems, and the European Commission have published guidelines on how to make LCA (for example the ILCD handbook) (European Comission - Institute for Environment and Sustainability, 2010). Even though great efforts have been made to standardise the LCA methodology, it is very complex to align the modelling of different products or systems. The results will always depend on the available data, the chosen method for assessing the data, chosen impact categories and in general what the practitioner chooses to include or not include in the assessment (also described as the system boundaries) (Iqbal, Liu and Chen, 2020).

2.1 Characteristics and limitations: LCA modelling of food waste management

In this thesis the focus is on waste management LCA, specifically focusing on the treatment of food waste from households. For waste management LCA there are, as with product LCA, certain norms and agreements on what elements are taken into consideration – which undoubtedly also leads to limitations of the methodology. By reviewing LCAs on the treatment of food waste and existing reviews of waste management LCAs, several characteristics that enable the modelling, but meanwhile creates limitations to the modelling of food waste treatment, have been identified and are described in the following. Some are specific to food waste and others are general to the modelling of waste management LCAs.

Waste LCAs are often focused on the environmental impact per kg of waste. This allows the LCA practitioner to compare different treatment strategies, but makes it difficult to identify the environmental benefits from reducing the total amount of waste (Ekvall et al., 2007; Astrup et al., 2018; Salemdeeb et al., 2022). This points to the fact that the current way of modelling waste LCAs are not good for creating waste prevention strategies, which according to the waste hierarchy is the preferred strategy to sustain the quality and value of the resources in the waste (Ekvall et al., 2007). This is also the case when comparing the environmental impact from recycling of food waste with food waste prevention. De Sadeleer et al. mentions that even a small reduction of food waste will outweigh the benefits from recovering energy and nutrients from it (de Sadeleer, Brattebø and Callewaert, 2020). But in reality, it is clear that there is still a remarkable amount of food waste that cannot be prevented – for example the non-edible fraction (peels, bones etc.). Thereby the need to focus on how the recovery of energy and nutrients from food waste is still highly relevant to achieve a circular economy (de Sadeleer, Brattebø and Callewaert, 2020).

Typically waste LCAs are modelled based on a zero burden assumption, meaning that the upstream environmental impacts from production, transportation and use of the wasted products are not included in the system boundaries (Astrup et al., 2018). In our case this implies that the production and transportation of food is not included in the modelling. Djuric et al. argues that if we want to transition to a circular economy, the use of the zero burden assumption cannot be accepted. They state that all parts of the system must be considered to address the global waste problems. The zero burden assumption also makes it difficult to see the benefits from reducing food waste across the value chain, both in production and households, it only allows to see the benefits from different treatment strategies (Djuric Ilic et al., 2018).
Another characteristic for waste management LCA is that the environmental consequences from waste management are mainly focused on the indirect impacts on the surrounding system. Meaning for example the avoided impact achieved when generating energy from a waste incinerator (burning waste), instead of producing energy from burning fossil resources, like coal or natural gas (Ekvall et al., 2007). In the LCA results, this would show as an avoided burden because something that would otherwise have been produced from a fossil resource is now substituted with waste as a resource.

Equally it is clear that one of the determining factors in the results from waste management LCAs are what the LCA practitioner assumes is being substituted by the recovered or recycled material. It has an impact on the results whether biogas from an anaerobic digester (AD) (treatment facility for bio waste) is directly substituting the use of natural gas in the grid and if it is assumed that the end product from the AD is substituting the use of artificial fertilizer (Bernstad, La Cour Jansen and Aspegren, 2011; Jensen, Møller and Scheutz, 2015; Xiao et al., 2022). For example Bernstad et al. finds that if energy produced from recycling waste is substituting energy produced from burning coal, the results are almost twice as bad as if it replaced energy produced from wind power (Bernstad, La Cour Jansen and Aspegren, 2011).

This also leads to the challenge of accounting for the benefits or consequences that are hard to quantify. This could for example be the soil improvement potential from using compost as fertiliser. It is hard to quantify the increased growth of a food producing plant as an environmental benefit. Other examples of additional benefits from using compost is a reduced water use and reduced soil erosion (Andersen et al., 2012). This issue could result in LCA results that favour waste management solutions where the environmental benefits are easier to quantify. Most of the LCAs identified in the literature review were based on data from the past. This creates a static picture of the impacts from the waste system. And it makes it hard to predict what impact future waste streams in future waste solutions will have, because the data available is reflecting the status quo or the past (Ekvall et al., 2007).

Apart from identifying typical characteristics of waste LCAs, the review also included an assessment of the results from existing LCAs looking at the treatment of source sorted food waste. The overall conclusion from reviewing existing results is that it is better to treat the source sorted food waste with biological treatment solutions (like anaerobic digestion and compost), instead of incinerating it with the residual waste. Meaning that there is an environmental benefit from source sorting the food waste (Bernstad, La Cour Jansen and Aspegren, 2011; Bernstad Saraiva Schott and Andersson, 2015; de Sadeleer, Brattebø and Callewaert, 2020).

2.2 Lack of focus on the households

During the literature review it became evident that the main focus of most of the identified LCAs were on the technological waste treatment solutions (Bernstad, La Cour Jansen and Aspegren, 2011; Andersen et al., 2012; Rousta and Ekström, 2013; Jensen, Møller and Scheutz, 2015; Edwards et al., 2017; Khoshnevisan et al., 2018; Kromann et al., 2019; Slorach et al., 2019; Dolci, Rigamonti and Grosso, 2021; Xiao et al., 2022). The content of these is elaborated in the literature library see **appendix 3: Literature Library.** A general pattern showed that the results from the LCAs relied on assumptions about certain amounts of source sorted waste being sent for treatment. This revealed a lack of focus on the actual source sorting at household level. We argue that source sorting in households is a key element in allowing the certain amounts of sorted waste to actually be treated. Without well-functioning source sorting in the households, the LCA results would probably look different. This illustrates a gap in the literature on LCAs of household waste treatment.
On Bornholm it is assumed that the inhabitants will generate 3000 tons of food waste per year (Bornholms Regionskommune, 2021). That is the amount decision makers will use to create the criteria for a tender on the treatment of food waste. But not much focus is on the actual changes it will require in the individual households to source sort the 3000 tons of food waste. And what consequences will it have on the chosen treatment solution if the households only manage to source sort a smaller amount?

To accommodate this issue Rousta et al. argues there is a need for multidisciplinary research within the field of waste sorting behavior and material recovery from municipal waste. They identify some key factors that affect recycling behavior the most. They are: appropriate physical infrastructure, shorter distance to collection points, reliable service, user convenience and adequate information (Rousta et al., 2017). The better the households are at sorting, the cleaner the material composition of the waste fraction, and, in the end, the recovered product will be in a higher quality. Despite this fact, there are to our knowledge only very few research projects which combine the technical approach with the sociological to understand the role of good source sorting in the households.

In an LCA study from Bernstad et al. they compare a real scenario for waste sorting in households (what is actually happening) with an ideal sorting scenario (what do we hope is happening) in a case study from Sweden. They conclude that an improved source sorting behavior in the household will result in a better environmental impact and higher quality of the recovered products (Bernstad, La Cour Jansen and Aspegren, 2011; Zhang et al., 2020; Woon et al., 2021). However, they do not address how the households can reach the ideal source sorting scenario.

2.3 Combining practice theory and LCA

The combination of the social science approach, in the form of practice theory, and LCA shows potential to improve the LCAs ability to reflect reality and create guidelines on how to reach or obtain a desired scenario or behavior. Therefore, we continued the literature review focusing on the combination of LCA and social science, to learn more about what impact the households' ability to source sort waste, has on the waste management system. The results of the search revealed few examples of actual LCAs that included analysis of "behavior" to model the system – most were product focused LCA. The methods used to understand behavior were in most cases either laboratory tests, living labs or questionnaires to create more "real" assumptions for the modelling of the use-phase in LCA (Daae and Boks, 2015; Pohl et al., 2019; Suski, Speck and Liedtke, 2021; Cooreman-Algoed et al., 2022).

There are many different branches of the field of social science that investigates how people behave, also described as 'behavioral science'. But as Spurling et al. describe, it is necessary to look deeper into behavior than just understanding what people do (Spurling et al., 2013). It is necessary to understand why people do what they do and it is not enough to trust people at what they say they do (Spurling et al., 2013). To create a sustainable change in peoples' behavior they argue that problems should be framed from a "practice" perspective, sometimes described as "social practice"

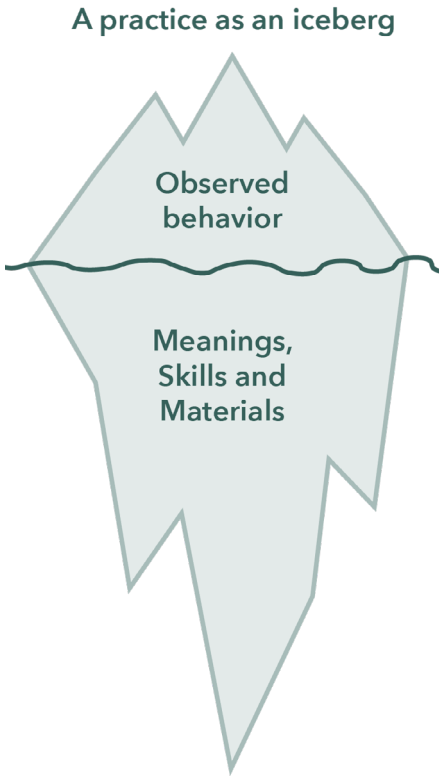


Figure 7: A practice seen as an iceberg analogy. Inspired by Spurling et al. (2013)

(Spurling et al., 2013). Thereby they suggest looking at practices, instead of behavior or technical innovation as the unit of intervention to create sustainable change (Spurling et al., 2013). They describe a practice as an iceberg (**Figure 7**). The observable behavior is the top of the iceberg, referring to the practice as a performance, while the rest of the iceberg describes the practice as an entity to understand the background of the observable behavior by looking at materials, skills and meanings (Spurling et al., 2013). The understanding of a practice comprised of materials, skills and meanings is elaborated in **section 3**.

Niero et al. suggest combining LCA with practice theory (PT) and actor-network theory (ANT) to address unintended side-effects from circular economy initiatives (Niero et al., 2021), but no empirical case-study, where the different fields are combined, is performed. Suski et al. propose a framework for combining LCA and PT to promote sustainable consumption. The purpose of the framework is to move the focus in the LCA from being product and use oriented, to focusing on consumption as a social practice containing material elements that can be coupled to the life cycle inventory of the LCA (Suski, Speck and Liedtke, 2021). Thereby they suggest a way to improve the use-phase modelling, but again no empirical case study is performed.

The literature search did not reveal any empirical case studies combining LCA and PT focusing on the impact of waste sorting in households. This thesis is aiming at filling out this identified gap in the literature.

To do this our literature review continued with the purpose to understand what the literature could offer when looking specifically on the social practice of waste sorting in households.

The practice of source sorting waste in the households

When looking specifically at practice theory combined with sorting of food waste, excluding the focus on LCA, only one relevant study was identified, made by Katan and Gram-Hansen (2021). Most of the identified studies were focused on the practice of reducing or preventing food waste, and not the actual source sorting of such (Schanes, Dobernig and Gözet, 2018; Carolan, 2021; Gojard et al., 2021; Keegan and Breadsell, 2021).

Katan and Gram-Hansen does a case-study on waste sorting in households in Denmark and investigates how social norms can interfere with the practice of waste sorting (Katan and Gram-Hanssen, 2021). They identify different social norms that make people deviate from their normal waste sorting practices. Specifically, they identify that when there are guests or bigger social events the sorting practice is often obstructed because the guests does not know the 'sorting rules' or it feels too cumbersome or impolite for the host to be the 'guardian of moral rectitude' (Katan and Gram-Hanssen, 2021).

In a report from a Danish consultancy, Naboskab, the practice of source sorting food waste was investigated with ethnographic methods from an anthropological perspective. They focus on what barriers the households meet when sorting their food waste within the specific waste sorting system in the municipality of Copenhagen. They identify barriers caused by social norms and the user journey; including lack of trust to the collection bag, lack of space for the ba-

sket for food waste in the kitchen, family members sorting in different ways and the fact that waste sorting is not a subject of conversation (Naboskab, 2021). In **appendix 4 – Sorting of food waste in Copenhagen**, more details from the report are gathered. Even though the report does not specifically mention the practice theory approach, many elements of it can be used to understand the practice of sorting food waste.

As with the report from Naboskab, some literature was not specifically using a practice theory approach to understand waste sorting in households but could still be considered relevant for inspiration for our own study. An example is a case-study from Palestine focusing on household solid waste recycling practices in developing countries. They find that:

"…lack of awareness and information on the process of waste separation and storage are the basic recycling barriers of the local population, whereas financial incentive is the major motivational factor for their active participation."

(Kattoua, Al-Khatib and Kontogianni, 2019, p. 1).

Whether this is also the case in a developed country like Denmark is being investigated in this master thesis project.
A pattern discovered in the literature review was that all identified studies were analysing and discovering already established practices of waste sorting. We find that there is a lack of investigating how an unestablished practice can become established. In other words, how to go from not sorting food waste to sorting it, which would require studying the elements that together could form a practice of sorting food waste. It must be investigated how a practice can be established in a specific context and how to predict what potential barriers that will occur. Rousta et al. describes the importance of doing context specific analyses because no waste management system will fit all. They describe how.

"…a good understanding of the local context is needed to achieve a functioning system."

(Rousta et al., 2017, p.1104).

To achieve the potential environmental benefits from collecting and recovering energy and nutrients from 3000 tons of food waste from households on Bornholm after the end of 2022, it is therefore relevant to do an empirical case-study specifically on Bornholm. In a context where source sorting of food waste is yet an unestablished practice in most households, because the system is not yet in place for it.

Theory and Methods

Section 3 + 4

3. Theory

This section will uncover the theoretical foundation for analysing and understanding the empirical knowledge in this thesis. The section will first provide the reader with our understanding of the term sustainability, by drawing on the concept of Circular Economy. Next, we will unfold Practice Theory (PT) as the main theory for analysing the collected empirical data. The goal is to investigate how PT can complement LCA results, to support decision makers in the waste management sector on Bornholm. Lastly, we will introduce the Actor Network Theory (ANT) as a way to analyse the different actors' roles and concerns in the food waste management system.

3.1 Sustainability from a Circular Economy perspective

The term sustainability, is a very broad and used wording with many authors referring to the Brundtland report from 1987 defining sustainability as:

"…development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

(United Nations, 1987, p. 37)

However, since this definition is quite broad and intangible, we need something more concrete when analysing how this thesis can contribute to the sustainable development. Therefore, we draw on the concept of the Circular Economy (CE) as our understanding and definition of sustainability in this thesis. The concept of CE does not have an original author but is a merge of different science fields trying to introduce an alternative to the so-called Linear Economy (Korhonen, Honkasalo, and Seppälä 2017). Though the concept is a merge of different scientific fields, the consensus of the circular economy is that waste does not exist, everything is a resource and therefore, we should design our resource economy in loops (Korhonen, Honkasalo, and Seppälä 2017; Bocken et al. 2016). According to the Ellen MacArthur foundation who are committed to create and design a circular economy (Ellen MacArthur Foundation 2022c), the circular economy is building on three principles:

1. Eliminate waste and pollution,
2. Circulate products and materials (at their highest value) and
3. Regenerate nature

(Ellen MacArthur Foundation, 2022b).

These principles build on the concept Cradle-to-Cradle developed by Braungart and McDonough in 2002 whose three key points is:

1. Everything is a resource for something else;
2. Use clean and renewable energy and
3. Celebrate diversity

(McDonough, 2002).

This is an example of how the circular economy is a merge of ideas and developed concepts. On top of this the Ellen MacArthur Foundation split the circular economy into two different cycles in what

they describe as a butterfly diagram with one cycle called the technical cycle and the second the biological cycle (Ellen MacArthur Foundation, 2022a), (**figure 8**). With a focus on keeping physical products in circulation the technical cycle fulfils the CE through reuse, repair and recycling where the biological cycle, focus on assuring

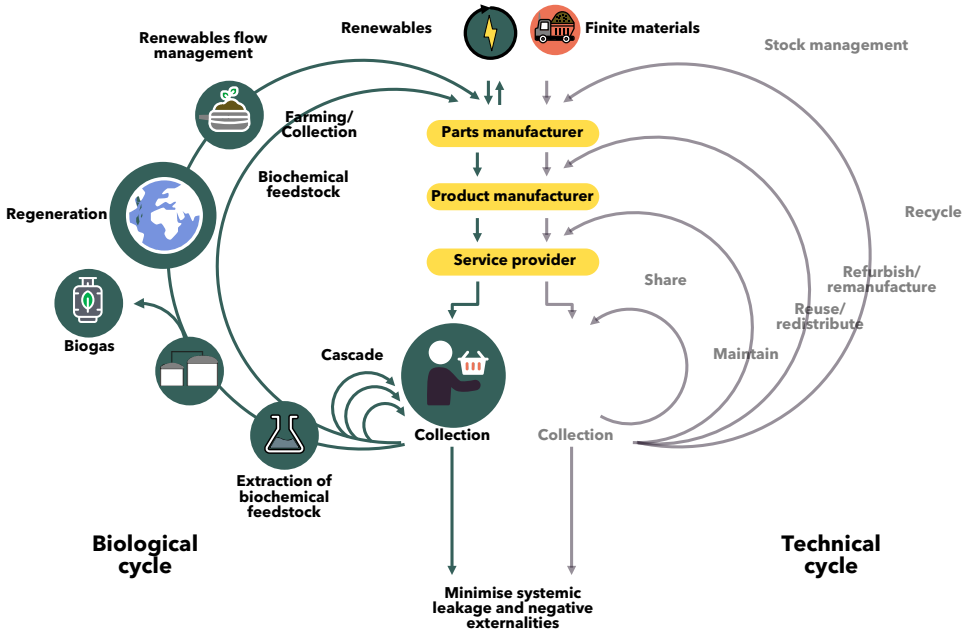


Figure 8: The butterfly diagram. Inspired by Ellen MacArthur (2022)

that nutrients from biodegradable materials (such as food waste) are returned to earth through methods like composting and anaerobic digestion (Ellen MacArthur Foundation, 2022a).
In this thesis the main focus will be on the biological cycle, since we are mainly concerned with the recovery of biological material from food waste. We will use this understanding of the CE to analyse the sustainability potential of source sorting food waste in households and as a mean to accommodate the overarching sustainable transformation described in **section 1**.

3.2 Practice Theory

In order to understand what it takes for inhabitants on Bornholm to start source sorting their food waste, we will recognise source sorting of food waste as a practice. We recognise it in this way because we do not only seek to study what people do (behaviour) but also why people do what they do (culture and meanings). As (Spurling et al. 2013) describes:

> *"…individual behaviours are, primarily, performances of social practices."*
>
> (Spurling et al. 2013, p. 8)

Behaviour is here considered the performance of a practice and does not cover the social aspect of the practice, meaning the socially shared tastes, meanings, knowledge, skills and materials for the practice performed.
The term practice is however not comprehended by one consistent framework. Rather different understandings and definitions exist among authors of what a practice is (Pantzar and Shove, 2010; Shove and Pantzar, 2005; Katan and Gram-Hanssen, 2021). Schatzki presents the view that practices exist across space and time but is very influenced in their local performance by the actual context (Schatzki

2002). Further he states that a practice is:

"…a temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleoaffective structure, and general understandings."

(Schatzki, 2002, p. 87)

While the doings, sayings, rules and general understandings are quite explicit, the concept of teleoaffectivity covers how individual actions are conditioned by circumstances in a specific context, which for example could be what is the acceptable performance of said practice and which socially shared understandings are embedded in the practice (Schatzki, 2002; Katan and Gram-Hanssen, 2021).
Drawing on Schatzki, Shove and Pantzar we acknowledge practices with the notion of:

"…the active integration of materials, meanings and forms of competence."

(Shove and Pantzar, 2005, p. 45)

The materials refer to the physical objects or infrastructures required to perform the practice, the meanings are the reasoning why you perform it, and the competence is the skills and knowledge needed to perform the practice (Pantzar and Shove, 2010; Shove and Pantzar, 2005).

We consent with the notion described by Shove et al. with intention to conduct an analysis of the source sorting practice of food waste by the above-mentioned means. The reason for this is the belief that by understanding the three aspects of the practice (materials, meanings, and competences) and their interconnections, it will allow us to gain valuable insights of what differentiate the current sorting practice from the future one. Thereby we will be able to investigate the dynamics in which a practice is formed and how it relates and affect other practices surrounding the source sorting practice in a so called network of practices. In order to investigate a not yet established practice in the future (source sorting of food waste in households on Bornholm) we adapt to the concept of a proto-practice (**figure 9**). A proto-practice is a practice not yet established with no clear interconnections of the elements which make up the practice (Pantzar and Shove, 2010, p. 5). To accept the concept of proto-practices we must acknowledge that the specific elements making up a practice, have a history both in the past and in the future which allows these elements to transform through specific integration in different practices (Pantzar and Shove, 2010, p. 6).

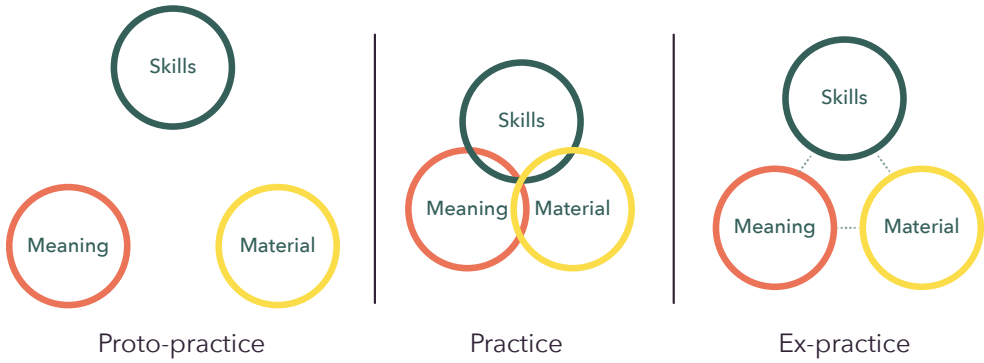


Figure 9: Proto-practice, practice and Ex-practice. inspired by Pantzar and Shove(2010)

This implies that a practice is not stable but dynamic with the potential of deformation between the different elements' integration in the practice, which could eventually also result in an ex-practice (**figure 9**). The concept of a proto-practice is interesting in the upcoming analysis because it allows us to introduce elements such as waste bins, bags and guidance of sorting food waste to get the practice established among the inhabitants on Bornholm, and afterwards analyse what each element meant for the establishment of the practice. However, it should be recognised that we as promoting this proto-practice can only do so much to get the practice established, as Shove notes:

"The producers can design and make certain elements available to promote specific associations between these elements, but in the end it is the practitioners, those who do, who ultimately make the integration and association."

(Pantzar and Shove, 2010, p. 5).

3.3 Actor Network Theory

The framework which the actor network theory (ANT) offers, gives an understanding that the world consists of constantly changing networks consisting of human and non-human actors and the relations between them (Latour, 2005). Even though these networks are constantly dynamic and moving, some networks with strong relations between actors (human and non-human) can be considered more or less resilient to changes or outside interfering, trying to break up or transform the network, for example with the purpose to create sustainable change (Callon, 1986; Latour, 2005). In order to create new relations between actors in an existing network the old relations need to redefined or changed. For this to happen the actors must go through certain processes referred to as the moments of translation (Callon, 1986). Translation, is what Callon describes as:

"…the mechanism by which the social and natural worlds progressively take form."

(Callon, 1986, p. 19)

Hence, this refers to how networks over time can take form in small steps with each step creating deformation of the old network and formation of the new one. The process of which an existing network breaks and a new one forms consists of four phases described at the moments of translation. The phases are: Problematization, Interessement, enrollment and mobilization (Callon, 1986). Establishing a set of actors and determining their identity towards a certain objective is what Callon describes as problematization (Callon, 1986). All actors considered in building the network needs to acknowledge this problematization in order to be part of the network. One thing is to acknowledge the problematization but to become part of the network, actors must also be interested in becoming part of it.

This is referred to as interessement:

"Interessement is the group of actions by which an entity attempts to impose and stabilize the identity of the other actors it defines through its problematization."

(Callon, 1986, p. 8)

In the interessement phase, interessement devices are used to help with this stabilisation of the new network (Callon, 1986). If the interessement is successful the actors should be enrolled in their new roles and tasks in the enrolment phase (Callon, 1986). When the network builders step out of the network, the network needs to stand by itself and not crumble into pieces. For this to happen key actors must become spokespersons of the network and obtain the role of mobilising other relevant actors to the network, here referring to the last phase, mobilization (Callon, 1986).

We have used actor-network theory to identify the key decision makers and their roles in the new food waste management system on Bornholm. This helped us to understand the different actors' interests and relations in the network, but also to identify which of the actors are already mobilised and which are not.

4. Methods

We have throughout the project continuously made use of different methods to be able to understand and navigate in the reality around us. In this section the different methods used in the thesis will be explained. What methods, why we have chosen them, and how we used them in the project will be elaborated.

4.1 Literature Review

When doing the literature for this thesis we have been using a systematic approach to review existing literature in available databases. Fink describes a systematic literature review as a:

"Systematic, explicit and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners"

(Fink, 2019, p. 6)

The purpose of doing the literature review is to build a knowledge base, for further research. According to Booth et al., there are at least three relevant considerations to have, before starting the literature review. These are clarity, validity and auditability, and will be explained in the following section (Booth et al., 2016).

When doing a systematic literature review, it is important to be clear about the methodology of what have been done and not. A clear structure, a focused question and being explicit about the search strategy helps the reader to navigate and interpret the scope and

terminology of the search. All these considerations benefit the clarity of the literature review and should enable others to replicate the search (Booth et al., 2016, p. 30). The second consideration is internal validity. According to Booth et al., the review should prevent potential bias. They mention:

"Systematic approaches require that items are selected for inclusion on the basis of their relevance and rigour, not on whether they report a favourable outcome or whether their results are intrinsically 'interesting'"

(Booth et al., 2016, p. 30).

The third consideration is auditability. The review should always be grounded in the actual data from the review process, and not just fabricated data, that is created to support a subjective goal by the practitioner. According to Booth et al., synthesis is important to act as quality control. In the following section, we will show and explain, how our literature review has been structured.

Search strategy

We conducted different searches with different focuses. The overall themes were:

- **The combination of life cycle assessment and practice theory**
- **LCA on waste treatment of food waste**
- **Waste sorting practices in households**

The different searches were structured using the template, as seen in **figure 10**. The actual search strings can be found in **appendix 2: Search strings**. By using this structured approach, it was possible anytime to backtrack our literature review and make it transparent and reproducible. In this process, we also identified new gaps in our knowledge. Based on this we were able to extend our search with new keywords. By doing different searches with different keywords connected to the overall search themes, we ended up with a large number of articles. The titles and abstracts of all these different articles were carefully read to decide if the article was relevant to our project.

All the literature that was assumed to be relevant, were put into an excel sheet, which we also refer to as the "literature library", which can be seen in **appendix 3: Literature library**.

