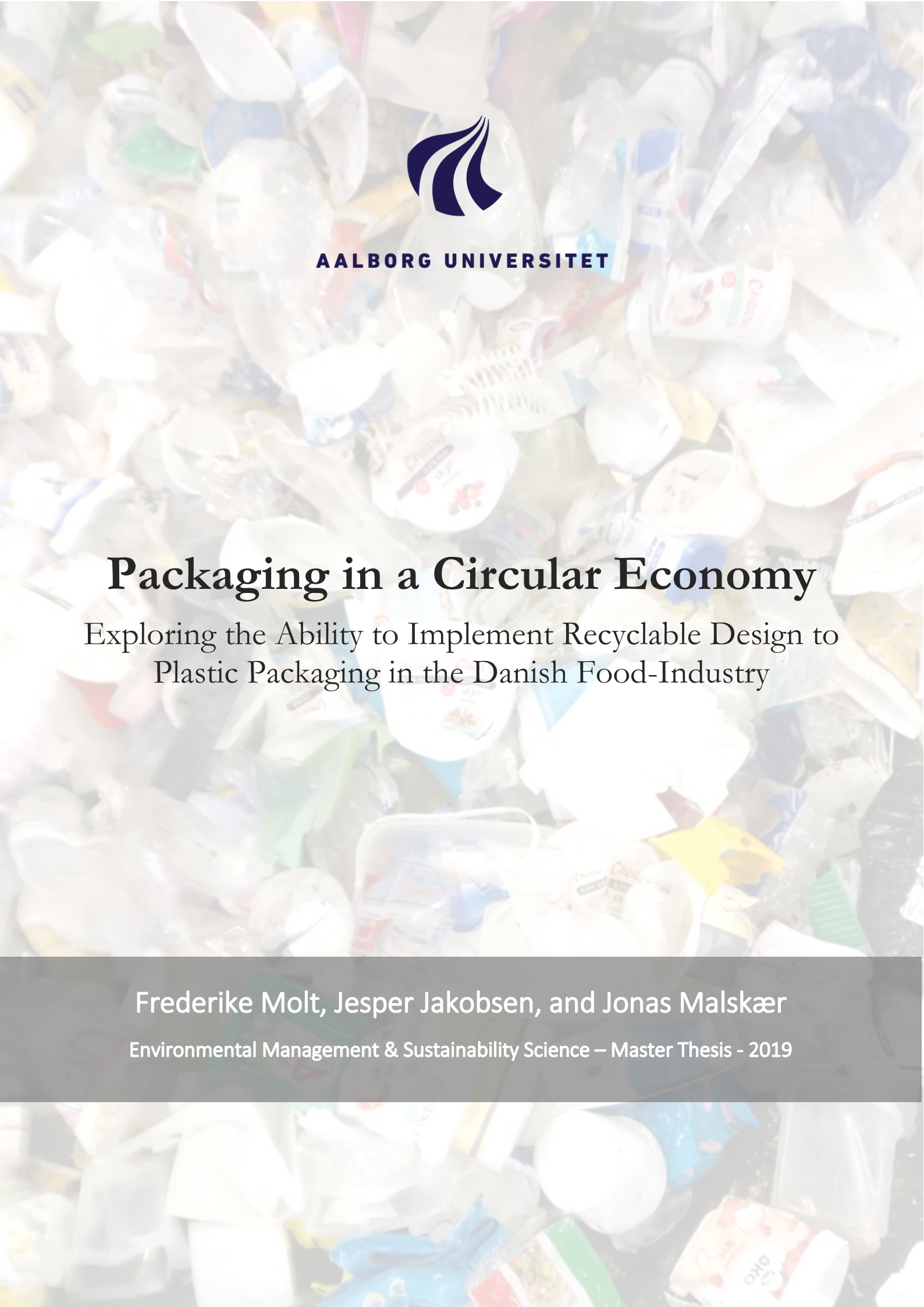

AALBORG UNIVERSITET

Packaging in a Circular Economy

Exploring the Ability to Implement Recyclable Design to Plastic Packaging in the Danish Food-Industry

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Environmental Management & Sustainability Science – Master Thesis - 2019