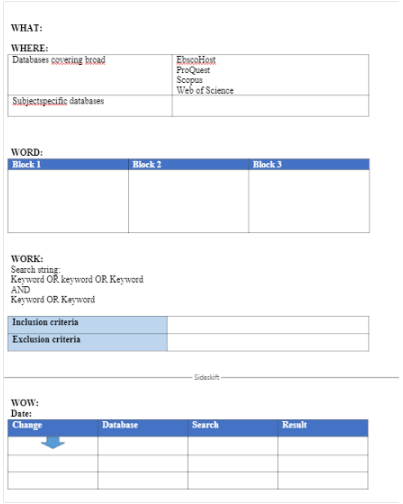


Figure 10: Template for search strings

Figure 11: The narrative of the literature review (see appendix 5)

To be able to navigate and structure all the relevant knowledge from the literature library, we created a narrative for the written literature review. This is shown with the blue post-its in **figure 11**. We then used the references from the literature library, to clarify which references should be applied in the narrative. We refer to this as a 'structural distribution of references' and are shown with white post-its. This structured process was done in an iterative process throughout the entire project and was made visible using an online whiteboard (Miro.com). As more knowledge emerged from the review, the narrative of the literature review was adapted accordingly.

4.2 Environmental impact methods

Stocks and flows

In the project we have used stocks and flow diagrams. This is inspired by the System Thinking Theory suggested by Meadows (Meadows, 2008). According to Meadows stocks are the elements in the system that you can see, feel, count or measure at any given time (Meadows, 2008) it is possible to change these stocks, by intervening in the system. Flows are described as:

"Filling and draining, births and deaths, purchases and sales, growth and decay, deposits and withdrawals, successes and failures. A stock, then, is the present memory of the history of changing flows within the system."

(Meadows, 2008, p. 18).

We have applied the method to map the flow of food waste from households on Bornholm in the current and future waste management system. This allowed us to understand the composition of the waste and the size of the waste flows being treated in different ways. This made it possible to understand where in the system it would make sense to change the current stocks or flows of waste. Furthermore, it has also been a useful tool to illustrate the complexity of the current and new waste management systems.

LCA

A method to assess the potential environmental impact made by products, services and systems is the Life Cycle Assessment methodology (LCA). According to the International Organisation of Standardisation (ISO) 14044, LCA is an instrument that:

"…addresses the environmental aspects and potential environmental impacts throughout a product's life cycle from raw material acquisition though production, use, end-of-life treatment, recycling and final disposal"

(International Organisation of Standardisation, 2008b, p. 10)

This essentially means that an LCA is a model of reality - which either can be a reflection of a current situation or a desired one.

The life cycle assessment methodology consists of four phases (**figure 12**) that are required to be covered in order to live up to the ISO standard:

1. **Goal and scope definition (What is the aim and framing of the LCA?)**
2. **Life-cycle inventory (What data should be included?)**
3. **Life-cycle impact assessment (Choosing impact categories and translating the inventory data into potential environmental impacts)**
4. **Life-cycle interpretation (Analyse the modelled data and draw conclusions)**

(International Organisation of Standardisation, 2008b, p.10)

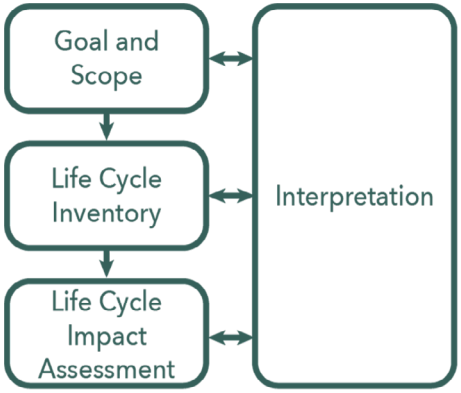


Figure 12: The four phases of LCA

The LCA methodology has over the years obtained its very own community and science field. By doing a search on "life cycle assessment" in Google Scholar, we retrieved approximately 2.070.000 results, and this is only during the last 10 years. One of the main purposes of the LCA is to use it as a supportive decision tool, to help decision makers choose solutions that are better for our environment (International Organisation of Standardisation, 2008; Pohl et al., 2019; Niero et al., 2021).

In this project we have used the LCA methodology to investigate what impact source sorting of food waste in the household has, on the overall environmental impact of managing household food waste from the island of Bornholm in Denmark. This is further elaborated in the actual LCA report in **section 6.**

4.3 Ethnographic methods

Semi-structured interviews

In the project, we conducted interviews with different actors. These interviews have been semi-structured. According to Ahlin, a semi-structured interview is defined as:

"a set number of survey questions that will be asked of all respondents while also incorporating opportunities for more detailed inquiry into topics that arise during researcher – respondent discussions"

(Ahlin, 2019, p.4).

We have used semi-structured interviews in the project when we engaged with the different actors. The interviews were structured in a way, that gave us the possibility to gain new knowledge from the respondents by asking them different questions. Furthermore, it was also possible for respondents, to affect the conversation. This led us to discover new knowledge about topics, we did not know we were looking for.

Observations

To improve our investigation, we also used observations to better comprehend if what people said they do is what they actually do. This was used because it is a primary source of gaining ethnographic knowledge (Hansen, 2009). Observations as a method can be executed in multiple levels depending on the situations and what the end goal of the observation is, as Hansen states:

"The basic difference lies in the respectively increasing degree of participation in which the researcher engages in the observation situation."

(Hansen, 2009, p. 4)

Observations can be done with the observer as a participant either with much or less interaction or as the observer with no participation with the observant in question (Hansen, 2009). We have used observations during our interviews and where waste sorting was embedded in the situation, for example after dinner. We have mainly done observations with little interaction besides a few questions in the performance of the observed situation. We have further used observation to understand how people were sorting in the area of Bo42 by looking in waste containers.

Cultural probes

"Probes are a method for developing a richly textured but fragmented understanding of a setting or situation. Developed in a design context, their purpose is not to capture what is so much as to inspire what might be." and "(...) can be understood as part of a conversation among designers and the people and places for which they design."

(Boehner et al., 2012, p. 185).

Cultural probes are artefacts that can be used to "provoke" inspirational responses from research participants (Gaver et al., 1999). Cultural probes can be materialised in many different ways e.g. notebooks, maps, camera, postcards with tasks or questions etc. Participants receive the probes and "live with them" for a certain period of time, after which the probes are returned to the designers/researchers. We used cultural probes, to gain inspiration and insight into the challenges of sorting food waste from people who are not used to sort their food waste. A clear limitation in the way we used this, is that we only managed to connect with five different households. To secure the reliability of the results, we also decided to create a survey.

Survey

In our project we decided to create a survey as a method to obtain empirical knowledge from the field in a more quantitative way, to supplement the qualitative empirical gatherings that we also did through interviews and cultural probes.
According to Pinsonneault and Kraemer a survey can be defined as a mean for

"…gathering information about the characteristics, actions, or opinions of a large group of people, referred to as a population"

(Pinsonneault et al., 1993, p. 6).

There is no exact definition of how to perform a survey. It is up to the survey practitioner to determine the outline for the survey. We decided to create a survey for the local citizens of Bornholm. This was done for two main purposes. Firstly, we wanted to use the knowledge we had gained from interviews with citizens in Bo42 and see if this was representative when we looked at the larger population of Bornholm. Secondly, we wanted to use all this empirical data to identify potential barriers or issues that could arise when the local citizens of Bornholm have to start sorting their food waste. It was important that the survey was only answered by citizens living on Bornholm. To ensure this the survey started with a question of whether the respondent lived on Bornholm, and the survey was distributed using Bornholm related Facebook groups, and through our personal networks on Bornholm.

Gathering Empirical Knowledge

Section 5

5. Gathering Empirical Knowledge

This section covers the actions of collecting the empirical knowledge for the thesis. As **section 4** covers the methods used to gain knowledge, this section describes the outcomes of what we learned from using the methods.

The section will cover our visit to BOFA on Bornholm where we did a semi-structured interview with one of the project managers, who also gave us a guided tour of BOFA's waste facility. Next, we show and describe the area around the housing association Bo42, called Nordparken, where we observed the current waste management systems and did a semi-structured interview with the administrator of Bo42, Keld. The reason for focusing on Bo42, is that the housing association was already related to the project "Much Less Food Waste" and willing to participate in tests. Thirdly, this section will unfold how we made cultural probes, consisting of food waste sorting kits for our test persons in Bo42. The section also covers the interviews we did with 5 inhabitants/households in Bo42, before and after the test period where they were asked to sort their food waste. Fourthly, this section will introduce the survey which was made and distributed to local inhabitants on Bornholm. The purpose was to obtain a more general understanding of knowledge and concerns on the subject of sorting food waste on Bornholm. Lastly, learnings from our visit to Biovækst, a biological treatment facility on Sjælland, is described.

The analysis of the gathered empirical knowledge will be unfolded in **section 6.**

5.1 About BOFA (waste management on Bornholm)

Unlike other municipalities in Denmark, Bornholm has a dedicated company who is responsible for the waste management on the island, the name of the company is BOFA. On Bornholm the name "BOFA" is also used directly as a synonym for the recycling centers on Bornholm. We visited BOFA in Rønne on the 8th of march with the goal of learning more about the organisation, and how they are set to handle the food waste fraction by the end of 2022. BOFA is owned by the municipality and is responsible for managing the waste from both households and businesses on the island. The current situation of waste management on Bornholm is that most of the collected waste is being incinerated by BOFA's own incineration facility on site. While other waste streams can be sorted at BOFA and send away from the island to be recycled (BOFA, 2022b).

Picture 1: BOFAs recycling center in Rønne

BOFA manages the following facilities (**figure 13**):

- 1 waste incineration facility (Rønne)
- 1 landfill (Rønne)
- 7 recycling centers

(Rønne, Vestermarie, Olsker, Hasle, Aakirkeby, Nexø, Østermarie)

However, the incineration facility is by 2032 fully depreciated which according to the project manager gives a unique opportunity to rethink the waste management system at Bornholm and settle on a new waste strategy. This birthed the ambitious vision 'Bornholm Showing the Way – without Waste 2032' and the project Zero Waste Bornholm (BOFA, 2019), as described in **section 1**.

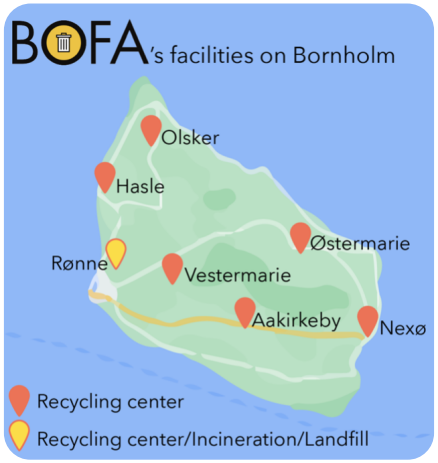


Figure 13: BOFAs facilities

The tender of food waste management

BOFA can independently take decisions on an operational level, but more strategic decisions must be made higher up in the municipal council. The role of the municipal council is further elaborated in **section 6.**

An example of something BOFA cannot independently decide on is how all the different waste fractions must be collected and send to treatment (different kinds of recycling). In order to find the right companies for collecting and managing the waste, public tenders are made. Waste management firms will then place offers and the decision makers on Bornholm, which for example include BOFA, must choose the most favourable solutions for their case that lives up to the criteria of the tender. To give an overview of BOFA as an organisation, the organisational structure of BOFA is shown on figure 14.

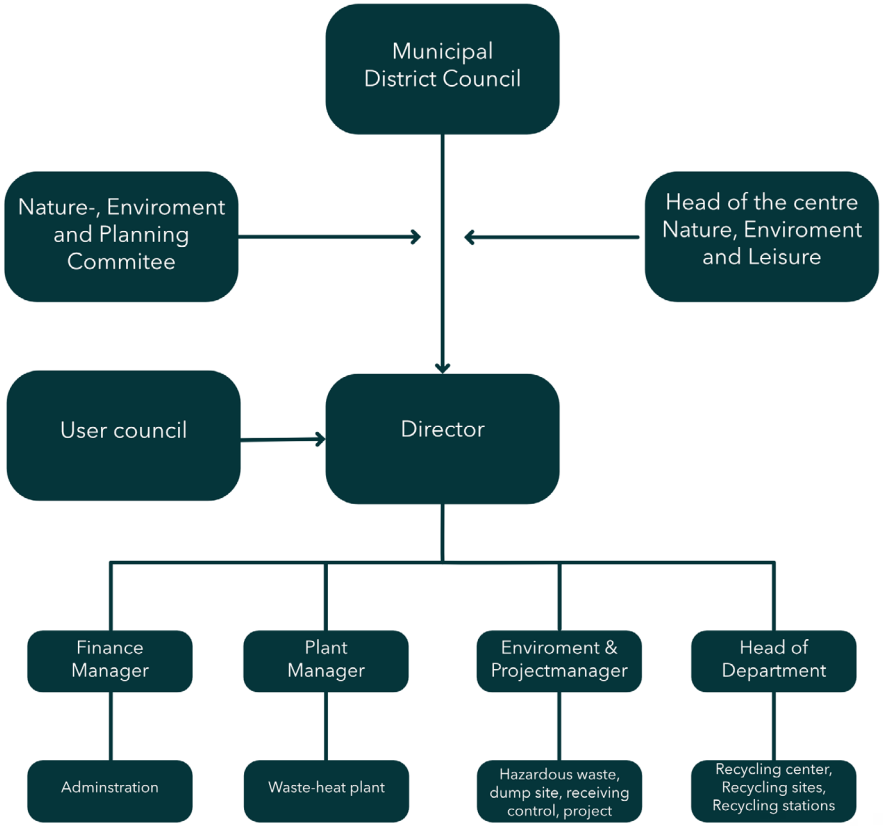


Figure 14: The organisational structure of BOFA

Current waste handling

In our interview with the project manager from BOFA, we talked about the current waste handling and what kind of possibilities there are in the current system. In the current waste handling system, it is possible to sort residual waste, paper, cardboard, textile and glass for collection at the households. In this system paper, cardboard and textile is sorted in one bin, residual in another and glass is to be dropped off at specific collections points – thereby not collected from households.

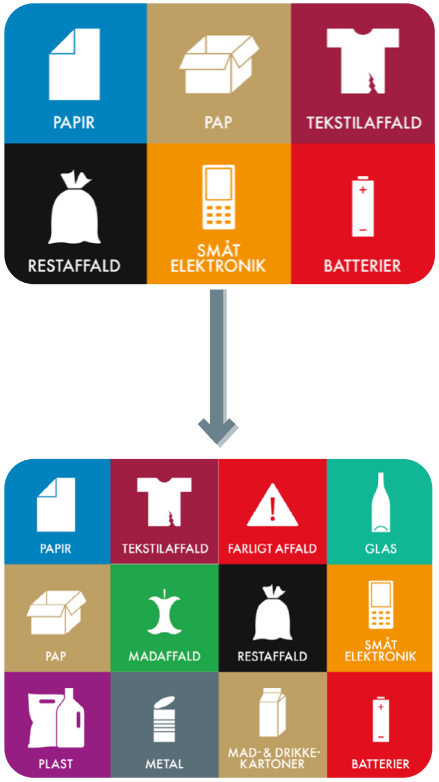


Figure 15: The change in the waste sorting scheme on Bornholm

If the households are willing to sort waste in other fractions than what is collected at the household, for example plastic, they can do it, but they are responsible of delivering it to the recycling center (BOFA) themselves (**picture 1**). But it is worth noticing that sorting food waste at one of these recycling centers is not possible at the moment. The only option to get rid of source sorted food waste is in your own garden compost or if you have animals which can eat it.

The new waste sorting system

In the new and upcoming waste handling system the households are required to sort in 12 different fractions via four different containers (**figure 15 and 16**). Batteries and small electronics are sorted separately in their own bags.For the private households BOFA will provide these collection containers, but for apartments and the densely populated small cities where there is limited space for containers, so called 'environment islands' (MiljØ'er) will be established (**picture 2**). These islands will be a central point with larger containers where households around the area can deposit their different waste fractions. In the new system some people will have to walk up to 300 meters to get rid of their waste (BOFA, 2022a). The project manager mentioned that BOFA will however not interfere how the individual households decides to design their sorting system inside their own home:

"BOFA does not interfere in the solutions in peoples own kitchens. It is their own decision and responsibility."
(Project manager, BOFA, appendix 6)

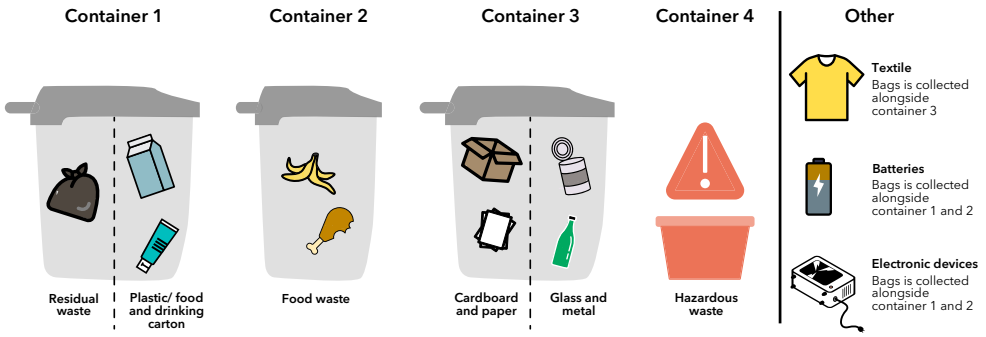


Figure 16: The 12 fractions will be sorted in 4 containers

BOFA would however be open to collaborate with industries on good solutions for sorting in the households, for example through the Zero Waste Bornholm network.

Picture 2: MiljØ on Bornholm

Other activities

Apart from handling waste, BOFA has several projects to support the project "Bornholm Showing the Way" with the vision of Bornholm without waste in 2032. Focus is among others to teach the younger generation about sustainable resource handling. For example, they use Affaldstårnet (The Waste Tower) to do so. It is a place, facilitated by BOFA, where knowledge on sustainability, innovation, waste, recycling and resources are shared with schools, companies and citizens (**picture 3**).

Picture 3:
Affaldstårnet (The Waste Tower)

5.2 About Bo42 (housing association)

Bo42 is a public housing association on Bornholm (**picture 4**). With their 1141 homes they offer different types of housing for a broad variety of people (both across age and nationality) – mainly in and around Rønne, but also near Svaneke. The reason why this specific housing association is part of our project is because they are part of the project "Much Less Food Waste". Their role is to provide test persons for the pilot project and therefore it was a direct connection for us to get in contact with local households on Bornholm. The part of Bo42 we have been collaborating with is located in Rønne and is called Nordparken. Most people in Nordparken live in apartments (**picture 5**), and some in smaller townhouses. The sizes of the homes are around 60-90 m2.

Nordparken is the biggest department in Bo42, and it is administrated by the housing administrator, Keld, and his colleagues. Nordpar-

Picture 4: Administration in Bo42

Picture 5: Apartment in Bo42

ken is divided into smaller departments that each control their own economy, while the housing administrator Keld and his team are responsible for the general operations across the departments.

Picture 6: Nordparken (housing association) in Rønne

Hereunder how the waste management system is working, and how Bo42 will adapt to the upcoming requirements for waste sorting.
In the following we will refer to Nordparken as Bo42 (**picture 6**).
During our visits to Bornholm, we went to Bo42 to understand the current way of managing waste in and around the households.

Waste observations in Bo42 – outside households

We observed a very high number of containers in the area. Basically, there were collection containers for residual waste and paper/cardboard/textile in front of each stairwell/entrance – giving the inhabitant a very short walking route to get rid of their waste (**picture 7**). Furthermore, glass containers were placed sporadically around the area, requiring the inhabitants to walk slightly further (**picture 8**).

Picture 8: Container for glass in Bo42

Picture 7: Waste container placed right outside the apartments in Bo42

Picture 9: Design engineer observing failed sorting in the paper/cardboard/textile container

Picture 10: Collection container with worn down sign

When looking into the waste containers we observed many cases of failed sorting in the container for paper/cardboard/textile, where plastic bags or pizza boxes had found their way into the wrong container (**picture 9**) It was also evident that the signs indicating what the container was meant for were in many cases worn down, and some places impossible to read (**picture 10**).

Another interesting observation was that none of the containers for paper/cardboard/textile gave the information that textile could be places in this container. We also observed cases where waste had been placed next to the containers. Maybe because the inhabitant where in doubt of where to throw it out or maybe they were just lazy (**picture 7**). The issue with waste that is placed next to the containers was described by the administrator as a big problem, since they use a lot of time to clean up after people and that interfere with the work they are paid to do. Especially in relation to when people move in or out of the housing association, which happens very often due to the big number of homes they are administrating.

Picture 11: Two chambered bin system in apartment in Bo42

Waste observations in Bo42 – inside households

Inside the apartments owned by Bo42, all the kitchens have recently been renovated and during this process it was decided to install a two chambered waste bin system beneath the sink in the kitchen (**picture 11**). This means that most homes already have the beginning of a sorting system available in their households – even though it is only with two chambers. We observed that inhabitants chose to use the "second" bin for different purposes. Some used it to store glass and paper for recycling, others to store vegetables in a dark place. Inhabitants living in the smaller townhouses did not receive the renovation of the kitchen, and therefore did not have the two chambered bins available. They just have a regular residual waste bin under the sink or the like.

5.3 About the test persons

To investigate the forming of a new practice of sorting food waste on Bornholm, we needed local households to volunteer in our test where they were asked to sort their food waste and reflect upon the new experience.

It was important to get diversity in the households chosen. We wanted to ensure a difference in age, gender and family proposition, to make the knowledge we gained representative. With help from the housing administrator, Keld, we got in contact with five households which were interested in helping with the project (**figure 17**). We wanted to use these households actively in the project. We did this in three different stages:

1. First Interview with focus on their current waste situation
2. Test period with the food waste sorting kit
3. Second interview with focus on the experiences from the test period

Name and age	Type/size of home	Current waste habits	Other
Dorte and Henrik (50's)	2 persons, 85 m2 apartment, ground floor	Sorts residual waste, cardboard, paper and glass	
Eva (40's) and Olivia (15)	2 persons, 85 m2 apartment, second floor	Sorts residual waste, cardboard, batteries and glass	
Ejvind (79) and Tove (83)	2 persons, 85 m2 apartment, ground floor	Sorts residual waste, paper, cardboard, extile and glass	
Brit (40's) (+ boyfriend or daughters visiting often)	1,5 persons, 87m2 house with two floors	Sorts all different fractions of waste and drives to the recycling center herself.	Board member in Bo42
Lene (60s)	1 person, 73 m2 apartment, second floor		Board member in Bo42. Did not participate in 1. Interiew.
Troels (50's)	1 person, single room apartment, ground floor	Sorts residual waste, cardboard and glass.	Did not participate in test.

Figure 17: Table about the test persons

The focus in the first interview with the five different households was first of all to get a better understanding of their current way of getting rid of waste. We decided to create an interview guide, to help us guide the conversation with the different people we visited. The three different main topics in the interview were:

- Knowledge about the vision Zero Waste Bornholm (ZWB),
- Current sorting of waste,
- Sorting of food waste.

The full interview guide can be seen in **appendix 7: Interview Guide**. The answers from the interviews are summed up in the following, while notes from the first interviews are summed up in **appendix 8: Key takeaways**

Knowledge about ZWB

It was very clear, that most of the different households had very limited knowledge about ZWB. Most of them had never heard about the ZWB vision. Dorte and Henrik mentioned:

"We have not heard about ZWB and the fact that the incineration facility closes in 2032"

(Dorte and Henrik, appendix 8: Key takeaways)

Others mentioned that they had read about it in the newspaper but have not thought more about it.

All of the households pointed to a lack of information about the entire project of implementing waste sorting on Bornholm. Dorte and Henrik even mentioned that this lack of information was a general problem on Bornholm, when new things were implemented (Dorte and Henrik, appendix 8: Key takeaways).
All interviewees where aware that the new waste sorting system is going to affect their daily lives, and the lack of information about what is going to happen was therefore a big concern for them. Some expressed a wish to be more involved in the process of deciding how the new system should be, but they did not feel like they had been offered the opportunity to be involved. Where some had heard about either ZWB or the fact that the incineration facility closes, only one person knew, about the exact change in the waste fractions that households will soon have to sort on Bornholm. This was Brit who was very engaged in these new sorting rules and really put a lot of effort in seeking the information by herself, which once again demonstrates the lack of information at the moment.

Test persons' current sorting habits

When engaging with the households, we identified that they were sorting differently and in their own way. In the case of Brit, she already sorts in more than 10 fractions. She has organized her house, so she could keep the different materials separated. Then she drives to the recycling station with the fractions that are not collected by BOFA at the household. The metal fraction, she sells to a metal company that gives you a price per weight. Brit also has her own garden composting bin for food waste. She uses this during the summer since she believes it is not possible during the winter, due to low temperatures. So, in the winter period her food waste ends up alongside with the residual waste. In many cases Brit was very unique when it comes to waste sorting on Bornholm. All of the other households were on a completely different waste sorting level, only sorting what was possible to get collected (residual waste, paper, cardboard, textile and glass).

Many identified a lack of information about the current way of sorting. Ejvind and Tove mentioned that many of the containers outside were misinforming people, because the text describing what should be sorted in the containers were missing. This lack of information also became clear since only two of the households knew that you could sort textiles together with paper and cardboard.
A general concern was the lack of space they had in the apartments. Which also meant that they found it problematic already to sort in too many fractions (although this statement is not applicable to Brit). Eva and Olivia further pointed out the skepticism they felt about sorting waste. Eva mentioned:

"I believe that people do not care about sorting correctly"

(Eva, appendix 8: Key takeaways)

Test persons' relation to food waste

In this part of the interview, we wanted to explore the households' understanding of food waste. But first a little disclaimer: When we did the interviews in Danish, we referred to food waste as 'bioaffald', in english translated to biowaste. Later in the project we decided to

change this terminology to food waste due to it being more used in literature and the newest policy making on the area. The understanding of 'biowaste' might be different compared to if we asked the households about 'food waste' (madaffald in Danish), and should be taken into consideration when interpreting the results.

We identified that most of the households thought they had a good understanding of what 'food waste' covered. Many thought it covered edible food waste, e.g. leftovers after meals or food that could have been eaten but was too old, as well as non-edible food waste, like bones and peels. Many also stated that they did not think they were generating much food waste, since they were focusing a lot on eating their leftovers. But observations showed that what you say is not always what you do.

During the interviews, which took place in the test persons homes, we observed how their kitchens looked like. In some cases, we also took a look into their refrigerators (**picture 12**). In one of the households, where they said they were not generating much food waste, we discovered a lot of old food that was obviously not going to be eaten. This was an interesting finding that confirmed us in the importance of observing and not only asking them directly what they do.

Picture 12: Refridgerator at a household

The interviewees mentioned guests as something that was affecting the amount of edible food waste being generated in their homes. Some felt it was embarrassing, if they did not make enough food for their guests. Often resulting in a big portion of leftovers, which in some cases ended up as food waste.

When discussing the future way of sorting food waste, we identified different concerns and important insights. Ejvind and Tove mentioned that it was important to have knowledge about how to sort food waste correctly. This information was something that almost all the households mentioned as a key aspect. Another worry was concerning the smell. Dorte mentioned that she was very sensitive to smell, so it was important for her that the bag was not leaking, and it should prevent smell as much as possible. Another aspect to the future sorting was about the distance they had to walk with the food waste to the container. Because food waste is smellier and more "disgusting" compared to other waste fractions, many found it less attractive to walk far with this waste fraction, while they would gladly walk longer with for example the glass fraction.

Several of the interviewed people were also asked if they wanted to participate in a test period, where they were asked to try to source sort their food waste. This is described in the following section.

5. 4 About the Food waste sorting kits and the test period

As described in **section 4** we used cultural probes as a method to collect inspiration and gain insights to the forming of a proto-practice of sorting food waste in local households.

This was done with 5 different households in the housing association Bo42 in Rønne on Bornholm. Participants were recruited with the help from the housing administrator of Bo42 and through digital posters in the stairwells with information to interest people around the area of Bo42 (**appendix 9: Poster for food waste**). The cultural probes consisted of a kit with a bucket, biodegradable bags (appr. 10 pcs.), a notebook, a welcoming letter with instructions and some chocolate.

Picture 13: Collection container placed near the participants homes

These specific elements were chosen based on the following. The bucket to hold the bag was one we got from BOFA but was something we identified from the literature as very important when sorting food waste (Naboskab, 2021). The biodegradable bags were some we got from BASF as a part of project 'Much less food waste'. The information we provided them with, was something we had identified as relevant, both from our first interview with the households and from literature (Naboskab, 2021). Furthermore, the test was made possible by the fact that Bo42 and BOFA allowed us to place a collection container near the participants homes, where they could deposit the sorted food waste (**picture 13**).

Figure 18: Preparing the sorting trial

We acknowledge that these elements that we have brought into the setting, were something that affected the entire test, and that different elements potentially would have created different results. On **figure 18** the process of creating and distributing the Food waste sorting kits is illustrated.
In the handed-out notebook different themes were presented to the participants to reflect upon continuously during the test period. The idea was that the households could use it to write down thoughts or frustrations within the themes, and it could function as a diary during the test period. The themes for reflection in the notebook included:

- The biobag (smell, size, quality)
- The location of the bucket (size, changing location?)
- Production of food waste (more/less, frequency to empty, amounts)
- Frustrations (inconvenience, doubts, forget to do it, lack of information)
- Reflections on the experiment (how was it? Enough information? Learnings?)

The instructional paper gave information about how to sort food waste, how long the test period was, location of collection container to drop of the food waste, instructions to write in the notebook and information about the tasks they will receive on text messages during the experiment. The letter with instructions can be seen in **appendix 10: Sorting guide.** We had 7 kits available, but only succeeded to recruit 5 participants to be part of the experiment.

After delivering the kits to participants text messages were send 1-2 times per week for approximately one month. Tasks included sending pictures, video and text about the following:

- Location of bucket
- Doubt about sorting food waste
- Picture of contents in the bag before emptying + trip to the container + How many bags are left?
- How are you doing with the sorting?
- Pour out the residual waste – what do you see? + How often do you empty?

In the following an excerpt from the text messages can be seen (**figure 19**). The full text message correspondences can be seen in **appendix 11: SMS correspondences.**

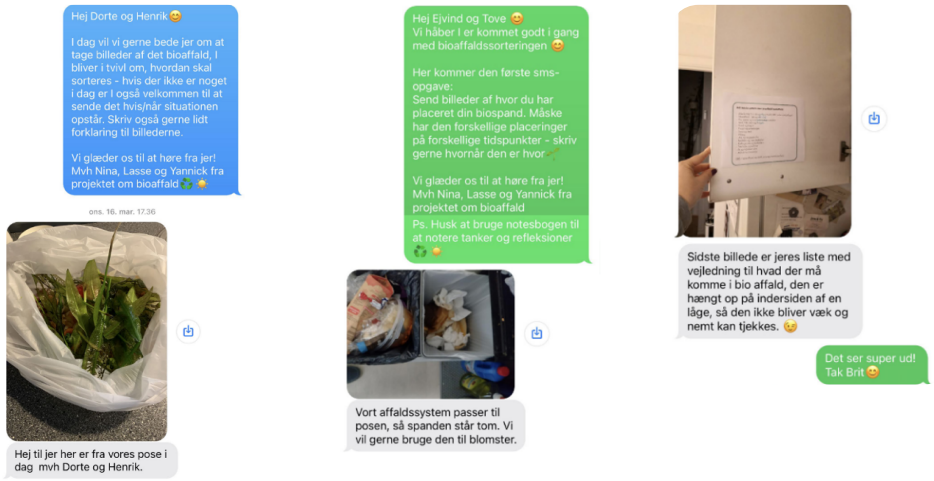


Figure 19: Messages and pictures send between the participants and us

Picture 14: The participants solving different tasks by sending photos on text messages

Overall, the SMS-tasks worked out great. This made it possible for us to continuously ensure that people were on track. On **picture 14** pictures received from participants are clustered into themes.

Besides the tasks we gave the participants through the text messages, many of them also used this communication platform, to ask questions when doubts occurred. This was not something we had planned for, but it turned out to be a great way of informing and helping each other. After the test period ended, we went back to the households on Bornholm to collect the notebooks and get a better understanding of how the test period had been for the participants. In the following section, we will present the most relevant results from the food waste sorting test.

What did we learn through the food waste sorting kits?
When we engaged with the participants after the end of the test period, the goal was first of all to acquire all the relevant insights and experiences they had made through the one-month test period.
All of the participants were positive about the experience of trying to sort their food waste. They had felt that it was not that hard to sort food waste. Ejvind and Tove explained it:

> *"It has been very easy and not even complicated!"*
> (Tove and Ejvind, appendix 12: Second interview)

This was something that all mentioned, also the ones that were skeptical about the test beforehand. Different elements were mentioned as the reasons why the sorting of food waste had been easy.

The bag
Many of test persons mentioned that the biodegradable bags we had provided them with were very good. They had not experienced any significant leaking or degradation of the bag. Furthermore, Brit also mentioned that she only once experienced that it broke due to eggshells that had pierced the bag. She mentioned that it was important that the bag, in the upcoming sorting system, was of similar quality.

Most of the test persons believed that the bag had a good size. Only Eva thought it was too big, firstly due to it not fitting the waste bin (it was too big for the handed-out bin), and secondly because they did not generate enough food waste to fill it up, before they wanted to empty it in the container. They often ended up dumping a half-full bag in the waste container.

On the other hand, Tove and Ejvind were very satisfied with the size of the bag because they had figured that it fitted perfectly into the second bin in their two-chambered bin under the sink in their kitchen. We gave the bag to the participants for free. But during the interview we got to talk about how households were to acquire the bags in the future system. Brit mentioned that she did not believe that people would spend money on buying a specific type of bag to sort their food waste. Through her role as a board member in the housing association, she had had conversations with other inhabitants in Bo42 about the upcoming sorting system:

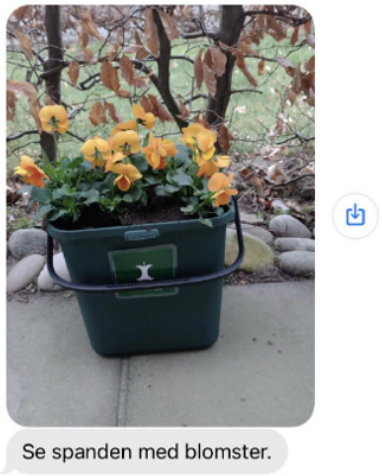
"Since it is you (BOFA) that tell us to sort differently, you should also be responsible for implementing it in the kitchen so I can sort it correctly, when will I receive the waste bins?"

(inhabitant in Bo42, appendix 12: Second interview)

This, Brit argues, shows that if the person also had to buy a specific type of bag it could be a hindrance to get the person to sort their waste. Rather, the bags should be for free or there should not be requirements to use a specific bag.

The food waste bucket

We provided every household with a green bucket to contain the bag for food waste. However, not all of the participants found this useful. As explained earlier, all the households in Bo42 had installed two different waste bins under the sink. Some decided to use one of these for food waste. Dorte and Henrik started using the green bin we provided them with, but quickly changed to the already existing bin under their sink, because it was too complicated to hide the bucket away, which was very important to them. Ejvind and Tove also decided to use the bin already installed under the sink. They liked to have the two bins placed close to each other. Instead, they decided to use the green bucket for flowers, as seen in **picture 15**



Picture 15: An alternative use of the waste bin

Other found the bucket very useful. Eva and Olivia mentioned that they preferred to have a mobile bin, that they could have on the kitchen table when preparing the food. Also Brit decided to use the bucket we had provided. She said:

"It took some time to find a good placement for it and get used to taking it out when needed. But it was easy enough"

(Brit, appendix 12: Second interview)

She also liked that it was possible to close the bucket with the lid and was happy that it did not have holes in it. She believed this was necessary to prevent the smell from getting out.

The distance to collection container

All test persons had between 50-200 meters to the container.
Many of the test persons mentioned that the distance to the collection container was appropriate, even though it was placed further away than their usual container for residual waste. Only Eva mentioned that the distance was too long. When we met her after the test period, the first thing she said was:

"Great – Then I don't have to walk that long distance to the food waste container"

(Eva, appendix 12: Second interview)

She also mentioned that she many times during the test period thought about just dumping the food waste bag in the container for residual waste, because it was closer to her apartment. She emphasized the importance of not making it too complicated for people to make the correct decision. Connected to this Brit also mentioned that the 300 meters, which BOFA has mentioned is the maximum distance you have to walk with your waste, is much too long. She did not understand how elderly or badly walking people should be able to walk that far with their waste. She believed that the distance in this test, which in her case was about 100 meters, was more appropriate.

The rest of the participants also said that they did not have a problem with the distance, but also thought 300 meters were too long.

The Information

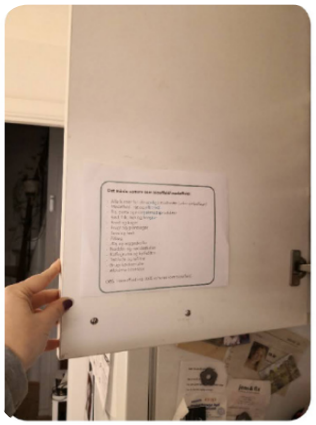
The information about how and what to sort as food waste, that we had provided the participants with at the beginning of the test, was something all mentioned as very important. Ejvind and Tove said:

"It was very easy, we just did what you told us to do. And when in doubt we looked at the list."

(Tove and Ejvind, appendix 12: Second interview)

Henrik mentioned that it was very important that this kind of information is available for all citizens before they start to sort food waste, believing it would make the implementation easier.
As shown in **picture 16** Brit decided to put the information on one of the cabinets in her kitchen, so it was available when she needed it. She mentioned that she in the beginning looked at it three times a day, but later in the test had learned how to sort correctly and therefore only used the list occasionally. Brit mentioned the possibility of using QR codes to communicate this information in a more modern way.

The interviews and the test period with the Food waste sorting kits helped us gain relevant knowledge about the potential challenges that can arise when establishing a new waste sorting practice. This knowledge created the foundation for our practice analysis that will be described in **section 6.**



Picture 16:
The information paper put into use

5.5 About the survey - Bornholm's inhabitants and sorting of food waste

As described in **section 4** we conducted a survey for this thesis to obtain general understanding of how inhabitants on Bornholm feel about the upcoming sorting of food waste system. And to understand their preliminary concerns and worries. It was also important for us to get a sense of their willingness to start sorting.

The survey went public to citizens of Bornholm on the 30th of March and were closed again the 26th of April and thereby giving us 3,5 weeks to obtain answers to our questions. In the period we gained 180 responses, where only 2 respondents did not live on Bornholm and were therefore excluded from the survey results. Respondents came from all over the island and 80% where living in some sort of house with a garden. This section will go through the results and further analysis will follow in **section 6**. The data from the survey is available in **appendix 13: Survey results.**

The first set of questions were mostly concerned with the inhabitants' knowledge and relations to food waste and sorting of such. From here it was found that **66,3 % of the respondents do not sort their food waste at the moment (figure 20).**

When asked for reasons why not, 85,6 % answered because of the lack of a collecting system. 20,3 % also highlighted the lack of space for anymore bins in their homes and approximately 10% thinks it is too troublesome to sort food waste.

1/3 of the respondents answered they did in fact sort their food waste. 80% of these inhabitants have their own composting bin in their garden, where they produce their own compost to be used in the garden. 38,3% of the people who sorts mentioned they feed their animals with the food waste.

Figure 20: Results from the survey

What is food waste and how much do I generate?

The next section in the survey was concerned with what different types of products (for example meat, eggshells etc.) which can be sorted as food waste for treatment in an anaerobic digestor. The purpose was to get a glimpse of the respondents' knowledge of what can be sorted for such treatment. We found that 28,1 % of the respondents admits that they simply do not know what can be sorted as food waste. When faced with different products which cannot be sorted, a total of 26,4 % thought that at least one of these could be sorted (for example cat litter, diapers or packaging with food residues in). However, approximately half of the respondents answered correctly in terms of what types of food can be sorted for an anaerobic digestor.

According to Miljøstyrelsen the average Dane produces around 1,5 kg food waste per person per week (incl. non-edible and edible food waste) (Miljøstyrelsen, 2018). When asked about how much food waste the respondents thought they produced per week, 64,1 % of the respondents believed they produced 1,5 kg or less. The other 35,9% believed they produced more. When asked specifically to the edible food waste (that could have been eaten but was thrown out) around 75,8 % of the respondents believed they produced 0,5 kg or less, while the numbers from Miljøstyrelsen says the average Dane throws out 0,84 kg edible food waste per person per week (Miljøstyrelsen, 2018).

Readiness for the new food waste sorting system

Around half of the respondents knew that Bornholm is set to sort their food waste in 2022 leaving the other half not knowing when this is going to happen. This can also be transferred to the next question, which seeks to understand if they feel prepared for sorting food waste. **Here 57,3 % respondents do not feel ready for the upcoming sorting of food waste (figure 20).**

Of those who do not feel ready, 50 % says it is due to the lack of knowledge of what can be sorted as food waste. 79,4 % states it is due to the lack of information about the upcoming sorting system. Further to this some respondents have other concerns such as the lack of knowledge on which bag can be used (39,2%), lack of space for the extra bins (42,2%) and the fear of smell (23,5%).
The 76 respondents (of 178) who feel ready for sorting food waste highlighted they were already sorting other fractions of waste, so food waste was not a problem (77,6%) and 53,9% believe they have the knowledge of what can be sorted as food waste. They also comment that they know which bags to use (32,9%) and know exactly where the extra bins should be placed in the kitchen (25%).

Distance and final comment

The next section of the survey the respondents were asked to answer how far they have to the nearest residual waste collection container and how long they are willing to walk to get rid of waste in the upcoming sorting system. Here 90% of the respondents said they currently have between 0-50 meters to the nearest container. When asked how far they would be willing to go to dump their residual waste, 80% answered between 0-100 meter, and when asked how far they would be willing to go to dump their food waste the answer was almost the same, 83,1 % would be willing to walk a maximum of 100 meters (**figure 20**). In the new sorting system, some households may have to walk up to 300 meters to get rid of their waste.

In the last section of the survey the respondents had the opportunity to make an additional statement or comment on something they did not have the option to tell earlier in the survey questions. Here we got a total of 36 responds all with different opinions and comments. We can see from the comments (**figure 21**) that some people are very excited about the upcoming food waste sorting system and cannot wait to start. Several of these feel embarrassed to live on the "Bright Green Island", while not sorting waste. Others are more resistant and do not look forward to it. They argue that it is a waste of

time, is more expensive, it will be ugly with more waste containers and that they do not believe in the environmental benefits from sorting waste (**figure 20**).

In general, there is a strong request for more information about how the new system is going to be, what can be sorted as what, what happens to the waste and a clarification of what expectations that BOFA has to the inhabitants.

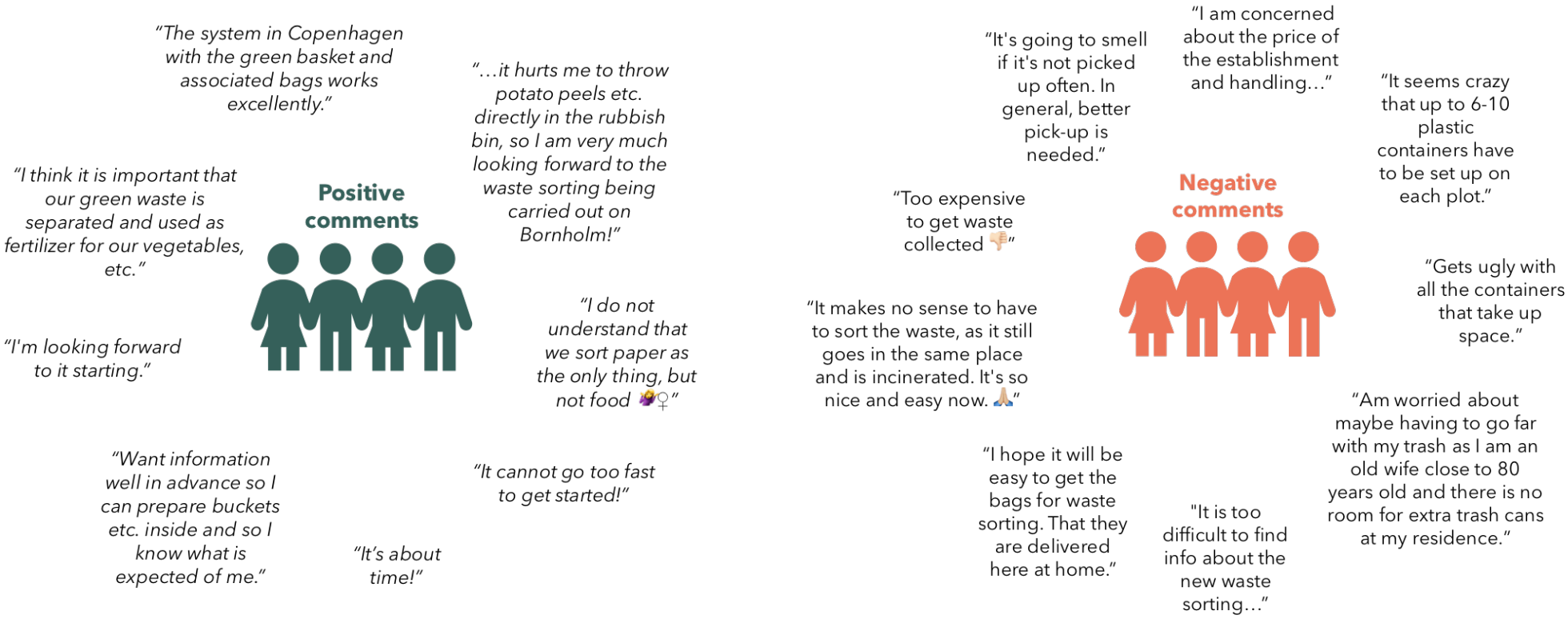


Figure 21: Positive and negative comments from respondents

5.6 About biological treatment

After sorting the food waste in the households, it is being send for biological treatment. There are different treatment processes available to do this, but the most common is to use an anaerobic digester that produces biogas and fertiliser. The food waste is sent to a pre-treatment facility where it is sorted, and the bags are separated from the biomass. The biomass is made into pulp, and the pulp is put into the anaerobic digester where microorganisms "eat" the biomass and produce biogas and a by-product called digestate, that can be made into fertiliser for agriculture (**figure 22**). This process is further described in **section 6**.

To learn more about the process of treating food waste in an anaerobic digester (AD) we arranged a visit to Biovækst A/S' facilities near Holbæk. We thought it was a regular anaerobic digestion facility, but we learned that Biovækst has their own special technology including special composting techniques to supplement the biogas production. However, we still got a good understanding of the differences from their facility and the more regular ADs. Different biological treatment methods are also described in the **appendix 14: Different types of biowaste treatment.**

Size of the tender

We learned that when a treatment facility is bidding on a tender it is highly relevant for them that the amount of food waste offered in the tender (in Bornholms case 3000 tons/year) is in accordance with the capacity of their facility. The capacity of Biovækst is 20.000 tons/year. And the capacity of another big treatment facility on Sjælland is 100.000 tons/year. When knowing this, it makes sense that 3000 tons is not a lot. Thereby not necessarily an attractive amount to receive or to invest in building treatment facilities on Bornholm for.

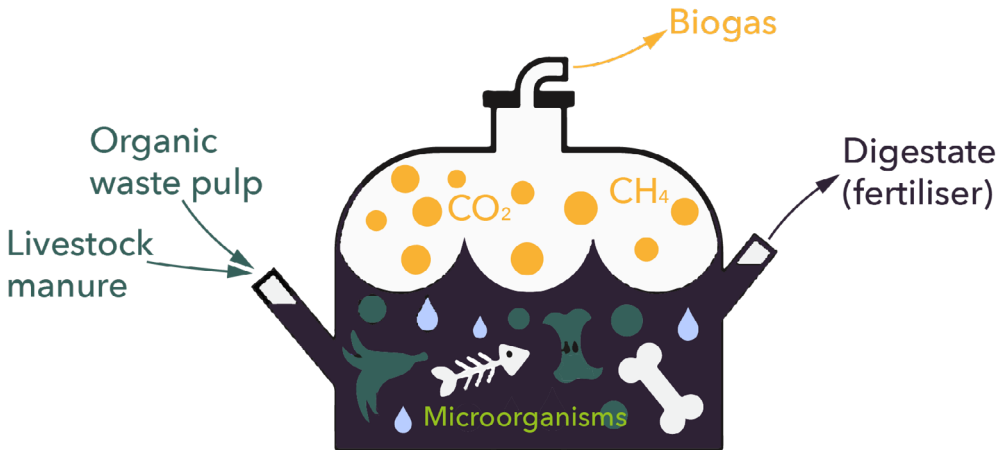


Figure 22: The process of an anaerobic digester

Biodegradable plastic bags for food waste – is it a go or no go?

Biodegradable bags are fine in Biovækst's technology because they do composting in a way that allows the biodegradable bags long enough time to actually degrade. But other pre-treatment facilities who creates the pulp that will be send to the AD, would argue that the biodegradable bags are not preferred because they have mechanical problems of separating the bags from the pulp. In regular AD facilities, the process time is not always long enough to allow the biodegradable bags to actually degrade, resulting in residues of plastic being spread on the fields with the produced fertilizer. And as soon as the biodegradable plastic bags are out in nature, they

cannot degrade due to a lack of the right temperature and moisture. Biovækst are receiving rejected material, consisting of biodegradable bags with residues of food waste, from other pre-treatment facilities that have separated it from their pulp (**picture 17 and picture 18**). Biovækst can, with their technology, treat the rejected material and still exploit the benefits from the residual biological material in the bags.

Picture 17: Pile of rejected material (left) and pile of bags full of food waste from households (right) ready to start the journey in the treatment facility to be turned into biogas and compost

Picture 18: The finished compost ready to be used as soil improvement

Analyses

Section 6

6. Analyses

In this section the analysis of the gathered empirical knowledge will be presented. The section consists of four separate analyses. Initially an actor network analysis to understand who are the decision makers that we are targeting with this project. Then the flows of food waste on Bornholm will be mapped. Then the life cycle assessment comparing different food waste source sorting scenarios will elaborate on the importance of sorting the food waste. And finally, the full analysis of the practice of sorting food waste will be presented. The purpose of making these analyses was to enable us to create the recommendations that is presented in **section 7.**

6.1 The network of decision makers

Since we want to target all the knowledge we have gained through the project to relevant decision makers on Bornholm, it was important to understand which actors are involved in decision-making. And which actors are able to support or affect decisions concerning waste management and what are their interrelations. When we refer to decision makers we are referring to actors who takes decisions in regard to waste on different levels in the system. It ranges from decisions made on a political level to decisions made on a daily basis in the households. We believe the enrolment and mobilization of these actors are essential for the new sorting system on Bornholm to become successful. The network also consists of several non-human actors that are not directly described in the following but must be acknowledged as equally important for the success of the new network. This is for example the trucks for collecting waste, the collection containers, the storage space for collected waste, the small bins for sorting inside the household etc. They are not defined as decision makers and are therefore not part of this analysis. We have discovered six relevant decision makers in the network for managing waste on Bornholm, their roles and relations will all be elaborated later in this section. They are:

- National policymakers (Danish government),
- Municipal policymakers (Bornholm's regional municipality),
- BOFA (waste management on Bornholm),
- Waste collection companies,
- Waste treatment companies and
- The people in the households.

Currently, the network for managing waste on Bornholm is undergoing a transformation. Bornholm are about to implement completely new waste sorting rules. This is something that affects all the actors in the network. Actually, the entire new network for handling waste on Bornholm is dependent on these actors' willingness to be a part of the new network. Before this can happen each of the different actors have to understand, accept and take part in their role in the network. This is also what Callon refers to as the moments of translation (Callon, 1986), as described in **section 3.**

The mapping of the network of decision makers, enabled us to navigate in the complexity of the system and to simplify parts of the network. This simplification means that the actors mentioned are actually a clustering of many different human as well as non-human actors. For example, BOFA is a clustering of all the different emplo-

yees in BOFA and their related facilities/materials, whom in itself is constituting its own network. The aim of analyzing the network of decision makers was to understand each of the different actors' role in the network. And their willingness to take part in the new network, to accept their new role, and potentially become a spokesperson for the new network. The network of decision makers is illustrated on figure 23.

The national and municipal policymakers as decision makers

National policymakers, like the Danish government, has the power to make decisions on national levels which affect all the other decision makers in the network by creating the frame in which the other actors can act. They are the ones regulating on a national level about waste sorting, and recently they agreed on the new sorting rules, requiring all households in Denmark to sort in the same 12 different waste fractions across municipalities (Miljøministeriet, 2020).

Connected to these national policymakers, are the municipal policymakers. The main actor here is the municipal council (Kommunalbestyrelsen) in Bornholms Regionskommune. They are the ones who are in charge of implementing the new waste sorting regulations on a municipal level – in this case on Bornholm. Just like the national policymakers, this actor consists of multiple people with different political standpoints and agendas. As mentioned in the introduction section, the implementation of the sorting rules has been postponed on Bornholm as well as in other municipalities. This means that the municipal council are obliged to implement the new sorting rules before the end of 2022 putting pressure on an implementation plan

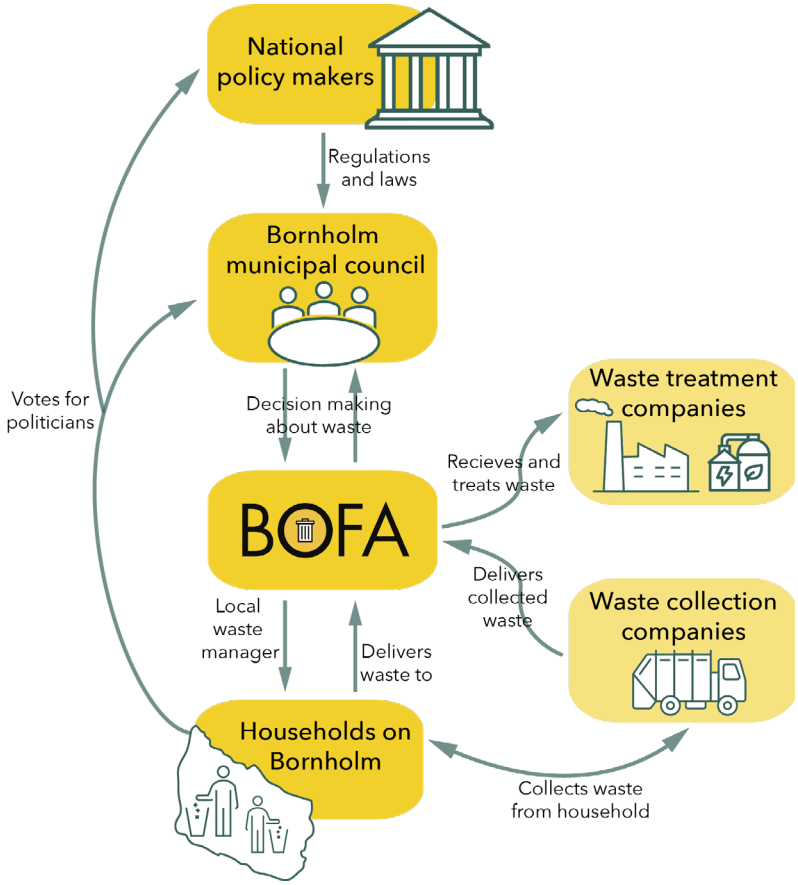


Figure 23: Network of decision makers

and building the new infrastructure necessary to handle the task. It is up to the municipal council to decide how the new sorting rules should be implemented on Bornholm. For example, they need to decide who is collecting the waste from the households, who is treating it and how they are going to teach the inhabitants about the new system.