AALBORG UNIVERSITY
STUDENT REPORT

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Master Thesis

Title:	Packaging in a Circular Economy: *Exploring the Ability to Implement Recyclable Design to Plastic Packaging in the Danish Food-Industry*
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Submission date:	07.06.2019
Pages:	93
Appendix:	1

Abstract

Plastics are a widely used material which have experienced an exponential growth since 1950 where its annual global production was estimated to be 1,5 million tonnes which has grown to 322 million tonnes in 2015. "Poor" handling of plastic and non-recyclable plastic designs causes plastic waste to be a rising issue. In Denmark only 36% of plastic is recycled due to plastic design and waste management not being designed to be compatible.

In this thesis, two Danish design manuals describe recyclable designs, and in relation to these, the stakeholders responsible for the product design in a Danish context are compared. Food packaging is the focus of this thesis, due to its strict requirements, which often constrains the design possibilities. The involved companies were found by back-tracking household waste products. Of these, the food companies and plastic manufacturers who participated in the development of the design manuals were chosen and interviewed about their experiences and ability to implement design for recyclable packaging.

The interviews showed that, in theory, it is possible to implement the outlined design principles, but that external circumstances, created by relations within the network, limit their implementation ability. Network relations were analyzed through a network analysis, including a regulative, business and development network. This resulted in an elaboration on barriers to design possibilities created in the network of plastic packaging. In this process, opportunities for implementation in the network presented itself.

Preface

This thesis has been written as the final project for the Environmental Management and Sustainability Science master program at Aalborg University. The thesis was conducted by Frederike Molt, Jesper Jacobsen, and Jonas Fischer Malskær in the spring of 2019.

The purpose of this thesis was to assess how design principles for better recycling of plastic packaging, from two recently developed design manuals, can be implemented into the packaging design of Danish food companies. For this, the relations affecting the implementations in the surrounding network have been mapped and analyzed for their outcome.
This thesis was coordinated through a research design rooted in qualitative methods and a phenomenological approach, whereas empirical data created the foundation of the research.

We would like to thank all of our interview participants for their time and contribution, without which this project would not have been possible. Additionally, our thanks go to our study secretary Mia Fruergaard Pedersen who always managed to arrange a quiet meeting room for our interviews, even with short notice. Further, we thank Eric Falcon for his advice regarding language and grammar and the corrections he has made to our report. Finally, we would like to thank our supervisors Søren Løkke and Rikke Dorothea Huulgaard for their supervision. The guidance through motivational phrases, knowledge and constructive criticism has been a supportive platform for our research.

Aalborg, June 7 2019

Explanations

Abbreviations

CE Circular Economy

EPR Extended Producer Responsibility

EU European Union

FCPP Forum for circular plastic packaging

PE Polyethylene

PET Polyethylene Terephthalate

PP Polypropylene

PS Polystyrene

PVC Polyvinyl Chloride

SWOT Strength, Weakness, Opportunity, Threat

Nomenclature

Consumer = End-consumer, who buys the product from the retailer

Costumer = Business customer, who buys products within the value chain

Danish Summary

Plastik bliver brugt i mange sammenhænge, og forbruget af plastik er steget siden det kom på markedet. Det er vurderet at der har været produceret 7800 millioner tons virgin plast før 2015. I den 65-årige periode hvor plastik har været produceret industrielt er 50% produceret siden årtusind skifte. Plastik er kendt for dets barriere og resistens over for kemikalier, som gør det holdbart. Når dette materiale ikke bliver understøttet af en passende affaldshåndtering, samt et design som gør det genbrugeligt, ophober det sig i naturen for de fattigere lande, og for de rigere lande som Danmark resultere det i en ringe genbrug på 32%, men med højere potentiale.

To design manualer for genbrugelig plastik, som drager erfaring fra den danske industri, har dannet grundlag for design principper for denne rapport, da de skulle kunne forhøje genbrug af plastik i Danmark. Fødevare emballage er fokusset af denne rapport, da dette har de højeste produktionskrav, og derfor efter sigende ville være sværest at designe til genbrug. Firmaerne, inkluderet i rapporten, blev fundet gennem to metoder, **1)** ved at følge affaldsprodukter fra affaldshåndteringen til produktionen ansvarlig for designet eller **2)** ved deres deltagelse i dannelsen af en af disse design manualer. Disse virksomheder blev interviewet for deres muligheder for at implementere disse design principper, hvilket belyste at eksterne omstændigheder, fundet i deres virksomhedsnetværk og skabt gennem relationer mellem aktørerne, begrænser implementeringensmuligheder. En netværksanalyse blev brugt til at undersøge, og sammenfatte disse relationer med hinanden for at undersøge, hvordan de begrænser en implementering af bedre genanvendelsedesigns for plastikemballage.

Denne rapports resultater viser først og fremmest at disse designprincipper er teoretisk mulige at implementere. Netværksanalysen viser blandt andet at barriererne forstærker hinanden. Kommunikation fra emballage producenter og designer til affaldshåndtering, er en vigtig faktor. Den manglende kommunikation resulterer i dårligt fit mellem plastik design og affaldshåndtering. Strømlining af designprincipper på et nationalt plan (f.eks. national designmanual) ville hjælpe fødevareproducenterne i valg af design. Magtbalancerne, investeret i de forskellige relationer, kan hjælpe eller problematisere designets forbedring. En større barriere i netværket ligger i at infrastrukturen i Danmark ikke er ensartet, og at politikerne ikke ved hvordan de skal planlægge politikken om "Udvidet Producent Ansvar", hvilket skal implementeres i slutningen af 2024. I undersøgelsen af netværket viste det sig at der er fundamentale potentialer i disse relationer, hvilket ville kunne udnyttes til fordel for højere genbrug af plastik.

Contents

Introduction 1

This project started based on an initial interest in the production and consumption of plastic products. Over the last decades, plastic materials have replaced many conventional materials in a variety of different products where their material properties are often advantageous over the alternatives. Nowadays, a world without plastic has become unthinkable, they are used in cars, buildings, wind turbines, consumer products, and packaging, many of which are single-use items. However, plastics are also related to several environmental issues and especially the latter is seen to be problematic (UNEP, 2018).

Stories about plastics accumulating in oceans and on beaches have led to widespread discussion about the effects of human production and consumption. While plastics can have an impact in several areas, the environmental effects of plastic waste are most prominent. Here, single-use items play a crucial role, as they generally get discarded within minutes after their use. It is estimated that these items make up around 50% of the global plastic waste (UNEP, 2018). Many regions, however, lack appropriate waste management systems to collect and recover the material and even in regions where there are effective systems, most of the inherent material value is lost to the economy (European Commission, 2018; UNEP, 2018).

In order to find new solutions for the problems related to plastics, the European Union (EU) developed "A European Strategy for Plastics in a Circular Economy" (European Commission, 2018). This strategy outlines a vision for a circular plastic economy, which "respects the needs of reuse, repair and recycling" (European Commission, 2018, p.5). One focus area is packaging, the use of which should be reduced, and when it is used, it should be effectively recycled. However, initial research on the recycling rates for Denmark showed that only 36% of plastic packaging is recycled while the rest is incinerated (Eurostat, 2019).

By investigating plastic use cases at Aarhus University hospital prior to the project, it was found that the majority of their plastic was unrecyclable due to decisions made at the design and production level. These findings led to a shift of the project towards the investigation of design principles for plastic packaging, and the initial research question:

What is the current problem with plastic packaging and how is the design related to that?

Problem Analysis 2

To get a deeper understanding of the previously introduced problem, it is initially investigated in relation to the main properties of plastic as a material and the related advantages and disadvantages. Afterwards, the focus is put on plastic packaging, and its increasing consumption and related issues, are assessed. Additionally, the value chain is analyzed and the different actors are introduced.

The second half focuses on recent developments and possible solutions from politics and industry. Here, different legislation, strategies, and initiatives related to plastics in the EU and Denmark are introduced. A recent development in this area was the development of two design manuals for packaging products, which are compared and analyzed in the end of the chapter.

2.1 Plastic - An Introduction

The term 'plastic' derives from the Greek word 'plastikos' which means that something is moldable and can be shaped into a certain form. Nowadays, however, 'plastic' commonly refers to a large group of materials, made out of polymers, with a variety of different characteristics, properties, and applications (PlasticsEurope, 2018).