The people sitting in the municipal council are being elected every fourth year by the inhabitants of Bornholm. Since the constitution of political parties voted into the municipal council is affecting the decisions made in the council, the political direction and e.g. prioritization of different waste handling solutions can differ when there are changes in the members of the council over time. This is something that can potentially affect the handling of waste on Bornholm. An example will be given later in the analysis. We have learned that both the national policymakers and the municipal council, have accepted their role in the new network. Since they are the ones that have made the decision of implementing new sorting systems, they are already spokespersons for the network and are in a role of mobilizing other actors in the network. Since the municipal council does not possess the competencies or time to be the actor who actually manages the waste, they have created a company that is responsible for this which is BOFA (Bornholms Affaldsbehandling) and is the next key actor described in the network.

BOFA as a decision maker

BOFA, as mentioned in **section 5.1** is the company in charge of managing waste on Bornholm. The company has a close relation to the municipal council since they are owned by them. This implies that most of the decisions they make have to be accepted by the council. An example of this could be the decisions regarding a recent tender for treating food waste from Bornholm **(appendix 15: Interview with David)**. This also means that BOFA is already mobilized in the new network and are already engaging with different actors in the network to maintain and secure the existence of the new network.

However, BOFA is also a private company that has its own director and multiple employees. This also means that BOFA, in some cases, have the power to make decisions themselves. An example could be the decisions regarding the daily operations, which is not something that has to be accepted by the municipal council (**appendix 15: Interview with David**). This also means that these two actors are very dependent on each other, in the decision-making process which is illustrated in the network (**figure 23**) with the arrow going both ways.

Because BOFA is publicly owned, they are not allowed to collect the waste themselves. Instead, they use subcontractors. Because of the regulation for municipalities, this has to go through a public tender, where private companies have the opportunity to make different offers (Konkurrence- og Forbrugerstyrelsen, 2016). As a result of this, the collection companies become a key actor in the network. Currently, five different collection companies, are responsible for collecting the waste on Bornholm – some are responsible of industry waste and others from private households. These are Lennart Ibsen, Fugato, Marius Pedersen, HCS and BHS Logistics (**appendix 15: Interview with David**). Until now Fugato has been the company responsible for collecting all waste from households, and thereby also the company that BOFA had most contact with. However, this changed from 2022, because HCS won the tender for the collection of the 10 new sorting fractions (Kaas, 2021). We have identified this change in the network as highly relevant because this is changing the established relation in the network between BOFA and the collection companies.

We have discovered that the tender plays an important role in the relation since this is where BOFA are defining the demands and criteria that they want the collection company to fulfill. Then it is up to the collection companies, to make an offer where they describe how they will carry out the tasks. After this point, it is again up to BOFA to decide which of the proposals they believe are strongest, based on the different criteria. In the new tender for the collection of waste from households, the criteria were weighted as shown on **figure 24.**

Figure 24: Tender criterias

Based on these criteria BOFA decided HCS as winner of the tender. This decision is sent to the municipal council, that can decide to accept the solution or to give objections to change it or decline it. As mentioned earlier this is an example, where the political standpoint becomes highly relevant. Since the different political parties might look differently on the weighting of these criteria. Therefore, the criteria may also vary in different election periods (Nørmark, 2021). Because HCS won the tender, they have now become an important decision maker in the new network for managing the waste on Bornholm. We will argue that they through the tender has accepted, their role in the network and are working for and maintaining the new network.

Another interesting aspect of the relation between BOFA and the collection company is during the daily operations. Since all the collected waste ends up at BOFA's recycling and waste center, continuous communication is needed between the actors, to ensure that this is done most optimally. This also points to the importance of a close and strong relation between BOFA and the collection company.

Another key actor connected to BOFA is the waste treatment company. Much of the waste on Bornholm is currently being incinerated at BOFA's facility in Rønne. However, the sorted fractions like e.g. plastic collected at the different recycling centers on Bornholm, is sent to waste treatment companies elsewhere to ensure a recycling of the resources instead of just burning it. Because of the Zero Waste Bornholm vision, with the plan of disabling the local waste incinerator in 2032, more waste fractions will be sent for recycling facilities elsewhere in the future. According to BOFA this can be done in two ways. Either they make direct contact with different relevant subcontractors, or they create a public tender (**appendix 15: Interview with David**). In the example with food waste, BOFA me a tender. It is not yet public who will win the tender, but the process is the same, as in the collection tender. The different waste fractions might be divided between different companies, that have the necessary facilities to treat and recycle the waste. This also means that BOFA will have to collaborate with multiple different companies to ensure that the waste is treated properly. When a treatment company is winning the tender, they hereby also accept their role in the network.

Households as decision makers

In the end, we have identified the households as a key actor. They have an important say in the network, since they are the ones deciding how the sorting is implemented in the individual homes. They decide how many sorting bins they want to have inside their homes or how much effort they will put into sorting correctly. We have found that BOFA should be responsible for guiding and teaching people how to sort and thereby secure the best possible implementation. This is due to BOFA being the actor who in the end is responsible for reaching a high sorting rate. If not, this might have an economic consequence for BOFA. An example is in the tender for treating food waste. It is written that BOFA will pay for the treatment of at least 3000 tons of food waste yearly. If the number is higher, BOFA will have to pay the difference and if it is lower, they will still have to pay for the treatment of 3000 tons (BOFA, 2022a). This also means that BOFA should be responsible for guiding people in the households to sort as correctly as possible. It is important because many of our interviewees and respondents from our survey, explain that they do not feel BOFA is informing and guiding them well enough (see **section 5.3-5.5**). We have uncovered this as being very important to secure successful implementation of the new waste sorting system.

In the network, we also recognized an important relation between the collection company and the households. Since the collection company is in direct contact with the household every time they collect their waste, they are also the people in the frontline to be confronted with questions or complaints from the households.

Another interesting relation is between the households and the municipal council. It is the citizens on Bornholm that decide upon, who is elected for a four-year period in the municipal council. The citizens can thereby influence the political decisions that are made e.g. about waste on Bornholm. This is not much different than the constellation in other municipalities. But the special thing about this relation is that Bornholm is an island, where the local society is very closely related to the municipal council. This means that some actors can both belong to the group of actors that we define as municipal council, while also being in the network representing the households. This have shown to be a source of local rumours or gossip about what will happen in the new waste system (Mathiesen, 2022). If the local opinions are colored by false information based on rumors it can create changes in the network or changes to the willingness of sorting waste (BOFA, 2022b).

We have identified that the households are the actors that have the weakest incitement for fulfilling their role in the network, by sorting their waste in the upcoming sorting system. All of the other key actors have either economic or political motivations which are driving them. This also means that most of the other actors already accepted their new role in the network and will be working to secure the existence of the new network. We will argue that even though parts of the new network are not yet fully established (due to the delayed implementation of the sorting system), important actors like national policymakers, the municipal council, BOFA and the collection company are all mobilized. They have all accepted their role in the new way of sorting food waste on Bornholm, and have become what Cal-

lon refers to as a spokesperson for the new network (Callon, 1986). This also means that they continuously are working for the agenda in the network, which is a successful system for handling waste on Bornholm.

But for the households, this has yet to happen since they have not fully accepted their role of sorting in the households. We will even argue that some households have not even gone through the problematization phase yet. We have seen that some households are unaware of the new sorting rules, and some are very skeptical about all of it. This is something that will all be elaborated in the practice analysis in **section 6.4**.
Since the entire network, is reliant on the peoples' ability and willingness to sort, we believe it is highly important to understand how the households can be mobilized, which is why we decided to have a specific focus on this actor. With no source sorted food waste from the households – the network will crumble and fall apart.
This mapping of key actors helped us understand each of the different actors' roles, the interdependencies between the different actors and their relations. Understanding this helped us target our contribution in the network, to ensure this has the highest impact. Since we want to create recommendations that can be used in this complex network, it is important to be able to translate our knowledge understandably. In this way, the actor network analysis helped us to identify the differences in the knowledge that exists between the different actors in the network. And thereby make us able to focus our contribution based on this. We will later in the report, discuss which of the decision makers we focused our recommendations to and why.

6.2 Flows of food waste on Bornholm

Inspired by the System Thinking Theory's stocks and flows suggested by Meadows (Meadows, 2008), we have mapped the flow of food waste from households on Bornholm. This is done to better understand the composition and amounts of waste that is being processed in the current waste handling system. Also, we will analyse the current food waste management system and the future system that is expected to be at the end of 2022. The focus here is on the management process to give the reader a better understanding of the complexity that arises when changing the waste handling system on Bornholm.

Food waste is the largest waste fraction

The inhabitants on Bornholm are currently mixing their food waste with the residual waste – except if they have their own garden compost and therefore sorts it separately. The residual waste fraction is consisting of many different types of waste. We found it relevant to discover the composition of the residual waste to better understand the way people are waste sorting, or not.

Since it has not been possible to find a mapping of the composition of the waste fraction from households specifically on Bornholm, we have used a national mapping of a similar waste stream, explained as "Domestic waste" in Denmark. This term is covering the waste fractions "Organic waste, Plastic and residual waste". Excluded from the mapping is the fractions of paper, cardboard, metal, and glass, since this is assumed to be sorted into other waste streams (Miljøstyrelsen, 2018, p. 13). The mapping is from 2017 and is using data from four

different municipalities of Denmark. We will argue that there is no reason to believe that the composition of residual waste on Bornholm is much different from other municipalities. The only fraction which is not the same is metal, which on Bornholm also is a part of residual waste. However, this is the closest possible we can come with our available resources. In the mapping from 2017 the amount of "domestic waste" from households in Denmark was 995.000 tons pr. year (Miljøstyrelsen, 2018). This is distributed on around 2,67 million households in Denmark (number from 2017) (Danmarks Statistik, 2022b). This also means that one household in Denmark on average generates 373 kg of "domestic waste" per year. From these numbers we have extrapolated an estimated amount of 7615,2 ton of residual waste that is yearly generated from the 20.417 households located on Bornholm today (Danmarks Statistik, 2022a). Building on the mapping of "domestic waste" we have been able to map the composition of residual waste on Bornholm. This is done in **figure 25** (Miljøstyrelsen, 2018).

As shown in **figure 25** and **figure 26** almost 50 % of the waste (3483,3 ton) is assumed to be food waste. This also means that food waste by far is the most dominating waste fraction in residual waste, seen by weight. This confirms the importance of establishing a well-functioning sorting system for this specific fraction to reach the goal of a Zero Waste Bornholm.

	All households in DK (2,67 mio)	All households in DK	All Households on Bornholm (20.417)
	Tonnes per year	%	Tonnes per year
Avoidable food waste	246977	24,8	1888,6
Non-avoidable food waste	208552	21,0	1594,8
Garden waste	35081	3,5	268,3
Rigid plastics	53850	5,4	411,8
Flexible plastics	55445	5,6	424,0
Other Plastics	14180	1,4	108,4
Paper	34553	3,5	264,2
Cardboards	30647	3,1	234,4
Other Paper and Cardboards	103045	10,4	788,0
Textiles	19600	2,0	149,9
Magnetic metal	9491	1,0	72,6
Non-magnetic metal	7980	0,8	61,0
Glass	14335	1,4	109,6
Batteries	270	0,0	2,1
Other hazardous waste	4602	0,5	35,2
Waste electronics and cables	3860	0,4	29,5
Other combustible waste	114738	11,5	877,4
Other non-combustible waste	35662	3,6	272,7
Bags/lining	2385	0,2	18,2
Total	**995253**	**100,0**	**7610,5**

Figure 25: Composition of residual waste on Bornholm (Miljøstyrrelsen, 2018)

In the tender for treating food waste on Bornholm the municipal council and BOFA expect that the households on Bornholm will generate 3000 tons of food waste per year (BOFA, 2022). This number is lower than the expected number from the extrapolated data (3483,3 ton), indicating that the potential to collect even more than 3000 tons might be there if the households manage to source sort it correctly.

The system for handling food waste today and in the future

It is important to understand the impact it has when Bornholm later in 2022 will start to sort their waste into 12 fractions – here among food waste. In the following section we will illustrate the current and future system for managing the food waste from the island. The goal is to show how the complexity of the system increases when implementing the source sorting system.

As mentioned in the literature there are various reasons for food ending up as waste in the first place (Keegan and Breadsell, 2021). These various reasons are a part of the illustration. We believe that food waste at all times should be prevented, but also acknowledge that preventing all food waste is not possible.

In the current system for handling food waste, most food waste is sorted together with residual waste, constituting almost 50% of the weight making it the largest waste type in the fraction. This is being "sorted" in a waste bag in the household. When the bag is full, this is being put into the waste container for residual waste located outside the household. This container is periodically emptied by the collection company, who drives the waste to BOFA where it is stored. Residual waste is then burned with other waste fractions at the incineration facility on BOFA (**figure 27**).

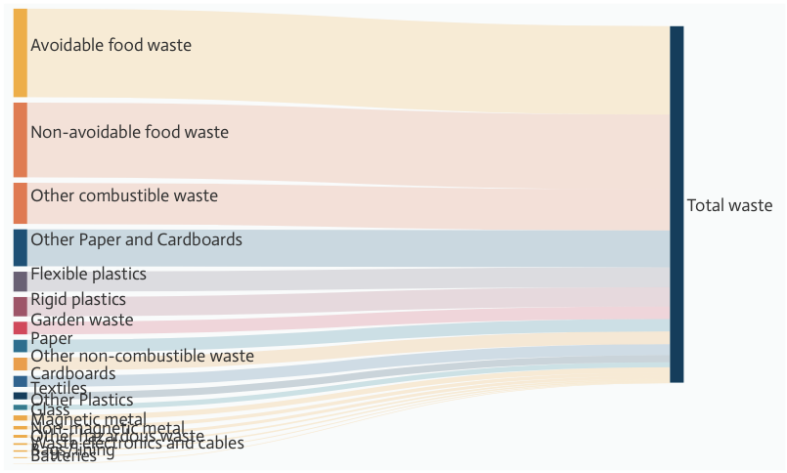


Figure 26: Composition of residual waste on Bornholm visualised in a sankey diagram

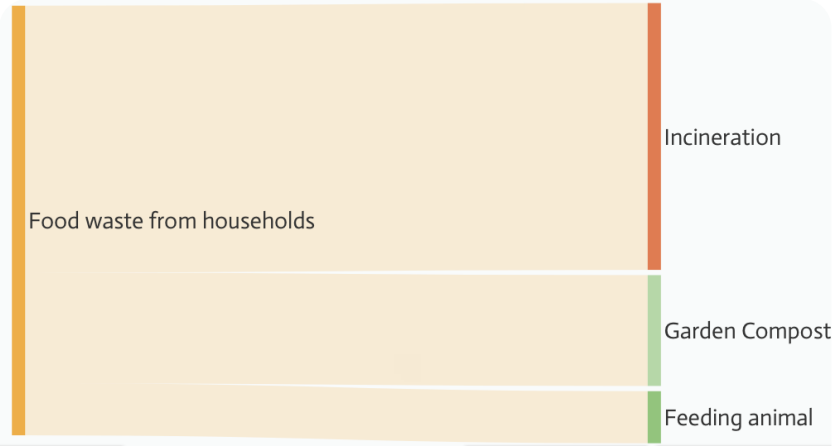


Figure 28: Possible treatments of food waste based on survey

Figure 27: Current system for handling food waste on Bornholm

According to data from our survey, asking people whether they sort their food waste and what they do with it, an estimation on where the flows of food waste ends up is illustrated in **figure 28**.

When comparing the current system for managing food waste to the future way it will be done on Bornholm, many new processes occur (**figure 29**). As seen in the new system, the consumer has two different opportunities when deciding how the food should be sorted. They can either decide to sort their food waste incorrectly (no sorting) and put it with residual waste or they can sort it correctly as food waste. If the food waste is sorted incorrectly it will end up being incinerated and the system will look similar to the current.

The other opportunity is to sort the waste as food waste and put it into the dedicated waste container for food waste. Just as with residual waste, this container will be collected by the collection company and kept separated from the other waste fractions. After this, the waste is emptied at BOFA's facility where they store it until the amount is high enough to send it to biological treatment in an anaerobic digester (AD). Most likely this biological treatment facility will be located on Sjælland. BOFA therefore has to pack the food waste in a container and drive it to the harbour in Rønne. Hereafter the container is shipped with ferry to Køge (Sjælland). Then a truck will come and collect it from the harbour and transport it to a pretreatment facility. Here the process for biotreatment starts. First, the bags and the food waste are being separated from each other and the biological material is made into a liquid pulp. Then the pulp is transported to the anaerobic digester. Here biogas is produced from the pulp. A by-product of this process is fertilizer that can be used in agriculture and biogas that for example can be used to make electri-

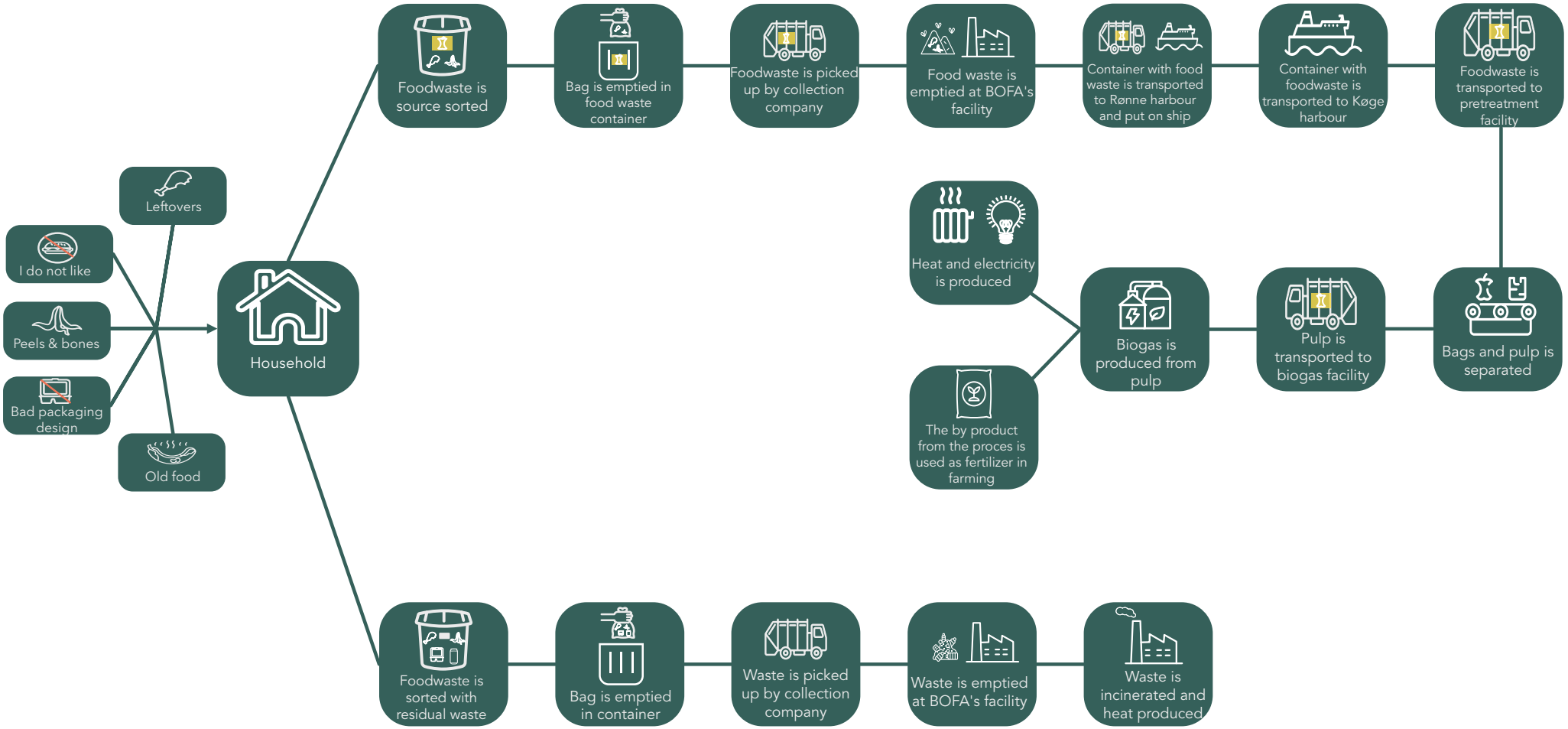


Figure 29: Future system for handling food waste on Bornholm

city. When using the biological treatment, it is possible to sustain the nutrients in the biological cycle, while the incineration process excludes this option by disintegrating the nutrients. When comparing the two systems it is very obvious that the new food waste management system is more complex and consists of several different processes, compared to "just" incinerating the waste. If looking into the flows of food waste in a desired future scenario with perfect sorting of food waste, it could look like what **figure 30** shows. Here it is assumed that the people who already use their food waste for feeding animals or have their own garden compost, will keep doing so, while the amounts that were previously send for incineration is now being send to biological treatment.

We have identified, as illustrated in **figure 31**, that the complexity of the system increases when moving up the waste hierarchy. This also

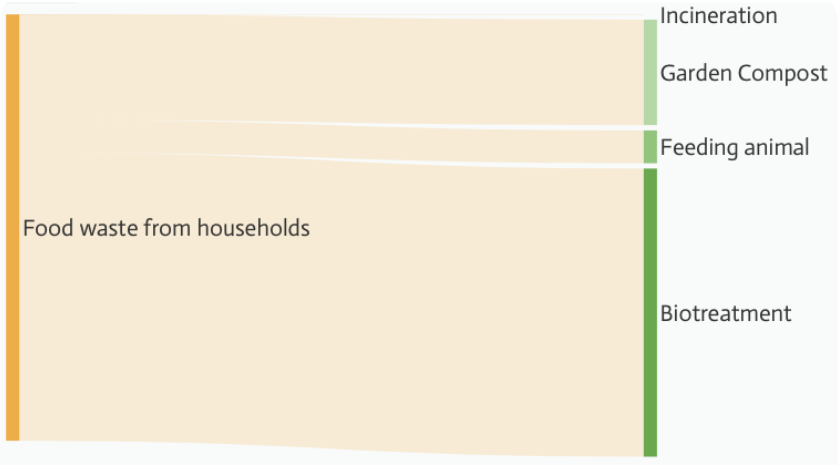


Figure 30: Sankey diagram showing the flows of food waste in a desired future

means that more effort will have to be put into the system in order to increase the amounts of waste that is send for recycling. This counts for both the people in the households and the waste management companies. This is what happens when Bornholm in the new system is trying to move the flow of food waste up in the waste hierarchy. The longer up in the waste hierarchy, we are trying to move waste, the more effort to secure the implementation is needed. This could mean that new technologies and new ways of thinking about the logistic systems for handling the waste might be necessary.

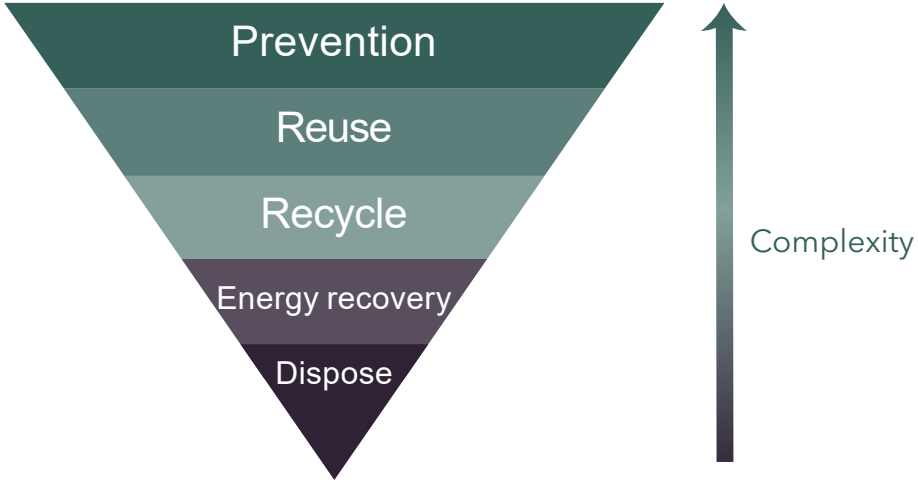


Figure 31: Complexity increases the higher you operate in the waste hierarchy

6.3 Comparative life cycle assessment: Sorting of food waste in the households on Bornholm

6.3.1 Goal and scope

The main goal of this life cycle assessment is to enable us to answer our first sub-question:

"How does source sorting of food waste in the household affect the total environmental performance of the food waste management system?".

Therefore, we investigate what impact source sorting of food waste in the household has, on the overall environmental impact of managing food waste from households on Bornholm in Denmark. The LCA is made to support BOFA in their work to support the inhabitants on Bornholm to start sorting food waste. According to BOFA it is estimated that the households on Bornholm will generate appr. 3000 tons of source sorted food waste when they in the end of 2022 start to sort the food waste (Bornholms Regionskommune, 2021).
The term "food waste" covers all organic household waste (excluding garden waste).

The study will compare three scenarios where the amount of source sorted food waste sent to biological treatment or incineration will be the differing element. The different sorting rates are estimated based on another LCA looking at a waste source separation program in Sweden (Bernstad, La Cour Jansen and Aspegren, 2011).
With this LCA we seek to answer the following questions:

- What are the processes that contribute most to the overall environmental impact?
- What is the critical amount of food waste to be source sorted to reach a lower environmental impact, than no sorting?
- Does it matter whether the treatment is located locally on Bornholm or if the waste is transported to Sjælland to be treated?

The functional unit is:

"Handling (including sorting in household, collection, transport, treatment and potential avoided burdens from end product) of 3000 tons of food waste from households on Bornholm."

The scenarios that will be compared are described in the following and illustrated on **Figure 32**.

High source sorting (HSS):
In this scenario 80% of the 3000 tons of food waste will be treated in an anerobic digester (AD) and 20% will be send to incineration.

Low source sorting (LSS):
In this scenario 33% of the 3000 tons of food waste will be biologically treated in an AD and 67% will be sent to incineration.

No source sorting (NSS):
This scenario reflects the current way of treating food waste on Bornholm (in 2022), meaning that 100% of the 3000 tons is send to incineration.

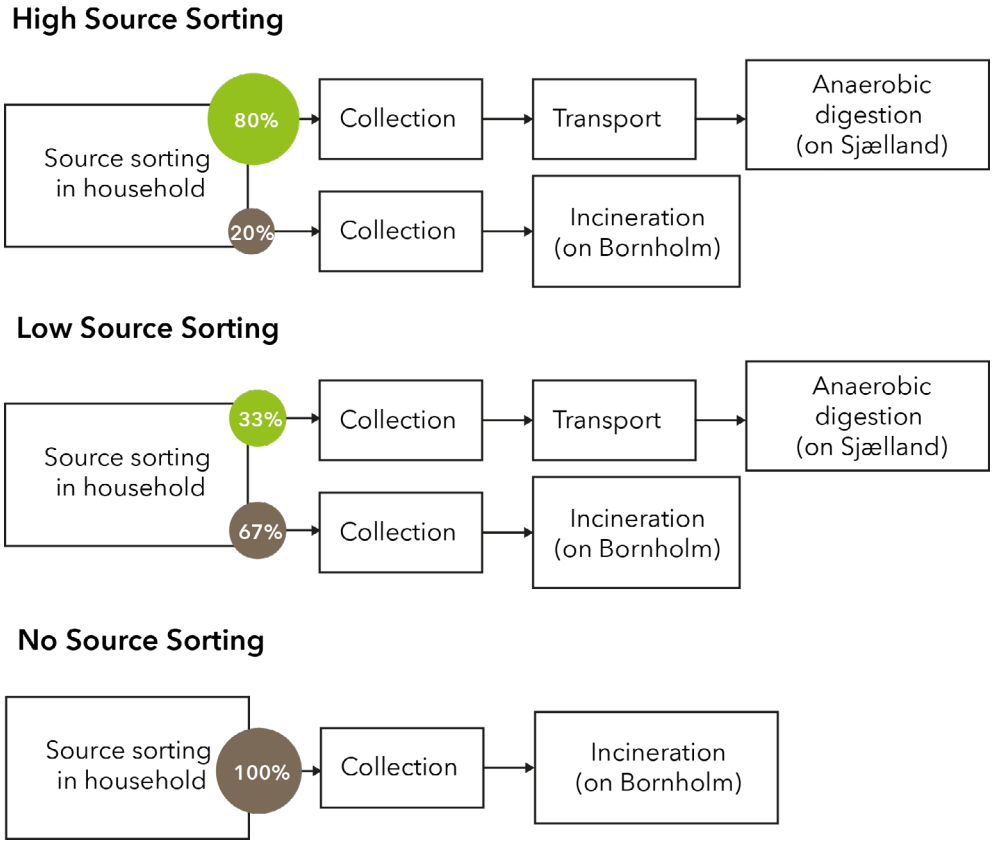


Figure 32: Scenarios that are compared in the LCA

The LCA study has, from the practitioners' best abilities, been completed in accordance with the ISO 14040/14044 standards for how a LCA should be conducted (International Organisation of Standardisation, 2008a, 2008b).

A consequential approach was taken, and multifunctional processes were handled by doing system expansion. Marginal data was used according to the consequential approach (Hauschild, Rosenbaum and Olsen, 2017). The consequential approach was chosen because the handling of food waste can be assumed to have an impact on the market for waste. When treating the waste, it will influence other systems, for example the production of energy and fertilizer, and it is therefore necessary to look at what consequences it will have on the system if a different treatment method is chosen.

System boundaries

Since the functional unit of the LCA is related to the impact of source sorting of food waste (referring to amounts), the upstream processes of production, transportation and storage of the food (before it turns into waste) is not included in the modelled system. This will result in an outcome of the LCA, that cannot show the benefits from reducing the total amount of waste in the system. But we are aware that according to literature the reduction of food waste is the best solution to reduce the overall environmental impact from the system (de Sadeleer, Brattebø and Callewaert, 2020). This is however not the focus here. **Figure 33** shows how the system boundaries have been defined.

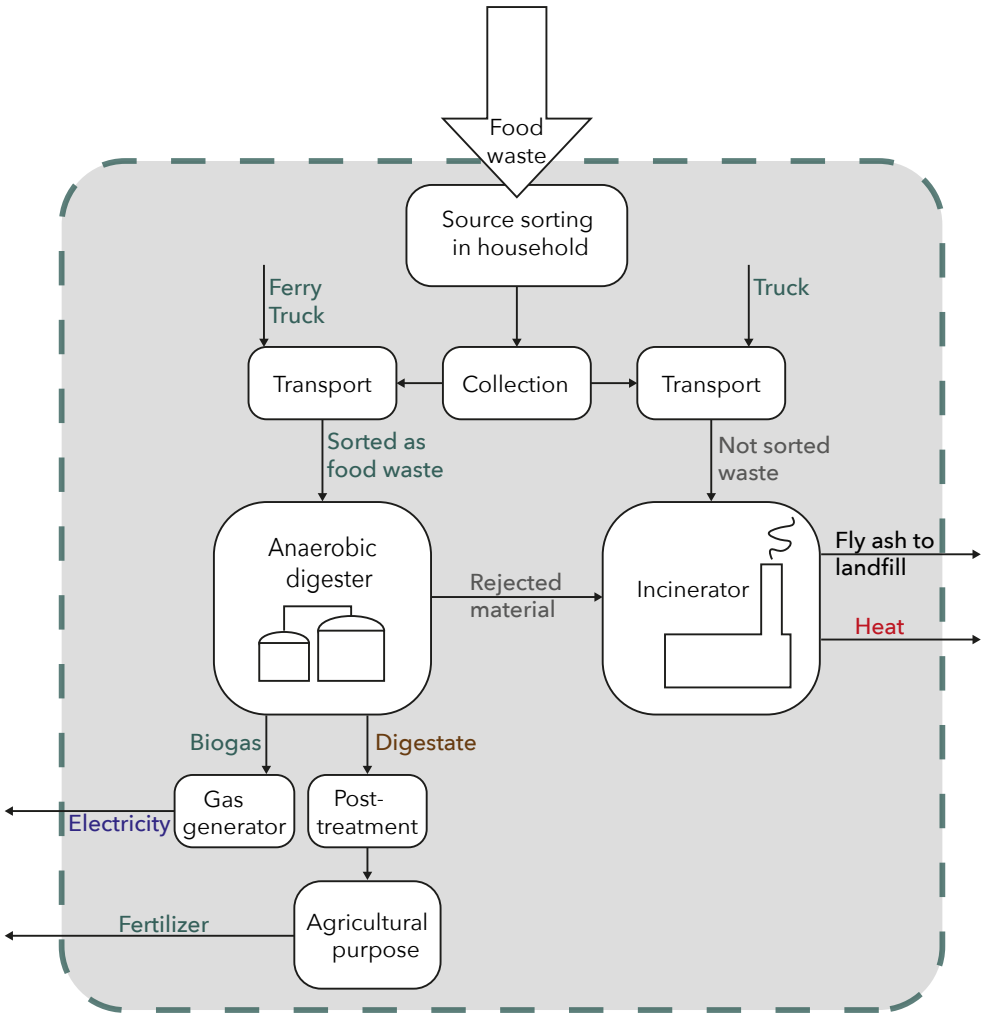


Figure 33: System boundaries

6.3.2 Life cycle inventory analysis

The three different source sorting scenarios (HSS, LSS, NSS) were modelled individually in SimaPro (version 9.3.0.3), using relevant available data mainly deriving from the Ecoinvent 3.8 - consequential database. Geographical distances were measured through Google Maps. The food waste in the system is either send to incineration or biological treatment in an anaerobic digestor. These options are the two of the most common ways of treating food waste in Denmark. On Bornholm, they have been used to incinerate food waste but are now changing this to anaerobic digestion, which is also why we decided to compare these two treatment methods. In **appendix 16: LCA**, it is possible to see how we modelled the inventory in the software. **Figure 34** shows the amount of food waste that is send to either incineration or AD.

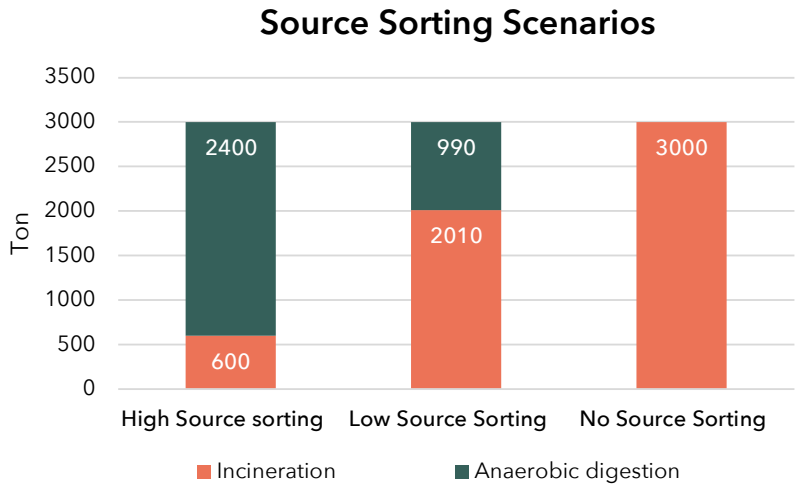


Figure 34: Source sorting scenarios

Anaerobic digestor

It is assumed that the source sorted food waste fraction is transported for treatment in an anaerobic digester (AD) on Sjælland, this includes the process of pretreatment of the food waste at the same site. Since the tender for the final decision on who will treat the food waste from households on Bornholm is still confidential, it has not been possible to gain site specific data. An average process from the Ecoinvent database was therefore chosen and adapted to match Danish conditions. The process chosen to represent this part of the modelled system is called: 'treatment of biowaste by anaerobic digestion - CH - biowaste' and is described below:

"Biowaste […] is defined as follows: Biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, comparable waste from food processing plants, it also includes forestry or agricultural residues and manure. It does not include sewage sludge, or other biodegradable waste such as natural textiles, paper or processed wood. The anaerobic digestion treatment is a collection of processes by which microorganisms break down biodegradable material in the absence of oxygen. The treatment process produces biogas (a mixture of mainly methane and carbon dioxide) and residual products called solid and liquid digestate."

(The ecoinvent Association, 2021).

As described, the process is not only covering the treatment of food waste, but also garden/park waste and manure etc. It has not been possible to divide these substances from each other to only look isolated at the food waste. But in reality, food waste would either way often be treated together with manure in an AD, since this is what most ADs are originally made for in Denmark (Hann et al., 2020).

The original process available in the Ecoinvent database is based on data from Switzerland. To adapt the process to Danish circumstances the electricity was replaced with an average Danish energy mix. The biproducts produced in the AD process (biogas and digestate) is assumed to substitute other products, and therefore credits were given to include this in the potential environmental impact results. Credits from using biogas as a source of energy to produce electricity was calculated using the energy content for biogas (lower heating value (LHV), also known as the calorific value) and multiplying it with the amount of biogas generated per amount of food waste treated.

1 ton of treated food waste is assumed to generate 150 m3 of biogas (affald.dk, 2022), which is calculated to substitute the production of 3,3 GJ electricity per ton food waste. This calculation is based on an average LHV for biogas assumed to be 22 MJ/m3 (the LHV ranges from 16-28 MJ/m3 depending on the methane content) (International Energy Agency, 2022). The substituted electricity is assumed to derive from the average Danish electricity mix.

The digestate is assumed to substitute artificially produced NPK fertilizer, that consists of nitrogen, phosphorus and potassium, this

credit is already included in the existing process in the database. At the AD plant there will be a presorting process where rejected material (bags or incorrectly sorted material) is sorted out and send to incineration, before the rest of the organic material (pulp) is send into the AD. It is assumed that 15% of the sorted food waste is rejected based on another LCA made for 'Miljøstyrelsen' in Denmark (Kromann et al., 2019).

Incineration

The process chosen to represent the incineration of food waste from the households is originally based on Swiss data. The name of the process is: 'treatment of biowaste, municipal incineration with fly ash extraction - CH – biowaste. And it is described as follows:

"This dataset represents the activity of waste disposal of biowaste in a municipal solid waste incinerator (MSWI) .[…] For average biowaste (mixture of garden, yard, food/kitchen waste) which goes to disposal as part of communal waste mixture."

(The ecoinvent Association, 2021).

As with the AD process the energy mix was adapted to a Danish context. The incinerator is located on Bornholm and is run by BOFA. BOFA's incineration plant is with fly ash extraction and the heat is used for district heating in Rønne, no electricity is co-produced. The heat energy recovery rate from the incinerator is 93,9% (BOFA, 2020) and according to Ecoinvent the LHV for incinerating biological waste is 4,289 MJ/kg (The ecoinvent Association, 2021). This leads to a heat generation of 4,03 GJ per ton food waste incinerated.

The heat that is produced is assumed to substitute the heat from the district heating generator on Bornholm, which is fueled mainly by wood chips (Bornholms Energi og Forsyning, 2020). See **figure 35.**

Process	Avoided product	Energy/ton FW treated	Comment/ calculation
Anaerobic Digestion (biogas)	Electricity (DK energy mix)	3,3 GJ/Ton	LHV for Biogas = 22MJ/m^3 1 kg of FW= 0,15m^3 biogas 0,15*22=3,3 MJ/kg
Inceneration (heat)	Heat (District heating, wood chips)	4,03 GJ/Ton	LHV for FW = 4,289 MJ/kg Heat energy recovery rate: 93,9% 0,939*4,289= 4,03 MJ/kg

Figure 35: Table shows the background calculations for substituted energy (avoided product)

Transportation

The impact from collecting and transporting the food waste from the households to the treatment facilities is described in the following. In Rønne, BOFA has their main collection site for waste from the island. This is where all waste is gathered before either being incinerated at BOFA or send to treatment elsewhere. An average distance to a random household on the island was assumed to be the distance between Aakirkeby and BOFA, since Aakirkeby is located approximately in the middle of Bornholm. Since the transportation is calculated in ton kilometers (in SimaPro), it is assumed that the

number of trips that the waste truck has to drive to collect 3000 tons of food waste is implicitly in the calculation. Since it is not yet clear what treatment facility will win the tender for treating the food waste, we have placed it where it could potentially be treated according to our research and the information we got from visiting the biological treatment facility described in **section 5.6.** The journey of the waste can be seen on **figure 36**.

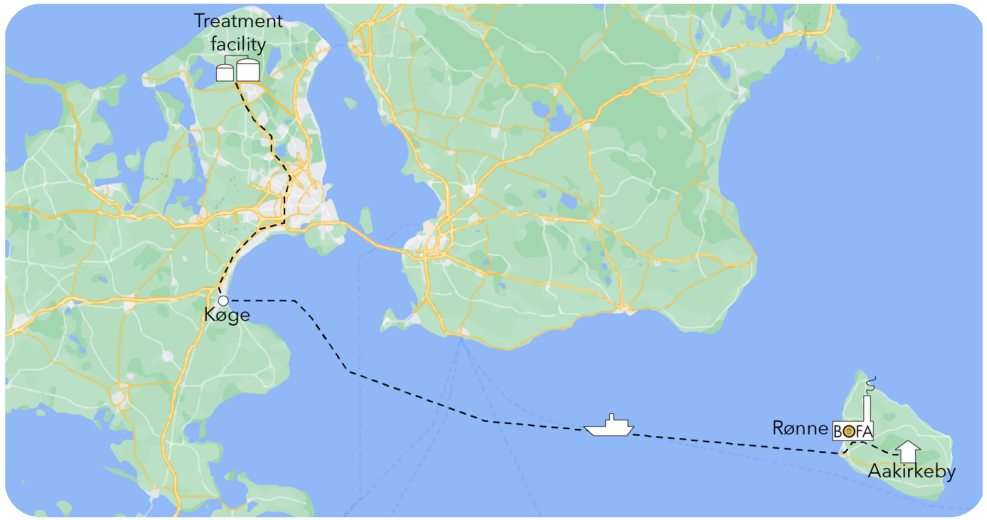


Figure 36: Food waste from Bornholm is transported for treatment on the route shown

Geographical distances (Google maps) and mean of transportation			
Truck from household to BOFA	17	km	Transport, freight, lorry 16-32 metric ton, EURO6 {RER}|
Truck from BOFA to Rønne harbour	5	km	Transport, freight, lorry 16-32 metric ton, EURO6 {RER}|
Ferry Rønne to Køge harbour	170	km	Transport, freight, sea, ferry {GLO}
Truck from Køge harbour to treatment facility	70	km	Transport, freight, lorry 16-32 metric ton, EURO6 {RER}|

6.3.3 Life cycle Impact assessment and Interpretation

To analyse the inventory data, the Environmental Footprint 3.0 (EF 3.0) method was used. This method was chosen because it is recommended by the European Commission for measuring the environmental impact from products and systems and has recently been updated in 2021 (European Commission, 2021).

The results from the comparison of the different scenarios are shown on **figure 37** in characterised data. In the characterised data the impacts are quantified via characterisation factors, which shows how much each of the different processes contributes with, in the different impact categories. Since the different impact categories have different units, it is all measured in percent to make it comparable (European Commission - Institute for Environment and Sustainability, 2010, p. 276)

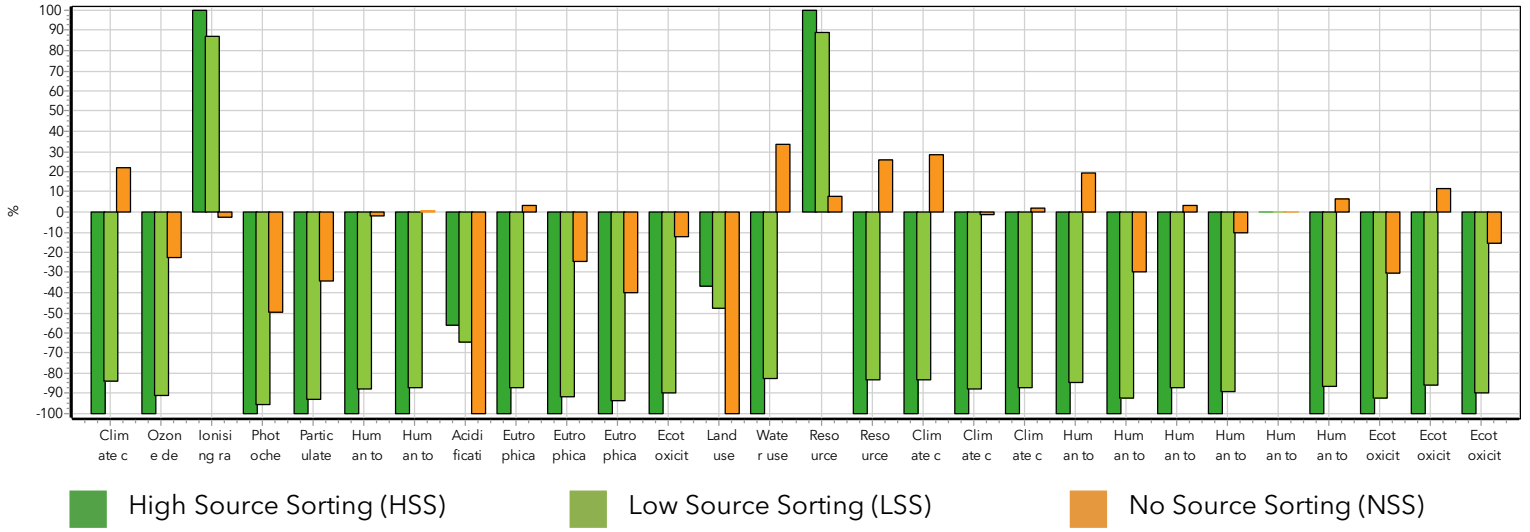


Figure 37: Characterised results - comparison of scenarios

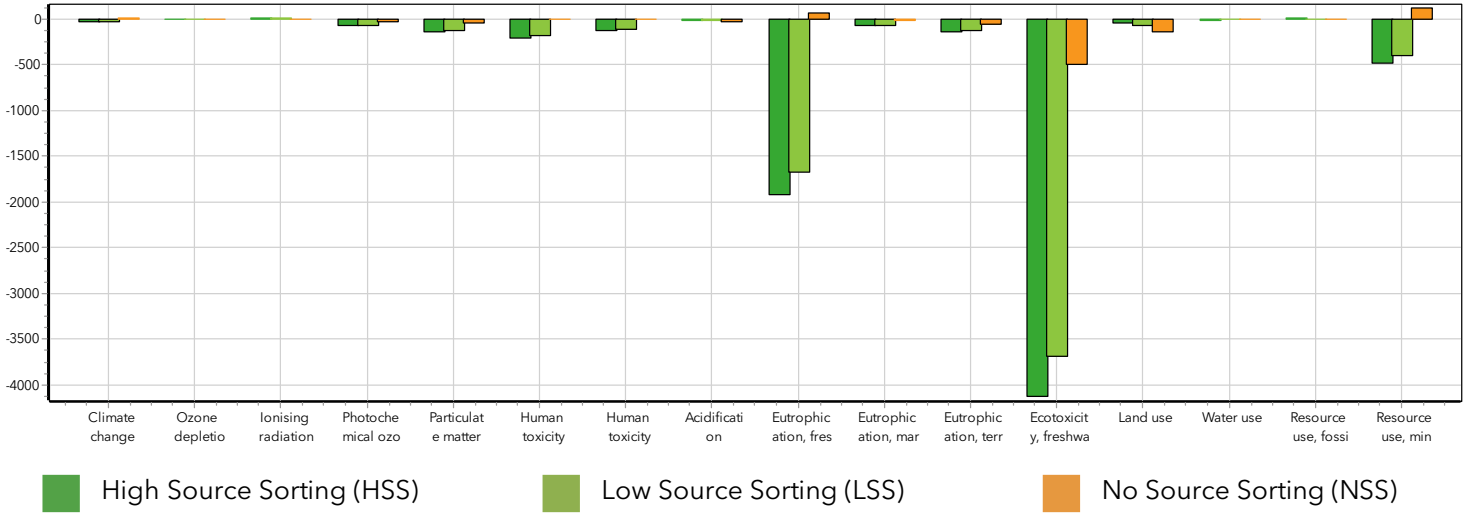


Figure 38: Normalised results - comparison of scenarios

On **figure 38** the normalised data is shown. They show for each impact category, on a midpoint level, how much the analysed system (each sorting scenario) is contributing seen relatively to the total impact from an average citizen, in the specific impact category. In this way it is possible to compare the different impact categories across different units and to see which of them the system under investigation contributes relatively more or less to (European Commission - Institute for Environment and Sustainability, 2010, p. 281).

In **figure 39** all impacts are aggregated to single scores. The single score is based on weighting, which is based on a compilation of three independently derived sets of weighting factors. Two of these sets are derived via traditional panel weighting (public and LCA experts) and the third is based on a hybrid 'evidence- and judgement- based' approach (PRé Sustainability, 2020, p. 24). The single score makes a great overview, but also contains uncertainties due to the weighting factors, since different panels or experts can weigh impacts differently than others.

The single score results make it visually very clear that there is a potential to reduce the total environmental impact if the households increase their source sorting. The values that go below 0 in the graphs indicate an avoided environmental impact. These avoided impacts come from the avoided production of heat, electricity and nutrients that are returned into the technosphere and biosphere (compost and fertiliser) when treating the waste. Thereby enabling the substitution of producing these products from other energy sources or nutrients.

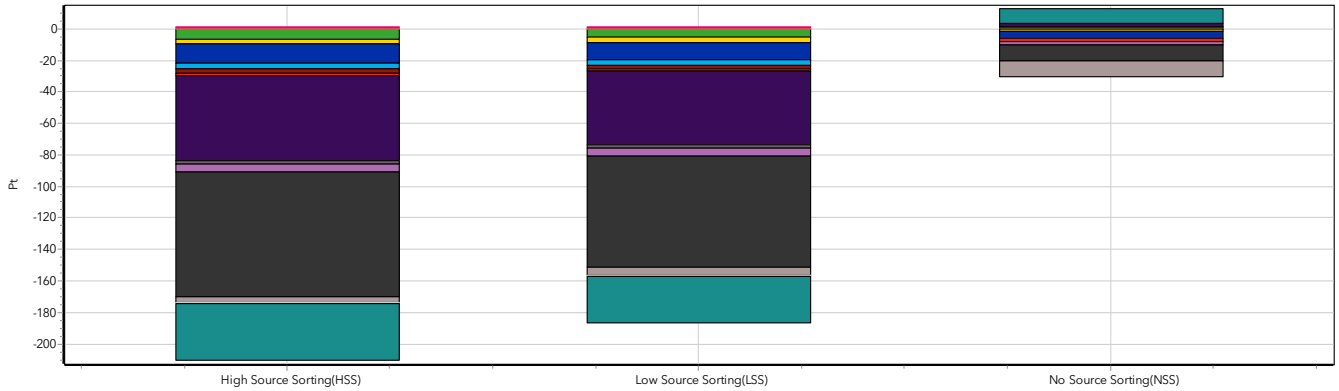


Figure 39: Single score results - comparison of scenarios

Especially the results in the impact categories of 'Eutrophication, Freshwater' and 'Ecotoxicity, freshwater' are worth noticing, since they in the normalised results indicate a relatively high impact. To further understand the results hotspot analyses of each treatment process were made.

On **figure 40** the hotspot analysis of the process for treating biowaste in an AD is shown in single score. It is clear that the biggest contribution is deriving from the benefits from producing biogas. The impact categories contributing mostly to the avoided burden is 'Eutrophication, freshwater' and 'Ecotoxicity, freshwater'. In the following we will describe why these impact categories benefit from using the AD. The production of biogas is closely related to the treatment of livestock manure from agriculture. The food waste is in most cases mixed with manure in the AD and microorganism makes sure to degrade it, which results in a degasification (biogas). After the degasification the digestate (the leftover product from manure and food waste) is filled with nutrients that can be used as fertilizer in agriculture. The large avoided "impact" from biogas (below 0) derives from artificial fertilizer (mainly in the form of potassium) that is assumed to be substituted by the nutrients in the digestate. Fertilizer from food waste is known to have approximately the same nutrient content as fertilizer from livestock manure (Karstensen, 2020). When treating manure in an AD the quality of the fertilizer increases because the molecular composition of the nutrients changes in a way that makes it easier for plants to absorb the nutrients. In this way the risk

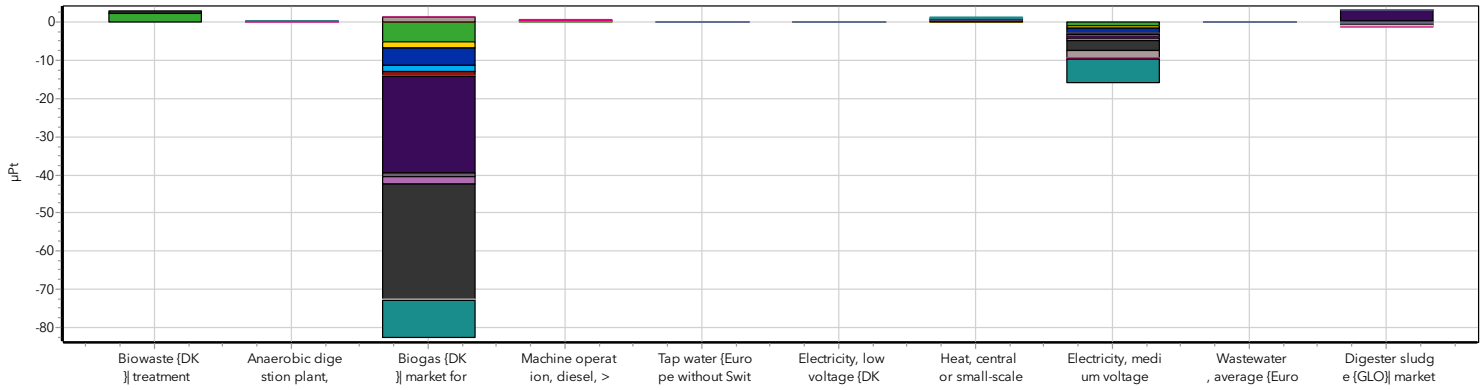


Figure 40: Anaerobic digestion - Hotspot analysis

of eutrophication and ecotoxicity is decreased when using fertilizer from digestate, instead of spreading artificial fertilizer or pure manure directly on the fields without knowing the exact content of nutrients (Solrød Biogas, 2022).

Furthermore, the substituted production of electricity, made possible by the biogas, can be seen on the graph as another avoided impact. The impacts that are above 0 are showing the emissions from treating the digester sludge. The sludge is the part that cannot be used for fertilizer and it is incinerated. Additionally, emissions from constructing the AD facility, driving the machinery on site, heating, water and electricity consumption at the facility is included. But the benefits from the avoided products seem to overrule the impacts from running the treatment facility. In the hotspot analysis of the incineration process (**see graph 4 in appendix 16: LCA**) the significant impacts derive from the avoided impact from district heating that is assumed to be substituted from incinerating the food waste. On Bornholm the local district heating system is, under normal conditions, fueled by 100% biomass (Bornholms Energi og Forsyning, 2020), which is currently considered a climate neutral source of energy in Denmark, when looking at climate accounting (Miljøministeriet, 2021). That means the credits available from producing heat from burning waste instead of burning wood chips (biomass) is not as large, as if it was replacing district heating based on fossil fuels like coal and gas – this is also described in the sensitivity analysis.

6.3.4 Sensitivity analysis

Depending on what products are decided to be substituted, by recovering nutrients and energy from the waste, the results could change. Likewise, the results could be sensitive to changes of the geographical locations of the treatment facilities, the choice of LCIA method or the amount of sorted waste send for treatment. Therefore, a sensitivity analysis was performed to see if the mentioned things would change the results radically. In the following a more in-depth assessment of the data have been conducted to answer the questions mentioned in the beginning of the LCA study.

What is the critical amount of food waste to be source sorted to reach a breakeven compared to no source sorting?

To answer this question, we changed the ratios of how much food waste is send for treatment where. The results showed that when approx. 5% of the 3000 tons of food waste is source sorted and send to AD, it can be considered a better environmental solution than 100% incineration. This means that the low source sorting scenario (LSS) could go down to a sorting rate of 5%, and still be an environmentally better solution. This indicates that it really does matter to support the increase of source sorting of food waste from the households.

Does it matter whether the treatment is located locally on Bornholm or if the waste is transported to Sjælland to be treated?

In the tender requirements from the municipality on the treatment of food waste from Bornholm, there are no requirements on the location of where the food waste is to be treated (BOFA, 2022). Even though there is a functioning AD on Bornholm, with capacity to treat

the 3000 tons of food waste, it is according to the project manager at BOFA, most likely an AD on Sjælland who will win the tender due to economic investments needed for a pre-treatment facility on the island. To show the impact from transporting the food waste, we changed the location of the AD in the high source sorting scenario (HSS) to be on Bornholm instead of on Sjælland – thereby saving the 170 km ferry tour and 70 km truck driving of 2400 ton food waste. The normalised results of comparing the two transport scenarios are shown on **figure 41**. It is clear that there are large environmental savings to win if the food waste is treated locally. Appr. 70% of the environmental impact from transport to Sjælland (HSS) comes from the ferry, while appr. 30% comes from the truck (**see appendix 16: LCA**).

However, this assessment is only looking isolated on the transportation and not the environmental or economic impact from building the needed pre-treatment facility to allow the treatment to be on Bornholm, or for that matter the economic expenses from transport. But when looking more holistically on both transport and treatment, it is clear that the transport is only a small part of the overall environmental impact. As shown on a hotspot analysis of the HSS scenario on **figure 42**, the impact from transport is much smaller than the benefits from treating the food waste in the AD.

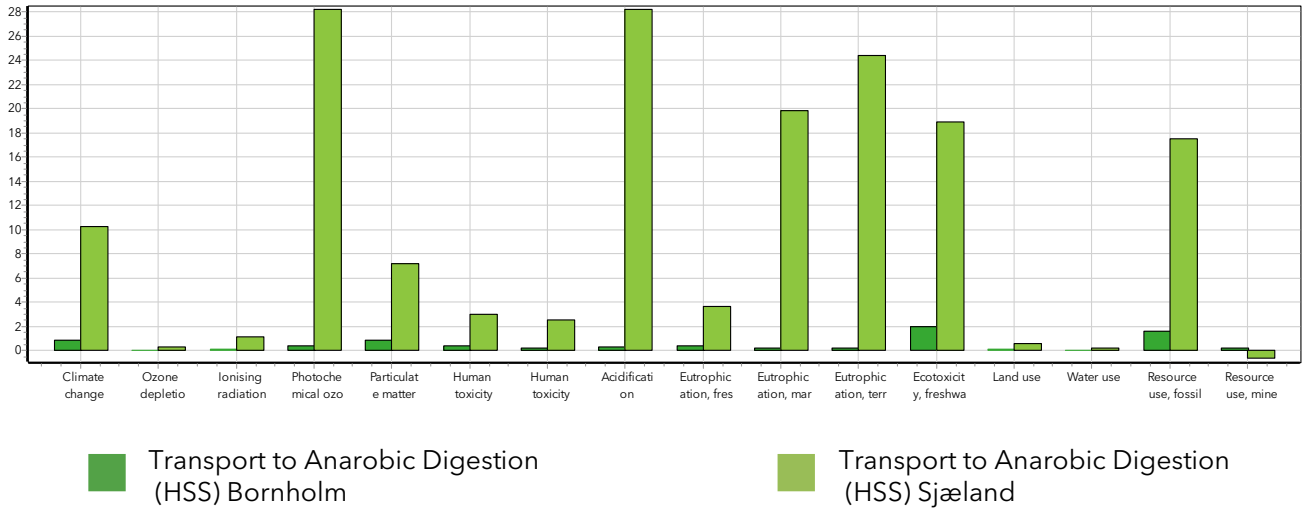


Figure 41: Comparing transportation to Sjælland with local treatment on Bornholm – Normalised results

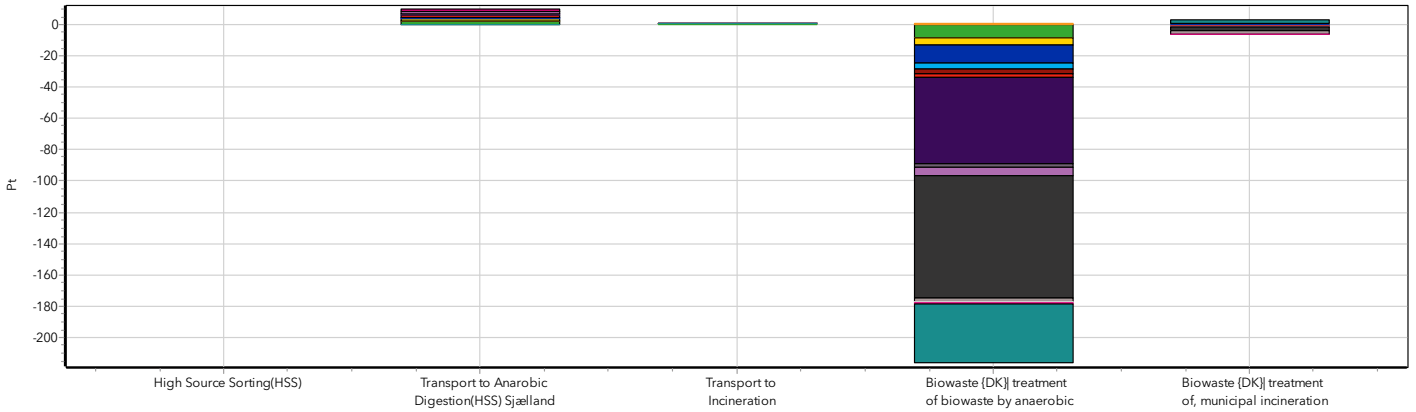


Figure 42: Hotspot analysis of High Source Sorting scenario

Another LCIA methodology – ReCipe 2016 Midpoint (H)

When conducting an LCA it is always important to check the results with another LCIA method, since the different methods are affecting the results showed. The results are more robust if they are somewhat similar across different methods. Therefore, we applied the Recipe 2016 Midpoint (H) to see if the results would change remarkably. This was not the case. The results still indicated a positive effect from source sorting. This can be seen in **figure 43**, that shows the normalized data, when using the Recipe 2016 Midpoint(H) method. The method includes a few different impact categories than the EF 3.0 method. The most significant impact category that is included here is the 'Human carcinogenic toxicity', that is related to an increased risk of cancer seen from a human health perspective.

Substitution matters

When giving credits for substituting one product with another, it is highly relevant what is assumed to be substituted. If the produced energy from biogas or heat is assumed to replace energy made from burning coal or natural gas, the credits will be bigger than if the energy replaced is made from renewable energy, like wind turbines or biomass, because the impact from consuming fossil resources are higher. When we changed the source of energy from being based mainly on coal instead of biomass, it would require that at least 20% of the food waste was source sorted and send for AD (instead of only 5%), before it could be considered a better environmental choice of treatment.

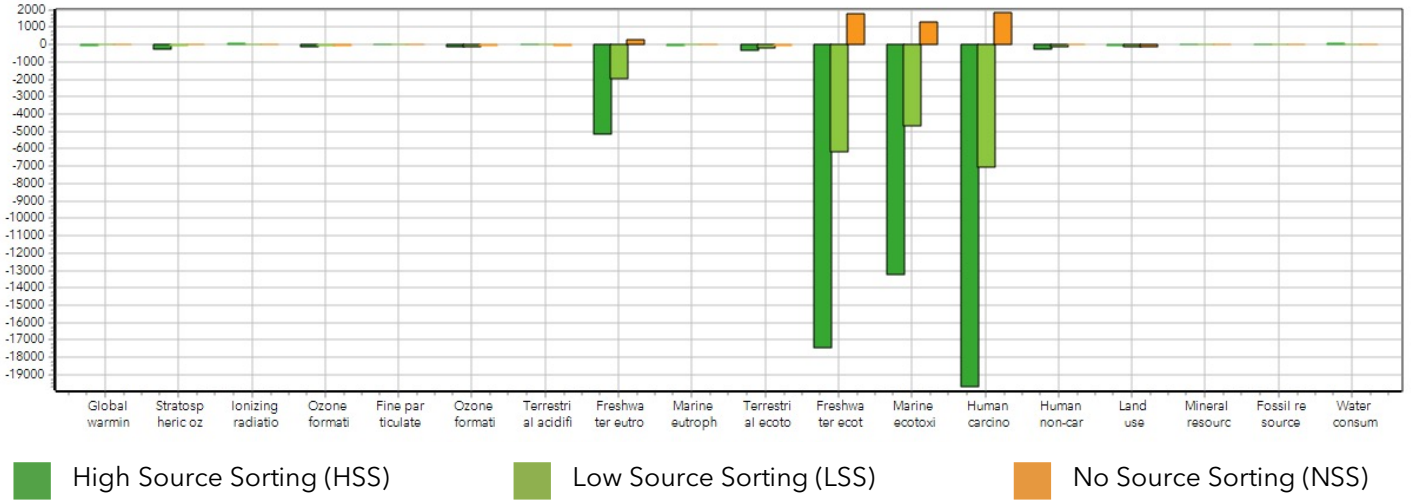


Figure 43: Normalised data - Comparison of scenarios with ReCipe Midpoint (H) method

Other LCAs – similar results?

Since the LCA we have made was restricted on time and by a lack of insight to site specific data, it was relevant to compare our results with LCAs from the literature assessing the same kind of system, focusing on food waste treatment processes and the importance of source sorting. Bernstad et al. finds that source sorting matters. Although they look at many different types of waste fractions and not exclusively on food waste, their modelling and results of the food waste fraction can be compared to ours. They conclude that the source sorting of plastic and metal matters the most, while the sorting of food waste is in comparison not as important to source sort, but it still matters (Bernstad, La Cour Jansen and Aspegren, 2011).

Jensen et al. from DTU compares different options for food waste treatment including transportation and comparing different compost, biogas and incineration facilities. They conclude that none of the modelled methods to treat the food waste can be concluded to be better than the others (Jensen, Møller and Scheutz, 2015). This also means that it is not considered a worse solution to do biological treatment instead of incineration.

De Sadeleer et al. also compare anaerobic digestion and incineration of food waste. They conclude that there is a high potential in recovering energy and nutrients through AD treatment, if the produced biogas is replacing diesel. Furthermore, they conclude that reducing food waste in the first place can outweigh the benefits from recycling strategies (de Sadeleer, Brattebø and Callewaert, 2020).

Another LCA and socio-economic impact assessment made for the Danish Environmental ministry, concludes that correct source sor-

ting and recycling of waste leads to positive environmental effects. They conclude that the source sorting of organic waste from households matters, especially if the produced biogas is upgraded to be used in the gas grid, to substitute natural gas (Kromann et al., 2019).

Conclusion of the LCA

Despite the uncertainties in the conducted LCA, it can, supported by other LCAs, be concluded that the higher amount of food waste sorted and send for biological treatment the better environmental footprint. This applies if at least 5% of the 3000 tons of food waste are send for biological treatment in a scenario where the substituted product to produce heat (from the other 95% that is send to incineration) is based on biomass – as is the case on Bornholm under normal circumstances. It can be concluded that the determining factor for the results are the choice of substituted products. The location of the treatment facilities does have an impact when looking at the emissions from managing the food waste. Local treatment, reducing the amount of needed transport, is initially prefered, but should be further investigated before any final conclusions can be made. The benefits from recycling the waste seem to overrule the impacts from the treatment and transport processes. The results can be used for decision support to argue for investing in efforts that can help the households to increase sorting of food waste – and supposedly also other waste fractions.

6.4 The practice analysis

Learning from the LCA that sorting does matter seen from an environmental perspective, it was essential for us to dig deeper into the actual practice of sorting food waste to answer our second sub-question: "What is the practice of source sorting food waste in households on Bornholm?". That is the purpose of the following section. To understand what households on Bornholm currently do in terms of sorting waste and how sorting of food waste can become an integrated practice, we will analyse the current sorting situation and what the future might look like. This will be done from a practice theoretical perspective as described in **section 3**. We will look into what factors influence and can trigger the deformation of the current practice, but also what factors can help form or deform the future practice of sorting food waste.

The main aim of doing the practice analysis of the current situation and the future situation is to answer the three following questions:

- What are people currently doing with their waste?
- Why do they do what they do?
- How can we change what people do?

The practice analysis of the current and future practice is based on our interviews and observations with the different households in Bo42, the cultural probes, grey literature research and the survey (**see section 5**).

The structure of this section will be as follows. First, we will analyse the current practice of getting rid of waste from households on Bornholm. Both with the perspective that the current practice of getting rid of waste is connected to a network of practices and that the practice has its own agency in the construction of this network of practices. Afterwards, we will analyse the proto-practice of sorting food waste, based on the cultural probes we facilitated in the households at Bo42. In the end, we will analyse what the future practice of sorting food waste could look like. This is followed by a sum-up of the important elements that are needed to get the practice established and what to be aware of that can potentially deform the practice.

A network of practices

As described in section 3 we understand a practice, as something that consists of meanings, competencies (also refered to as skills) and materials. When understanding the current practice of sorting waste in the household on Bornholm, it became evident that it is possible to sort three waste fractions in the households (residual waste, paper/cardboards/textiles and glass). Some citizens use the opportunity of driving to BOFAs recycling centre where it is possible to sort waste into many more fractions (plastic, metal etc.). We however focus on fractions which can be sorted in the households and be collected and not the fraction which requires the citizens to go to BOFA. Sorting in the households, therefore, implies that food waste is not sorted out separately but is a part of the residual waste which means we cannot look at the current practice of sorting food waste – since it is not existing, except for people with their own home compost in the garden. However, we will instead look into the practice of "getting rid of waste" since we argue it will connect to the future practice of sorting food waste and we can hereby use our findings to construct the proto-practice of sorting food waste. It also falls in line with the practice theory which argues that practices exist in networks with each other thereby also influenced by one another. So, for example, the practice of 'getting rid of waste' is connected to the practice of shopping and cooking (see **figure 44**). Part of cooking is also creating waste in terms of packaging or inedible food (e.g. peels and bones) and how we shop influences how much waste is generated and thereby is connected to how we choose to get rid of it. All though we acknowledge the practices in the network are well connected and influence each other, we will currently only focus on the practice of getting rid of waste.

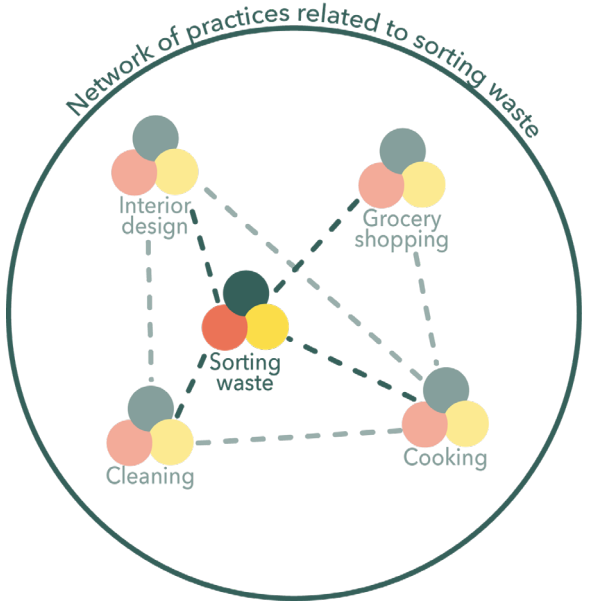


Figure 44: Network of practices

6.4.1 The practice of "getting rid of waste"

The following analysis will look at the meanings, skills and materials that together comprise the practice of getting rid of waste from households, mainly apartments, in the housing association Bo42 in Rønne. We argue that most findings are also representative of people living elsewhere on the island, but we acknowledge that the practice will differ depending on what type of housing you live in. Our understanding builds on our interviews, cultural probes, survey, and grey literature. **Figure 45** summarizes the current practice of "getting rid of waste"

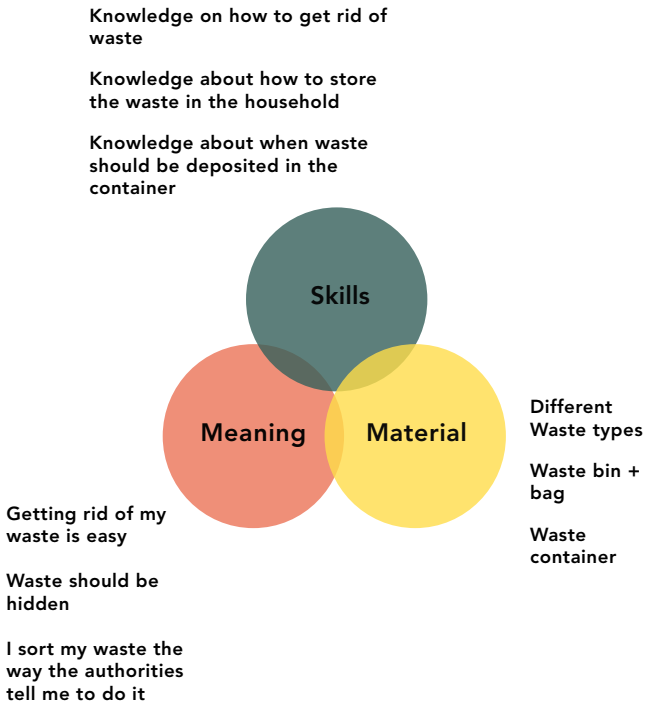


Figure 45: Practice of "Getting rid of waste"

Meanings about waste

"Getting rid of waste is easy and I don't want to deal with it"

In the current practice of getting rid of waste, waste is for many people sorted into residual waste, paper, cardboard and glass. This practice is described by many as being 'easy' and not something they use a lot of energy to think of. Since it is 'easy', for the households to get rid of waste, it is also why it is so established and makes sense for a lot of people to do it this way. We have identified two reasons mainly why it is considered easy.

Firstly, we observed in Bo42, due to the lack of space in the apartments, that many are quite positive about waste bins and fractions which are not taking up too much space. The small kitchens are very aligned with the current system for handling waste, where only one or two bins are needed for each household. Another key reason why getting rid of waste is considered easy is the quite short distance that residents in Bo42 must go to dump their waste in the waste containers. There is a collection container for every second apartment block in Bo42 giving the residents a maximum distance of 50 meters to get rid of waste. When we look at inhabitants living in their own houses getting rid of waste is also considered easy. They have their own collection containers meaning they in most cases have to walk an even shorter distance. These citizens have to roll out their containers to the roadside when the waste truck comes to collect the waste (**picture 19**). But since it has been like this for a long time, the practice is very well established, and it does not seem to bother them. Then comes the perspective that in the practice of getting rid of the

waste you do not have to think about sorting in broader terms - when something becomes waste you dump it in one universal bin and container, which gives the perception of it being easy. We further noticed that waste is described as something that should be invisible and kept away:

"Waste is not something you want to flag with, it should be able to be hidden away".

(Eva, appendix 8: Key takeaways)

The interpretation is that you do not want to deal with waste and if you have to, you just want to be able to hide it or get rid of it when it is generated in a good manner. The current system supports this particular meaning by only having to sort in three fractions , and thereby the residents can limit their interior waste bins to only a few. We see this highlighted in Bo42 where people are storing the residual waste bin, paper, cardboard and glass jars under the sink, and thereby in a place where it is not visible to them. This kind of distant relation to waste also points toward, that most households currently do not see the value in waste. They do not make an extra effort in making their own sorting system or delivering other fractions at BOFAs recycling station. This can influence inhabitants' motivation to begin to sort. If they do not see the value, why should they even start to sort in the first place?
We do recognize that there exist citizens on Bornholm who does see the value in waste and do sort by driving to BOFA's recycling facility. This is however not what we have identified as the dominant practice of getting rid of waste.

"I do what I am told to do"
Some inhabitants in Bo42 and respondents in our survey mentioned they get rid of waste in the only way possible in their households, namely the two different containers close to the households:

"We do as we are told. We just need some instructions."

(Tove and Ejvind, appendix 8: Key takeaways)

This implies certain obedience to authorities, explained for some as "I do what authorities say I should do". And currently, the authorities do not tell them to sort food waste in the households, therefore they do not do it. Though there might be some truth to this, it is important to know it is always a possibility to sort waste. Inhabitants can always go to BOFAs recycling centre themselves and hand in their sorted waste in the right fraction. And if you have a garden, you can get a home composting bin for the food waste. Since this is not the case for many of the people we have talked to and who have answered our survey there must be other reasons why households do not sort food waste other than; "I only do what I am told to do." However, we of course expect that when collection from the households of more different fractions, like food waste, becomes available at the end of 2022, it will affect the sorting habits.

Picture 19: Two collection containers available at a regular household in Rønne.

Competencies and lack thereof

If we start to look at the knowledge or competencies needed to perform the practice of sorting food waste, we can see that one of the main competencies required is to know how to sort correctly. Knowing the different fractions from each other is key - for example when something can be sorted as paper/cardboard. Some are very aware of which fractions can be sorted, but we identified that many were unaware of the number of fractions they could sort. For example, only a limited number of people knew that textiles could be sorted together with cardboard and paper. This lack of knowledge can be traced down to the lack of communication from the municipality, but also the lack of information on the containers, which do not state you can sort textile or even cardboard in some cases.

Picture 20: The cardboard/paper container in Bo42, notice the oily pizza box - an example of failed sorting

Picture 21: The cardboard/paper container in Bo42. Several plastic bags have mistakenly found their way into the wrong container.

Connecting to this lack of knowledge on sorting textiles we also identified that not all know what kind of paper or cardboard can be sorted in the correspondent container. We saw examples of pizza boxes with oily food leftovers in the cardboard paper container and even plastics in some cases (**pictures 20**) – which are both examples of waste not belonging in the paper/cardboard container. This points to the importance of making citizens aware of what can be sorted as what. Just because it is cardboard it does not mean you can sort it as cardboard if it has been contaminated with food and oil. This shows a complexity in the required competencies.

Another very important competency to the practice is the skill of how to store the waste in the household. For example, the households we have visited store their residual waste in a bag inside a bin. The purpose of the bag is to avoid a "disgusting" bin, and it makes it easier to empty the bin. But for example, paper and cardboard are usually just stacked in piles in random places, for some under the sink, others on the kitchen counter or in a paper bin in the office. However, we did also find evidence that some people could store these fractions in a bag as well since we found paper and cardboard in plastic bags in the collection container (**picture 21**). This means that the practice is not only how to get rid of waste it is also to store it until you deposit it - and how to store it is connected to the meaning that waste should be invisible.

Another related skill required is to know when waste should be deposited in the container. Some types of waste are known to be smelly if not emptied often enough. And the risk of a leaky bag increases

the longer you wait to empty it. These examples can function as indicators of when it is time to dump the waste. We have identified that some citizens are more affected by the smell or feeling of cleanliness than others, which also affects how often people are depositing their waste bags in the containers.

Materials that enable the practice

To fully describe the practice of getting rid of waste, it is important to look at the last element, which is the materials that go into the practice. The main material in this practice is the waste itself. In the current practice, residual waste, paper, cardboard, textiles and glass jars are sorted out in households. The waste requires some handling and interaction, and as described previously many want to make it invisible and hide it. Here comes another key material - the wastebin people use to store the waste. In the apartments in Bo42 the standard installation in the kitchen is two bins which are installed under the sink which they can use however they desire (**picture 22**).This helps people in the practice of getting rid of waste to already have a waste bin installed in a space that is convenient for them. In the waste bin, the households also have a bag which collects the waste and makes sure that the waste does not leak and makes the bin disgusting. The bag is very closely connected to the bin and households have specific requirements for this bag such as being easy to handle and with a size which fit the bin. All the households we have visited used plastic bags for their residual waste.

The collection container, where the waste can be dumped, is the next key material needed. Currently, in Bo42 these containers are placed very close to the households.

Picture 22: Waste system under the sink in apartment in Bo42

Picture 23: Waste container with missing text

Descriptions of where the different fractions go are written on top of the container lid, in Danish. However, as described earlier we have identified that many of the containers are missing this text, which complicates the dumping of waste for people (**picture 23**).

What is interesting about the container for glass is that it is not placed next to the other collection containers for residual waste and paper/cardboard/textile. There are less of the glass containers in Bo42 and the distance between them is therefore longer. This is how it has been for a long time and when talking to the households, it is something they have gotten used to, and the distance is very much embedded in the practice. This is an interesting aspect when we in **section 6.4.3** look at the proto-practice and the distance to the container for food waste.

The social norms forming the practice of getting rid of waste

It is worth mentioning that in the current practice of getting rid of waste, there exists no collection system for many waste fractions and for those that are in place, it is not clear what can go in which container as mentioned before. This reinforces the social norm of not sorting waste (**figure 46**). This means that the lack of a collection system does influence the individual actions made by citizens, thereby creating a specific social norm and structure, which is then being re-produced by people not sorting their waste. The social structure and norm of not sorting is very clear in our interviews with Brit (living in Bo42) who puts a lot of effort into sorting in her own home and even collects waste from nature when she walks the dog every single day. However even though this might seem to be how everybody should do to some extent, she describes herself as a 'freak' and an 'outsider' pointing toward that she is not part of the social structure and norm. When the system for sorting food waste gets rolled out, it is important that sorting food waste becomes a social norm and something that everybody does, otherwise, the practice will not get established.

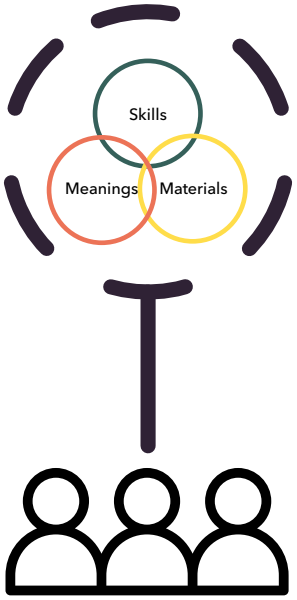


Figure 46: Social norms are formed amongst citizens and affect practices

Deforming the practice - what pushes for change?

As stated in the theory section a practice is not stable but dynamic. It is something that is continuously evolving and sometimes also deforming when the connections between the three elements are fading and new skills, materials or meanings are interfering (**figure 47**). We argue that to some extent the current practice of getting rid of waste is deforming on Bornholm right now - evidence is there. We have in a grey literature search looked at how sorting waste management has been described in the local

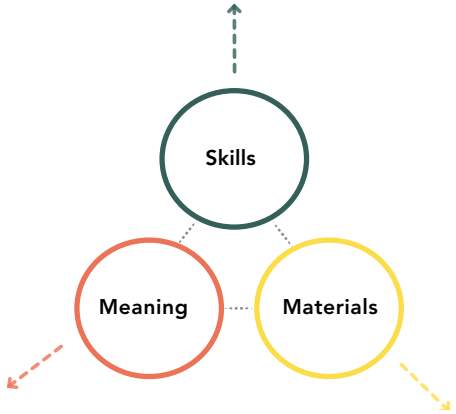


Figure 47: Deforming practice becoming an ex-practice

newspaper on Bornholm (Bornholmstidende). Here we identified several people claiming it is quite embarrassing to call Bornholm the 'Bright Green Island' when they are one of the municipalities in Denmark that is sorting the least waste fractions. This is also supported by respondents from our survey explicitly claiming they look forward to the upcoming sorting system, as one particular respondent put it:

"…I'm looking forward to a sorting system being implemented on Bornholm! It is just embarrassing that an island this size have not yet a well-established waste system. They call it the 'bright green island' but we are so far behind many other municipalities"
Respondent from the survey
(Appendix 13: Survey results)

These answers from respondents looking forward to start sorting can be defined as meanings that are deforming the current practice of getting rid of waste - for many inhabitants it does not make sense to sort waste in the current way anymore. Some of these people are also asking for solutions to be implemented now. In our survey, we see respondents who are tired of waiting and just want to get started. We see these as meanings that could result in what Shove defines as an ex-practice where the connection between meanings, materials and skills is deforming.

6.4.2 The practice of 'sorting food waste'

Since we have identified signs that point toward the current practice of getting rid of waste is deforming, due to changes in meanings and soon materials, when the new sorting system is implemented, we want to investigate and analyse how a future practice of sorting food waste could look like. To be able to analyse a non-existing practice of food waste sorting, we decided to give our test persons the different elements needed to enable them to start sorting food waste (food waste sorting kits). Shove would refer to this as a proto-practice (Pantzar and Shove, 2010), (**figure 48**). Through an analysis of this proto-practice, we would be able to gain relevant knowledge, about how to change the current practice of getting rid of waste and what key elements are needed to get the proto-practice to become an established practice.

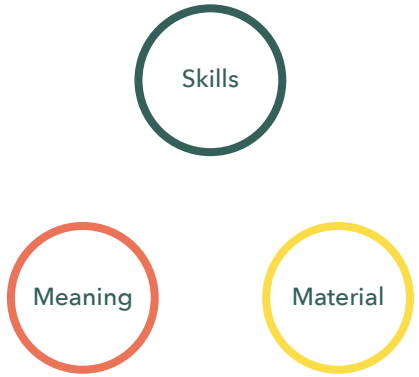


Figure 48: Proto-practice

Since we are dealing with a proto-practice, which is not yet established, we will explain what helps form the practice and what helps to deform the practice. For people on Bornholm, it is a new thing to sort out their food waste. Therefore, we decided to divide the different meanings, competencies and materials into positives (forming the practice) and negatives (deforming the practice). The elements we introduced to create the proto-practice are described in **section 5** where our food waste sorting test with inhabitants in Bo42 is described.

6.4.3 Forming the proto-practice of sorting food waste

Meanings in the proto-practice

"I want to sort food waste"

From the test period with the food waste sorting kits, we saw how one of the main meanings to help form the practice is that people have a certain willingness to sort. This is connected very well with people who think it is embarrassing that Bornholm is not a frontrunner in sorting waste. This willingness to sort is for many of our test persons something that is connected deeply with their own culture of social norms and structures. For example, Brit mentioned that she has been raised by her parents to be very conscious about resources and has sorted waste since her childhood. This willingness is very important to get the proto-practice established as a practice, because no matter what kind of material and knowledge you have, if you are not willing or see the meaning behind doing it, you are not going to sort. The actors must understand the meaning behind doing it before they become willing to.

"Sorting food waste is easy"

Some of the test persons in Bo42 mentioned that it was easy to sort their food waste. This statement was both made by people that already had a willingness to sort, but also people who in the beginning were more sceptical about more sorting. This points towards that people are susceptible to change if they have the possibility and the courage to try the new thing. This was very important because we knew from the current practice, that people perceived sorting as something which should be easy. We identified two main reasons why people thought it was easy to sort food waste in the test. The first one is that because some of these persons already sort paper and cardboard they do not see it as a struggle, to begin to sort food waste. It is described as just another fraction to deal with - it is no big deal. This supports the meaning of being willing to sort because they do not see it as annoying and full of struggle.

The other reason why it has been described as easy is because of the framework we developed for the proto-practice. Said in another way, because we have provided them with a bin, bags, guidelines for what can be sorted as food waste and clear instructions on how and where to dump it, it has been described as straightforward:

"It has been very good, we have just followed your instructions. It was both easy and without any struggle"

(Ejvind and Tove, appendix 12: Second interview)

"If you don't have a dedicated food waste bin in your house, it is hard to get started. It is very important with good guidelines, so you know what to sort"

(Brit, appendix 12: Second interview)

This shows that if you support households with good information, and the materials needed, sorting food waste might not be as hard as you think or fear. Providing these elements further supports the willingness to sort because you feel confident and have guidelines on what to do. However, we need to acknowledge that this way of implementing food waste sorting is not representing how BOFA is

going to do it. As for now, they will not provide bins or bags for sorting food waste inside the household. This might make it less easy for households and may even contribute to a deformation of the new practice before it has even started.

Competencies in the proto-practice

"Food waste what is it"

If we look at the competencies required to fulfil the proto-practice and to get the practice of sorting food waste established, the most evident one is to know what food waste is or what can be sorted as food waste. This skill can be quite hard to acquire because it depends on what kind of treatment the food waste is being sent to. In the case of anaerobic digestion, there are some specific not very intuitive things which can be sorted as food waste. Two examples of these are used paper towels and coffee filters. You will have to be very invested and have made some good research to know that this is correct sorting. This competency can however easily be supported. In the proto-practice, we provided guidelines on what can be sorted or not.

From our second interview with Tove and Ejvind, we got some follow up questions regarding what can be sorted as food waste (NB test persons were presented with the word "biowaste"), besides what our guidelines showed. It was specifically asked if you could sort diapers as food waste - which you cannot. This points to how the perception of what food waste is can be very different and households need support ad clear guidelines to obtain a correct sorting habit. We also saw similar incidents in our survey, where quite a lot of people (23%) thought for example cat litter and packaging with food could be sorted as food waste.

The best bag for food waste and dumping frequency

Another quite important skill is to know what type of bag can be used for sorting food waste, but also what kind of bag is most resistant to for example leakages. In the proto-practice, the bag was proven to be very good and the test persons were very satisfied with its use. From the tender we have learned that there is no specification as to what bag is going to be used which means that this specific bag is not going to be a default bag for the households but they must acquire their own (BOFA, 2022a). This puts a lot of responsibility on each citizen to know what bag is best. They might not choose a bag that is good in the beginning, which can make the learning curve and the establishment of the practice longer and harder. In the case of using a biodegradable bag as the households did use in the test, another key competence regarding the bag is knowing when the bag with food waste should be deposited. In contrast with other waste fractions, food waste decomposes, and it is happening a lot faster than you might expect. This means that people will have to deposit the waste more often, to prevent issues with the bad smell.

The materials in the proto-practice

The importance of the bag

Already before the proto-practice was tested with the inhabitants in Bo42, we identified several concerns with one of the key materials making up the practice, the bag for food waste. Many brought up concerns about how they thought it would smell, be very dirty or leak (**figure 49**). This meant that already before the test they had

little trust in the bag. When asked about this perception it derived from stories from other municipalities where the bags were not functioning well (Naboskab, 2021). However, the test persons did not have this perception after the test period. Meaning that their lack of trust in the bag was proven wrong. This shows how a good trustworthy bag can support and help form the practice of sorting food waste. If the bag is not good, then it might hinder the proto-practice from being established.

Figure 49: Concerns related to the bag for food waste

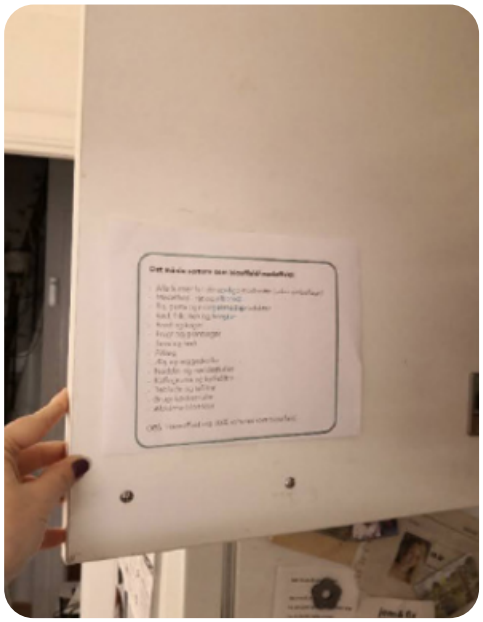
Food waste as materiality in the practice

It might sound obvious but one of the most crucial materials in this practice is food waste. Even though the test persons were used to being confronted with food waste in the current practice, they acquired a new understanding of food waste during the test. Before starting the test almost every test person mentioned proudly that they did not have very much food waste but were surprised during the experiment how much they actually generated. This experience made some of them think more about saving and reducing food waste amounts. Essentially being able to see very clearly how much food waste you generate by actually sorting, might affect you in preventing the amount of food from ending up as waste. However, there is also a possibility that because the households know that the sorted food waste is being used to create electricity via anaerobic digestion and the leftover can be used to create fertilizer, they might not think it is that bad to throw out food. This will create an effect where more food waste is being generated and we do not seek to accommodate that.

The bucket for food waste

Highly connected to the proto-practice is the waste bucket for food waste we provided in the test. We experienced different use cases depending on the test person. For example, Lene had in the beginning placed the bucket next to her kitchen counter but thought it was ugly and thereby ended up placing it under the sink. This talks into the meaning of the current practice by wanting waste to be invisible. Ejvind and Tove ended up not using the bucket because the bags fitted into the already existing extra bin under their sink. For other test persons, the bucket changed positions depending on the activity. For example, when Eva and Olivia were peeling vegetables, they placed it next to the sink so it would be easier to get rid of peels, and when they were done, they would place it under the sink. This highlights that having a mobile bin can be quite important to support the functionality and how easy sorting food waste will be. For the proto-practice, we also added an icon of “food waste” on the bin to illustrate more clearly it was different from the residual waste bin. To have a visual difference was important as some were concerned that when more sorting inevitably would be implemented, more bins

would be needed, and you must be aware of what bin is for the different fractions.



Picture 24: Guidelines inside of a cabinet in a test persons kitchen

Clear guidelines to follow

For the proto-practice, we also added guidelines to what can be sorted as food waste and what could not. This element was proven to be very central in not only helping the test persons with the sorting but also to increase the correct sorting of food waste. The guidelines were taped on refrigerators and on different cabinets to make them visible and easily available when the test persons were in doubt about whether a specific material could be sorted as food waste or as residual (**picture 24**).

"The last picture is your guidance list of what can be sorted as food waste. It is on the inside of my cabinet so I don't lose it and easily can check when in doubt."

(Britt, appendix 11: SMS correnspodence)

One of the reasons why this material is important is because it connects to the skills that people will have to possess to correctly sort food waste which will be elaborated on in the competencies section.

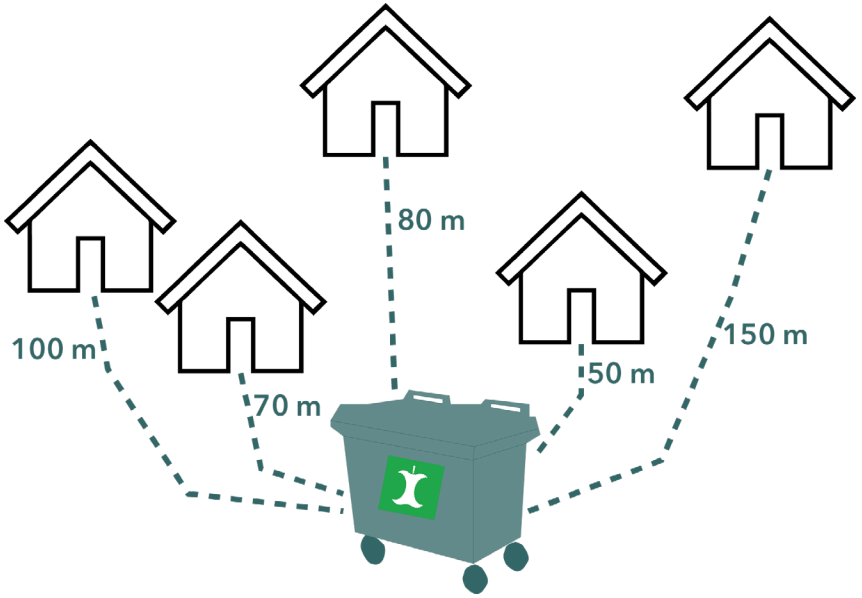


Figure 50: Distances from test households and the collection container for food waste

The collection container for food waste

The last important material in the proto-practice is the collection container where the test persons were to dump their food waste. According to the test persons, the container was easy to find when dumping their food waste. The main topics regarding this element were distance to, and the placement of, the container. It was highlighted by several that the distance to the container was fine, but it should not be further away (**figure 50**). Especially because the placement of the container was not next to the regular residual and paper/cardboard containers due to practical reasons. So, it was a bit annoying for some to first go to the residual container and then continue to the food waste container.

Deforming the proto-practice

We have in the previous section analysed the elements between meanings, materials and competencies which are forming the proto-practice. Meaning the elements that help to get the proto-practice to become established. We can however not neglect elements which might have the effect of deforming the proto-practice and thereby prevent it from getting established. Deforming elements are described in the following.

The distance to the collection container is too long

Even though, for many of our test persons, the distance to the food waste container was not a big issue, we got a lot of comments on the fact that the distance must not be too long. Many mentioned that a longer distance will make them unwilling to sort their food waste. This was e.g., due to issues like the smell, filthy bag, fear of a breaching bag, all something you would not walk too long with. For example, this became such a big issue for one of the test persons, that she often thought about dumping the bag in the container for residual waste, instead of the food waste container to avoid walking the extra distance.

"I think the distance has been too long - it is something I have spoken with my mom and boyfriend about. It is very important the container is close to me. I have several times considered just dumping my food waste in the residual container instead"

(Eva, appendix 12: Second interview)

When the new sorting system is being implemented some people, including Eva, potentially have to walk up to 300 meters to the nearest collection container, according to the criteria in the tender (BOFA, 2022b). This quite long distance can be a critical deforming element to the practice of sorting food waste. We saw similar concerns in our survey where a group of the respondents (22,5%) directly mentions that they are worried about the distance they eventually must walk to get rid of food waste. This means that there might be a balance between willingness to sort food waste and willingness to move a certain distance. This is a key aspect because it does not seem that the decision makers are aware of this balance of willingness. You might think that the sorting is not worth it if you will have to use a lot of time and energy to do it (**appendix 13: Survey results**).

The distance concern can also be traced in the grey literature where articles in the local newspaper mention that especially elderly people or people who have trouble walking, will have a hard time getting rid of waste if they must walk up to 300 meters to the collection container (Gravgaar, 2022; Jørgensen, 2022).

"I am not a policeman"

We noticed something interesting when we talked to the test person about the proto-practice experiment. We could identify guests and visitors as something that could be a direct initiator for a decreasing sorting rate. We have identified two reasons for this. The first one is if the guest does not have a food waste sorting practice themselves and thereby not ask questions like "where is your bin for food waste", but just dump it in the residual waste bin. The second reason

is that some test persons do not want to act as policemen and correct their guests if they sort food waste the wrong way. Some of the test persons mentioned that it is difficult and feels useless to teach guests about sorting when they are just there for one evening. We identified that this in many cases was due to social matters. The test persons did not want to correct their guests, because they are afraid of how this would be perceived. However, some of them also confessed to having picked up food waste from the wrong bin to sort it correctly afterwards.

"I expect a full solution from BOFA"

In the proto-practice, we had supplied each of the households with a full sorting kit, containing both bin, bags and instructions. This was mentioned as very important by the test persons, one even stated, that she saw it as a must, that BOFA was equipping people with bins, bags, containers and the collection system around it. If not, it would affect people's willingness to sort. Especially the possibility that the bag should be available to people for free, was something many liked. One even mentioned that she thought people would be less susceptible to sort correctly if they had to buy one more bag themselves compared to the practice today, where they only have one bag for residual waste. The expectation of a full solution can also be connected to the fact that the new sorting system when implemented is more costly and the inhabitants' waste bills have gone up by 1300 DKK/year (Andersen, 2021; Vestergaard, 2021b). Many inhabitants are furious about this, especially because they in the first place were promised a bill raise by only 55 DKK (Vestergaard, 2021a). So now they also want something for their money, like a full solution with bin, bags and so on. This is currently not going to be the case since the setup is that BOFA will not interfere with how people decide to sort inside their household (Mølle, 2021). This balance between how much BOFA should 'interfere' is interesting because providing inhabitants with material elements like a bin, bags and guidelines have in our study proven to be good supporting factors to get the practice formed. But on the other hand, it should be up to people themselves how they will handle sorting inside their own house. Connected to the set-up in the household, it was stated by Brit that interior design was important. Brit, which by coincidence is a real estate seller, men-

"It does not make sense to sort, it gets burned anyway"

"It will smell if not collected often"

"It will be ugly with all these bins and containers lying around"

"Again, i do not want the containers they are ugly"

"I think it is rubbish and i'm sure I will be very bad at sorting

(Respondents from survey, appendix 13 Survey results)

This highlights that the specific meaning exists across time and influences other practices as well. It leaves a very important question unanswered - how do we get these people to sort food waste? If they are very resistant and do not seek change in what they already do, it will be very hard to get a practice established because a practice has

tioned that people are very much aware of what they want and do not want - and they want very clean lines and not a lot of bins laying around in the kitchen. The waste bins must fit into the specific household, otherwise, it might be seen as ugly, and not be something that people use.

"No need for change - we are fine"

Some of the respondents in our survey reveal themselves to have high resistance against starting to sort food waste. We got a lot of comments and statements from people stating that they think it will be difficult, it will smell, the bins are very ugly, it will not matter from an environmental perspective and so on. The interesting aspect is who do take a stand and are willing to sort their food waste. that none of these respondents sorts their food waste, yet they seem to have a very clear and defined perception of how sorting food waste is going to be. The respondents who highlight these concerns and frustrations all take part in the negative perception of sorting the food waste. It follows a certain resistance to change and from a practice theoretical perspective connects very well with the cultural meaning of "this is how we have always been doing it" in the current practice of getting rid of waste. It describes a specific culture which has been echoed to us when we have visited the different actors on Bornholm and talked to the inhabitants. According to the local people we talked to this meaning goes far beyond sorting food waste. It is a characteristic element to describe a lot of inhabitants on Bornholm - they do not want change and they are good with what they got. to make sense to people - otherwise they will not do it.

When looking into the grey literature exploring how the new waste sorting system has been developed over the last four years it paints a quite negative picture and is even described as a 'waste tragedy' (Gravgaar, 2022). Firstly, the company that won the waste collection tender were not ready to handle waste because of a lack of trucks (Andersen, 2021). Then broke the story of the waste bill raise from 55 DKK to 1300 DKK (Vestergaard, 2021a). Thirdly, many are frustrated and worried about having 3-4 containers at their house which takes up space and looks ugly (Andersen, 2022). Lastly, people say they do not have room to sort in all these different fractions in their household connected to the issue with the interior design. On top of this, it turns out that some streets on Bornholm are too small for the trucks to collect the waste at certain addresses, which means these will have to go to shared collection containers (MiljØ) which can be up to 300 meters away (Hvassum, 2022). All of this has made the sorting system come off bad from the beginning and it might hinder people from wanting to sort because they do not necessarily see the benefit or have faith in the system. We will argue that to get these types of people to sort food waste, they must change their current perception about the change unfolding. If they think it is not environmentally efficient, show them it is. If they think it will smell, show them it will not or provide ideas on how to come around it. They need to be heard and feel like they are being heard. The fear is that if you just implement the new system with little to no interaction or offering help to the households, they will work against the transition, which would be a shame both for the environment and the households who do take a stand and are willing to sort their food waste.

6.4.4 The practice of sorting food waste - important elements for its establishment

We have in this analysis exploited the current practice of getting rid of waste on Bornholm, highlighting the elements which go into the practice, the social norms for making the practice established, but also the landscape structure with new meanings which risk deforming the practice. From this we have through our food waste sorting kits tested a proto-practice of sorting food waste, to investigate what elements help the proto-practice get established and become an embedded practice and what could hinder the proto-practice from being established.

From this, we can sum up the important aspects of getting such a practice established, see **figure 51**.

There is without a doubt great potential and some willingness to sort food waste in the households on Bornholm. But there is a price to this potential and willingness. In our quest to understand what a food waste sorting practice can look like, we stumbled upon resistance to sorting and the future waste management system. It is key to support the households the mentioned deforming meanings can get demolished and the willingness to sort get higher. We will in the following section 7 elaborate on our recommendations for BOFA to support the households to increase the rate of source sorting of food waste on Bornholm.

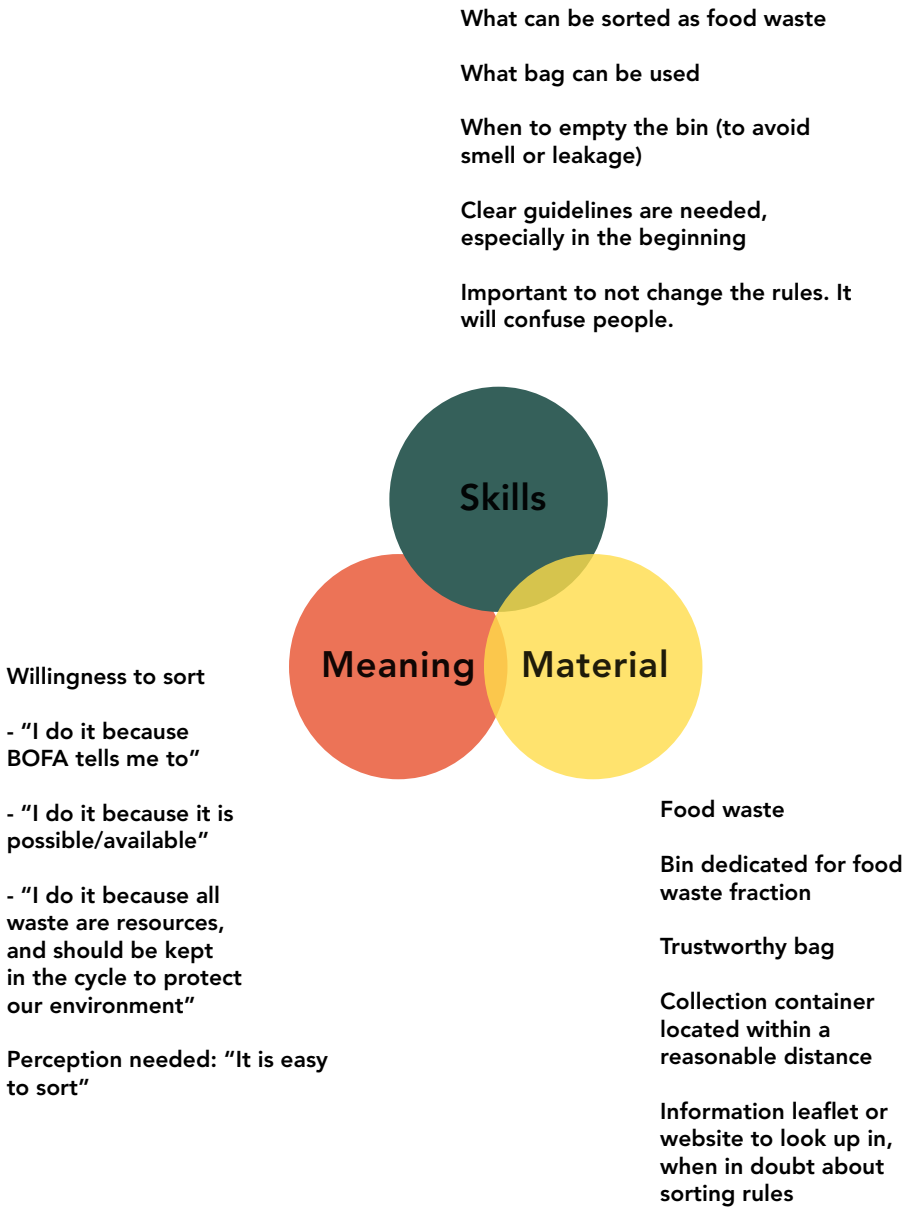


Figure 51: The practice of "sorting food waste"

Recommendations

Section 7

7. Recommendations

In this section, we seek to answer our last sub question:

"What kind of support should decision makers provide to households, to help them increase source sorting of food waste?"

We will from our analysis and research, conduct recommendations targeting the decision makers on what kind of support they can provide to the households to increase the source sorting of food waste. We also believe that many of these recommendations apply to other waste fractions. Firstly, we will describe the different layers of support, which we have identified through a practice theoretical approach, and elaborate on which decision makers these recommendations are especially targeting. Secondly, we will explain the specific ideas and advice we believe are relevant to support the households in sorting. Lastly, we will conclude on these recommendations and explore what further can be done by the decision makers to accommodate the recommendations.

The four levels of support

We have in our practice analysis concluded that a change in the practice from 'getting rid of waste' to 'sorting food waste' is needed. This requires a change in both material, competencies, and meanings to form the new practice. Based on this we understand support as something that can talk into different levels in the practice, from the material level to forming the practice level (**figure 52**). We use this understanding to identify specific ideas and solutions, which decision makers potentially can develop to help the households to obtain an increasing sorting rate and to establish the practice of sorting food waste. It is important to notice that we in this project have decided that the decision maker who make sense to communicate these recommendations to is BOFA. This is due to the fact that BOFA has been our primary contact organisation through this thesis project and is also the decision maker which is connected most directly to the households. Because of this we argue BOFA has the agency to mobilise the households in the new sorting system for food waste as well as for other waste fractions. The recommendations are divided into three different sections that each describes a specific kind of support BOFA should explore to secure an establishment of the new practice. The sections are physical support, information support and involvement support. In the next section we have made an overview of the recommendations.

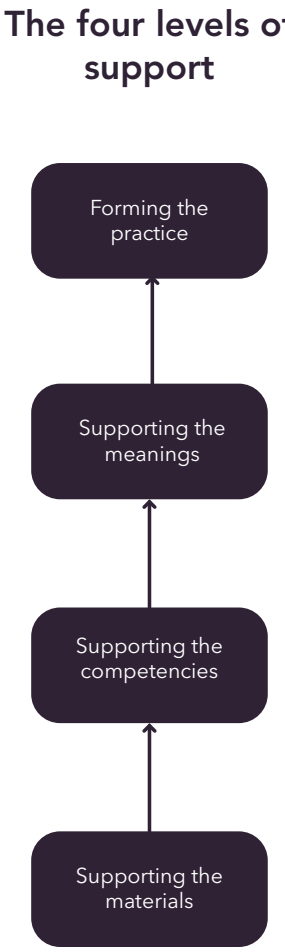


Figure 52: Levels of support

7.1 Recommendations elaborated

Physical support

In the physical support recommendation, we point at the physical objects BOFA can use to support the households in sorting. We have identified four main recommendations in this type of support (**figure 53**).

The **first** physical object refers to an inspirational catalogue which should mainly contain different concrete solutions and ideas to how households can design their sorting system within their home. We recommend that the catalogue both contains solutions for waste systems that are very simple and cheap, but also some that are of higher quality and more aesthetically pleasing. BOFA could do a collaboration with local stores to ensure that the solutions are available and can be bought in a set for a special price or the like. From our analysis in **section 6** we saw some households were expecting a full solution provided by BOFA and some households were very much in doubt how they could fit extra bins into their home. This catalogue is set to accommodate these concerns from households by providing ideas and inspiration on how the households could arrange a new sorting system in their homes. An idea is to recommend the households to install a smaller bin for residual waste to 'nudge' themselves to produce less of this fraction.

The **second** physical support is specifically related to the households that are obliged to dump their waste in a common collection point (MiljØ), because they live in an apartment or a densely populated

Figure 53: Recommendations for BOFA

area with small streets preventing the collection truck to enter. The idea is about supporting the elderly and poorly walking people to dump their waste at the common collection point by providing a service system. This service system could take many forms, an example could be a system where these people can simply place their waste outside their front door and a service worker will pick it up and do the dumping for them. This could also be done by creating a 'community vibe', where the neighbours to these citizens help out and as a thank for their service BOFA give them a small discount on their waste fee. We believe that BOFA should further explore possible support on this issue to allow all types of citizens to be included in the possibility of sorting waste.

The **third** physical support can be connected very much to the second. We recommend that it should be an option to borrow a small trolley wagon from the 'MiljØ', so the households only have to walk one time with all their waste (since it could be up to 300 meters). As mentioned in the analysis citizens are not that willing to move a long distance to this 'MiljØ' and to accommodate this BOFA could ease this up by making trolly wagons available.

The **fourth** physical support which BOFA should consider is making the 'MiljØ' and the collection containers aestheticly pleasing. We believe that changing people's perception of waste as something disgusting and something you want to get rid of, into an important resource that is usefull, is important to accomplish the Zero Waste Bornholm vision. Changing the look of the 'MiljØ' and the collection containers into something that people perceive as beautiful would benefit and play an important role in creating this transition. Furthermore, BOFA should also be very good at having clear icons and text on the containers so both citizens and tourists can sort without any doubt to where waste should go.

Information support

Information support refers to how and what kind of information BOFA should provide to the households in order to obtain an established practice of sorting food waste (**figure 54**).

Firstly, we recommend to provide very clear guidelines to what can be sorted as food waste and what cannot. From our analysis we found that even though we provided guidelines for this, we still got a lot of questions about if something should be sorted as food waste or not. This shows how important these guidelines are. Further to this we recommend that BOFA develops QR-codes which can be placed on the waste containers. When scanning with your phone this takes you to a website where you can see these guidelines - also in other languages than Danish to accommodate the many tourists that arrive to the island every year.

Secondly, we reccomend that BOFA, in the transition period to the new sorting system, establishes a waste hotline where citizens can call or chat if they have any good ideas, doubts or questions about the system. Furthermore, BOFA should update their current Q&A on their webpage to fit the upcoming system better.

Thirdly, we would recommend BOFA to be very transparent with what happens to the waste and the potential environmental benefits of sorting waste, by using LCA results as an example. This way the citizens can get an understanding of how much it matters that they sort. This can potentially also kill some of the myths about sorting, like citizens who think it does not matter from an environmental per-

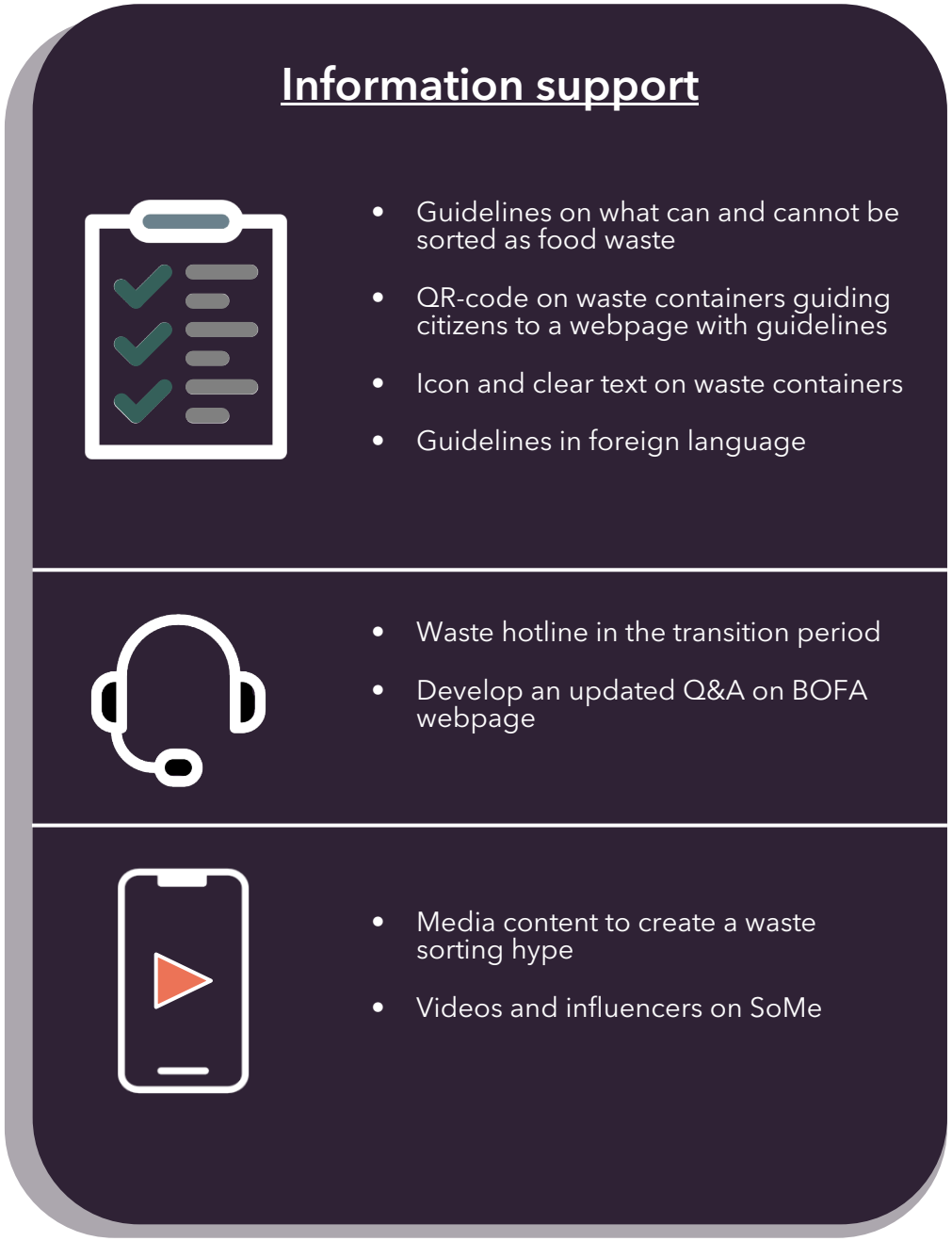


Figure 54: Recommendations for BOFA

spective if the waste is just sailed to Sjælland.

Foruthly, BOFA should consider spreading out information in a fun and interactive manner, by developing media material like videos and such which can be shared on various social media platforms. This way BOFA can make sure that the new sorting system can be perceived as fun and entertaining, and not just something that is exhausting and boring. It is about breaking with the tabu of not talking about waste and getting people excited about the new system.

Involvement support

In the last category of support, we recommend BOFA to focus on involving the households as much as possible to ensure the citizens have a say and feel like they can contribute and be part of this aspiring project (**figure 55**).

The **first** recommendation is regarding something BOFA is already doing. BOFA has a concept they call the 'BOFA Bus' where they drive around to different cities on Bornholm, and talk about the new waste sorting system (Kring, 2022). Here they are in direct dialogue with citizens on for example where these new 'MiljØ' should be placed. We want to highlight that BOFA should expand on this concept, by using the opportunity to e.g. show them different waste solutions households can implement or having some kind of engaging activity where neighbours for example can battle in waste sorting.

Secondly, we recommend to do workshops with specific households of similar types (apartments, houses with garden, town houses etc). This could for example be with households in Bo42 where many of the kitchens are designed the same way. Here BOFA could facilitate a workshop and show how these households could design their waste sorting system and give the opportunities to households with good ideas to share and inspire others.

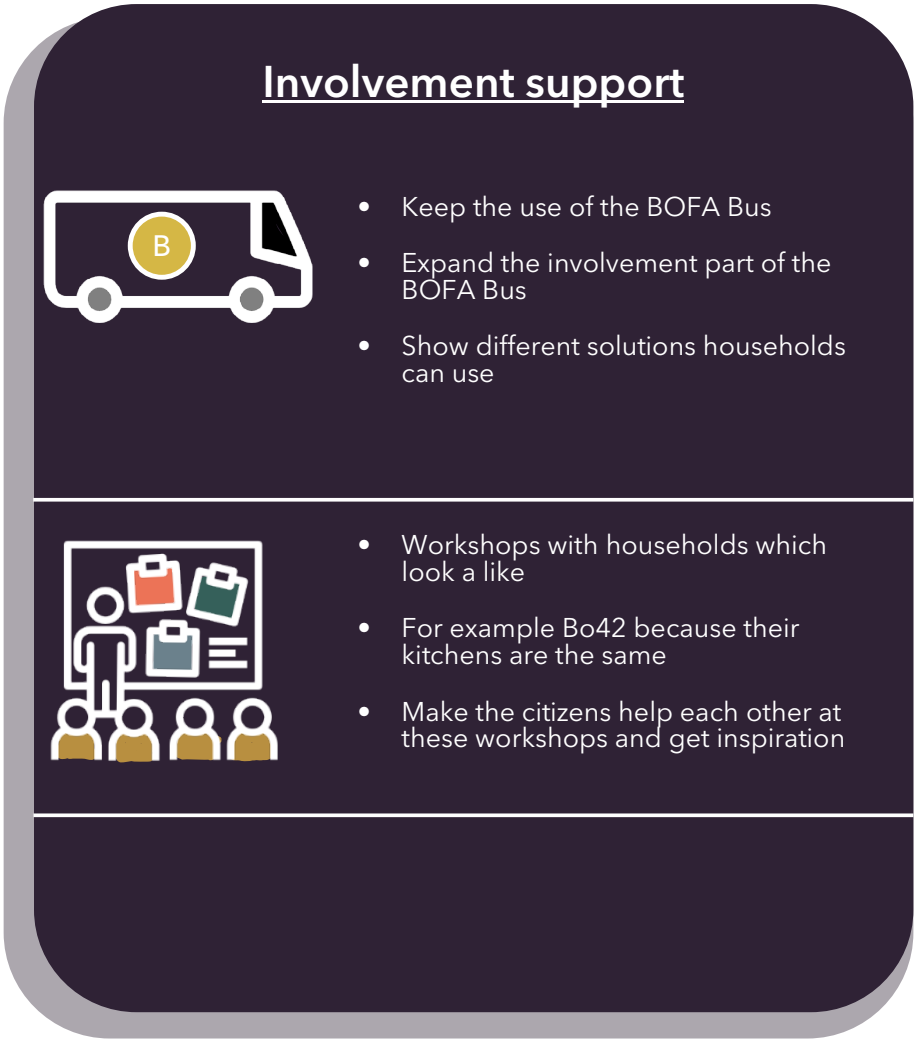


Figure 55: Recommendations for BOFA

Discussion, Contribution and Conclusion

Section 8 + 9 + 10

8. Discussion and limitations

This section will open a discussion on our thesis from the framing of the project to the analysis and recommendations. We will also highlight limitations to the study. We have in our study identified six major discussion and limitation points we will elaborate in the following.

Food waste as our object of analysis

In this thesis we have focused on the source sorting of food waste in households on Bornholm and used that as our main object of analysis. However, we have also put high effort in focusing on the new sorting system that are about to be established on Bornholm, which not only requires food waste but also several other waste fractions (12 in total) to be sorted. One could ask why we have only been focusing on food waste when the new sorting system and thereby the new practice of sorting in the households, will include other fractions as well. We recognise the narrow scope and acknowledge the beneficial value of also looking at other waste fractions as object of analysis and see it as a complete system.

But we will point to the fact that this thesis project was initially part of the project Much Less Food Waste (MLFW), where focus is specifically on food waste. But as the project went by and the time plan of project MLFW was postponed, the project MLFW began to be less relevant if we wanted to stay aligned with our main objective of combining LCA and practice theory. So, the focus of our thesis had to adapt to the already gathered empirical knowledge focusing on food waste in Bo42, since the timeframe did not allow further collection of empirical knowledge in the desired amounts and quality. However, as we mentioned in the practice analysis sorting of food waste exists in a network of practices and therefore, we argue our findings can to some extend be used on a broader scheme and also influence the practice of sorting the other waste fractions. As mentioned in **section 6.2** in the analysis of 'Flows of food waste', food waste is responsible for almost 50% of all residual waste generated on Bornholm (in weight). Therefore, it makes sense to look at this specific fraction and the related practice of sorting.

Representative empirical knowledge

One of the limitations in this study is concerning the involved test persons. All of these were part of the same housing association and almost all of them lived in an apartment. The practice of sorting waste is undeniably affected by the housing type of the person who is performing the practice. For example, it makes a difference if you have a huge house with plenty of space for bins or a small apartment with restricted space. It can be discussed if our findings can be translated and be representative for people living in bigger house with a garden, which many people on Bornholm do. We argue that some of our findings are more general than others and can therefore to some degree be translated to the inhabitants on Bornholm living in houses. Also, since it is backed up by the results from our survey, that was aimed at all types of housings on Bornholm. In this sense we have still managed to gain insights to other types of waste sorting related challenges related to living in a house or with a garden.

Further it can be discussed whether the sample size of 5 test households included in the study is representative to conclude general fin-

dings about households on Bornholm. This is a limitation which we are aware of. In an optimal situation we would have had more participating households from different kinds of housing, different places on the island (in cities and more rural areas) and a bigger diversity in the family size. This would have required more time spend on doing interviews, maintaining the relations to the test persons and logistic issues of getting BOFA to collect the sorted food waste in the test. All in all, we argue that a larger and more diverse sample size would also have meant a process that could have been too elaborate to allow us to go in depth with each household. There are pros and cons of the small sample size. But together with the survey and literature review we argue that most of our findings are representative for most people on Bornholm.

Relevance of the topic

In other municipalities in Denmark sorting of waste, including food waste, is not a new thing and it can be debated if it is worth using resources on a topic that has already been investigated and is successfully implemented in many other municipalities in Denmark. It can be argued that Bornholm is a unique municipality since it is an island and consequently, they have their own specific challenges that other municipalities do not. Literature does also point to the fact that waste management should be treated from case to case and what works in one context might not work in another (Rousta et al., 2017). One of the specific challenges which exist on Bornholm becomes evident during the summer where many tourists from all over the world is visiting the island. Every year it is estimated that 600.000 tourists visit the island while there is only appr. 40.000 local inhabitants (Visit Bornholm, 2022). It is in these periods with many tourists where most activity on the island is happening and also where a lot of waste is generated. The new waste management system will have high influence on these people, and we have not looked at that specific effect.

Further to this, a key limitation to our thesis and contribution is that we do not get to see the waste sorting system being implemented due to the timing for the implementation and the end of our study. This means we do not get to know how our recommendations will affect the sorting rate and we do not get to investigate how easy it will be to get the practice of sorting food waste established in the new sorting system.

Breaking news, launched on May 31th 2022, only few days before handing in this report, tells us that 36 of the 74 municipalities that postponed the establishment of sorting and collection schemes in 2021, are still not reaching the goal of being ready at the end of 2022 (Juul and Greve, 2022). This underlines the present relevance of the topic of supporting citizens to learn how to sort waste.

Combining LCA and Practice theory

Even though the main aim of this thesis has been to understand how decision makers can support the households to sort food waste, another less obvious purpose has been to combine two scientific fields of knowledge to analyse the problem. In the following we will discuss how we have combined LCA and practice theory and present alternative ideas to how they could be combined.

For this thesis we have assessed the effect sorting have on the environmental performance of a waste management system by conducting an LCA. We conclude that having a higher sorting rate provides a better environmental performance of the system. We have then used practice theory to identify what kind of changes is needed to obtain this desired high sorting rate. We could say that we have used the two approaches parallel to each other to improve the decision support needed to help the households reach a higher sorting rate, a sort of combination where the results from the two types of analyses are equally important (illustrated as potential combination A in **figure 56**). The way we have combined the LCA and practice theory is just one way in which these two methods could complement each other.

If the LCA was a product related LCA, in contrast to a waste LCA, the combination could be to integrate practice theory more directly in the methodology of the LCA concerning the life cycle inventory (illustrated as potential combination B in **figure 56**). For example, when collecting data to model the use phase of said product, it could be relevant to understand the practice of using the product to create more precise assumptions about the actual real life use case. The material element of a practice could also be directly coupled to the life cycle inventory of the LCA. For example, to know exactly how much of a product is needed to perform the practice and thereby calculate the potential environmental impact from a certain practice.

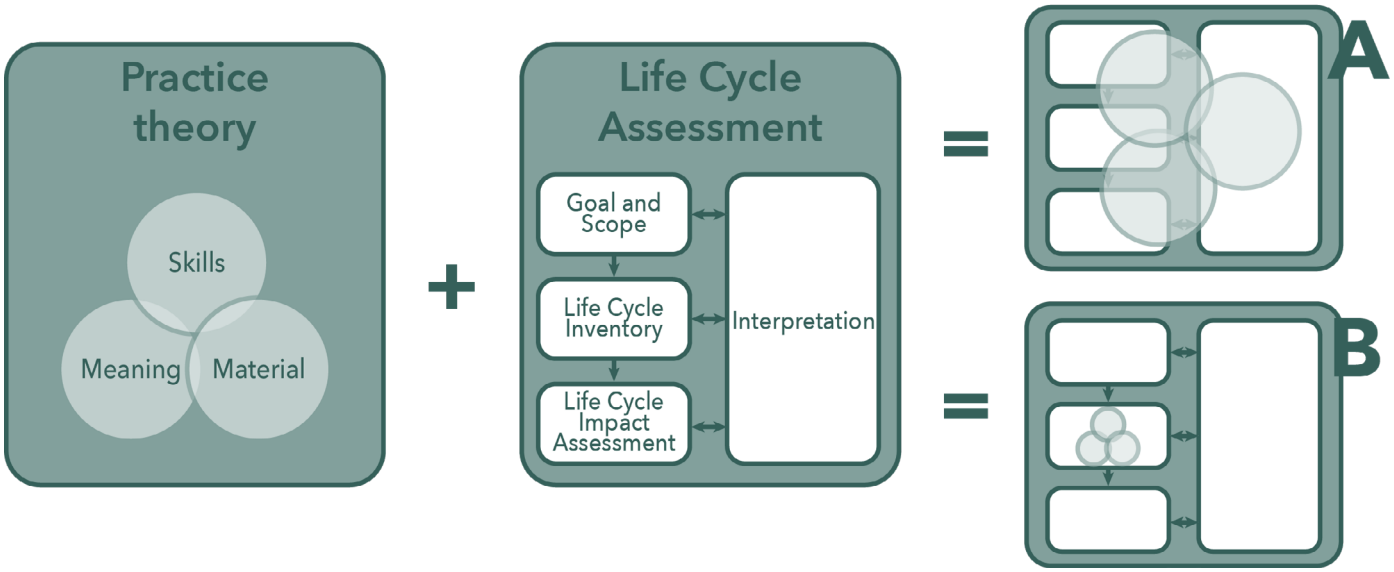


Figure 56: Potential combinations of LCA and practice theory

Further to our way of combining the methods, it can be discussed if 'sorting waste' can even be considered a practice. Some would argue that 'sorting waste' is merely the result of performing other practices – like cooking, cleaning etc. This is debatable because it can be pointed out that in order for something to be a practice it has to make sense for the practitioner. The question is why you sort, is it because you are obliged to do it or because you want to.

Comparing our study to others

In our quest to answer the research question for this thesis, our analysis pointed towards what we have divided into three overarching levels of support. The purpose is that decision makers can use it to support the households to establish the practice of sorting food waste:

1. Physical support
2. Information support
3. Involvement support

Similar recommendations can be found in other literature. For example Rousta et al., in their mini review, identified seven key recommendation which is specifically highlighting **information**, **infrastructure** and **social aspects** to be in focus when designing waste management solutions (Rousta et al., 2017). Since we are recommending focus in these areas as well, we support what has previously been identified as key aspects, but we do also go beyond and for each recommendation level points to specific ideas which are context specific for Bornholm.

Further the study performed by Kattoua et al. investigated the household solid waste recycling practices in developing countries (Kattoua, Al-Khatib and Kontogianni, 2019). As described in the literature review, they identify lack of information and knowledge about the recycling system as barriers, and financial incentive as a driver for motivation. In our case on Bornholm, we can endorse these findings, from our analysis we found information and awareness as main concerns and potential barriers when the waste handling system gets rolled out. We have further learned the waste fee for each households will increase with 1300 DKK which has made a lot of citizens furious about the waste handling before it is even implemented. It highlights how finances can either be a motivator as in the study from Kattoua et al. but also an obstacle if it does not have a positive effect on the households as in the case of Bornholm where the citizens are requested to pay more now, but yet still without the possibility of sorting their waste.

BOFA's agency in the system

Working with the waste management company BOFA made us aware that they are part of a much larger political system and therefore do not have the independent agency to just do whatever they desire. As the project manager explained in an interview a lot of their decisions need to go through the municipal council before BOFA can implement some of their ideas or solutions. This means we expect some of the ideas in our recommendations are not something BOFA can execute immediately, they would need some form of approval from the council. It points to the discussion of how much BOFA can actually do with these recommendations themselves, and which of these

requires to be send further up in the system to the council, with the potential of never being looked at again.

Following this is the lack of focus on the economic perspective of both our recommendations and the thesis overall. One could argue that it is good with the LCA and practice analysis and that the findings are relevant to help the households, but where should the money come from to implement the ideas we recommend. Questions like: Who is going to pay and what role does economics play, are not investigated in this thesis, but could be relevant for further studies or if more time was available.

9. Contribution to the field of Sustainable Design Engineering

When doing a master thesis project within a scientific field, the overall purpose is to contribute with new knowledge to the field. Something that can expand and drive the knowledge in the scientific field, in our case sustainable design engineering (SDE), forward. We argue we are contributing to the field of SDE on three different levels:

- Research field
- Methodology
- Empirical case study

When looking at SDE as a **research field** we are helping to translate knowledge between two fields of knowledge that each build on different ontologies and epistemologies to understand the world. By using our transdisciplinary approach to understand and solve problems, we have sought to combine knowledge from the technical field of life cycle assessments with knowledge from the sociological field of practice theory to frame and analyse the problem of food waste sorting. When working with this socio-technical approach to solve problems, it is not enough to look holistically on the knowledge belonging to the fields. It is necessary to go deeper and look into the methodology from each field.

We have done so by using **methods** from two fields that in each their way is trying to address the issues of creating a more sustainable world. We have done this while also reflecting on other potential ways to combine the ethnographic methods with the environmental

assessment method – for example by using ethnographic methods to improve the life cycle inventory of the LCA. Or to use the results from the LCA to motivate people to change their practices.

We looked at the relationship between practice theory and LCA. And made an example to show how they can support each other. Both fields of knowledge and related methods have their own strengths and weaknesses, and by combining them we see a potential to achieve sustainable solutions that are both environmentally beneficial, while also being relevant for the actors involved, who are to change their current practices to become part of and support the sustainable transition of our society.

Another important contribution this thesis provides is an extensive **empirical case study** on sorting food waste from households on Bornholm. We have provided important insights to the practices and opinions of the households on Bornholm. These insights are highly relevant for decision makers on Bornholm (e.g. BOFA) to learn from if they are to succeed in establishing a successful waste sorting system in the future. We provide them with data that argues that it does matter to increase sorting of food waste, and additionally we provide recommendation on how this can be made possible.

As explained in the literature review, we identified a lack of empirical case studies on exactly the combination of LCA and PT. Doing the empirical case study on Bornholm, where practice theory from the social science is combined with life cycle assessment, is something where we are going from the theoretical level described in literature to the practical level and thereby filling a gap in the literature by providing empirical knowledge to the field of sustainable design engineering.

10. Conclusion

In this master thesis we have pursued to answer the following research question:

How can decision makers support source sorting of food waste in households on Bornholm, to encourage the transition to a circular economy and thereby towards a Zero Waste Bornholm?

To answer this question, we have done an empirical case study on source sorting of food waste on Bornholm. We have explored and identified what changes in the current practice of getting rid of waste are needed to obtain a new practice of sorting food waste. These findings were made into relevant recommendations local decision-makers on Bornholm can use to support the households in sorting food waste.

This was done with the use of practice theory and ethnographic methods to analyse and understand the field of 'food waste sorting'. By providing test households with the needed elements (food waste sorting kits) we, together with them, created a proto-practice of 'food waste sorting' in a context where sorting of food waste was not an established practice. The purpose was to foresee what potential challenges the household will meet when a new sorting system is implemented on the island at the end of 2022. To further support the argument to improve source sorting of food waste we have investigated what impact source sorting of food waste has on the environmental performance of food waste management. This was done in a comparative life cycle assessment, where three scenarios with different levels of source sorted food waste was send to either incineration or anaerobic digestion (AD) to be waste treated.

The results show that the higher amount of food waste that is source sorted and send for biological treatment (AD), the better environmental performance and the closer we are to create a circular economy where resources are kept in the cycle to be used again in some form. Secondly, to enable an establishment of a practice of sorting food waste, changes in both materials, skills and meanings are required. These findings resulted in recommendations for the local waste management company, BOFA (here representing the decision-makers). The recommendations are highlighting three different levels of how they can support the households to increase the source sorting of food waste. The three levels connect to what we have called physical support, being material objects, which support the practice of sorting food waste; Information support which is key to obtain the required knowledge for sorting food waste; Involvement support giving the households the opportunity to be part of the development of the sorting system, make them inspire each other to build the best individual sorting system for their specific needs and to motivate their willingness to sort waste.

While contributing to create a successful food waste sorting system in the context of Bornholm, this thesis also contributes to the field of Sustainable Design Engineering on a more general level. By showing how the combination of LCA and practice theory can be used in practice, we hope to inspire other researchers within the field to

explore the potential of working across disciplines from different scientific fields. With the purpose to create truly sustainable solutions to support the development towards a world based on a circular economy where all “waste” is seen as a resource.

10.1 Further work

For further work we see the potential to look more broadly and include other waste fractions in the object of analysis. Hereby, it could be interesting to see the environmental potential depending on the treatment for multiple waste fractions but also what changes in the practice is required to know how to sort for example plastic.

In addition to our study, it would be very interesting to conduct a new practice analysis once the new sorting system has been implemented on Bornholm, to investigate the proto-practice’s ability to foresee the future, both in terms of challenges but also in terms of successes. This can be used to validate the use case of such an approach. It could also be interesting to expand the practice analysis by also looking at quantifying the amounts of waste our test persons actually did sort when performing the practice. In that way it could be investigated how much different elements help to increase the sorting of food waste.

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