Plastics are a relatively new material. Though some plastic polymers had already been discovered in the 19th century, the rise of plastics actually started in the first half of the 20th century with the development of new polymer types (Andrady and Neal, 2009), which replaced natural materials in a variety of different application areas (Andrady, 2015). Since the 1950s, plastics have experienced an exponential growth in annual production from 2 Mt in 1950 to 381 Mt in 2015 (Geyer et al., 2017, table S1.), as can be seen in Figure 2.1. Geyer et al. (2017) have found that the total amount of plastic produced between 1950 and 2015, amounts to 7,8 billion tonnes, with more than half of this amount having been produced since the year 2000. Considering the ever rising demand for plastics, it can be assumed that the total amount of plastic ever produced might now be around 9 billion tonnes.

Plastic materials are split into two categories: *Thermosets* and *Thermoplastics*. Each of these categories consist of a large family of different plastics (PlasticsEurope, 2018). Additionally, it is also possible to adjust a plastics' polymer composition with additives to achieve specific material properties (PlasticsEurope, 2019).

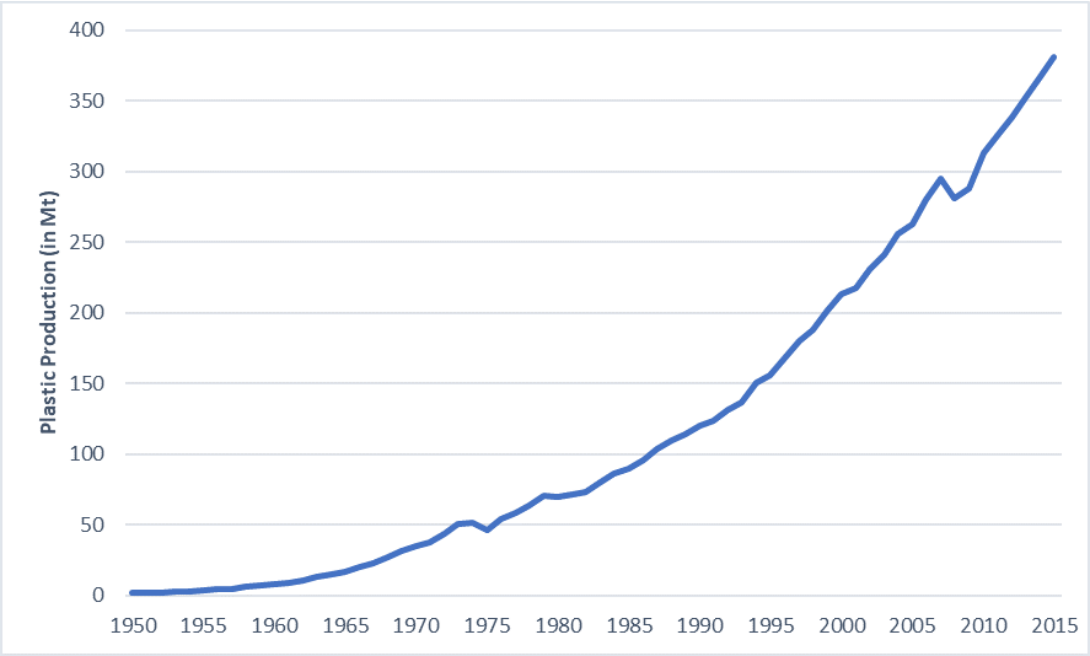

Figure 2.1: Global plastics production (in million metric tons) from 1950 to 2015 based on Geyer et al. (2017, table S1.)

Thermosets undergo a chemical change during the production, that cross-links the polymer chains together (Hahladakis and Iacovidou, 2018). This reaction can be caused by heat, a chemical reaction of multiple components, or a mix with non-plastic materials. The result of this is an irreversible structure change of the material, making thermosets hard to recycle (PlasticsEurope, 2018).

Thermoplastics do not undergo this chemical change, as their polymer chains are held together by the chemical Van der Waals forces (Hahladakis and Iacovidou, 2018). Thus, their polymers stay reversible and can be remelted and reshaped multiple times, some more than others, but all of them more than thermosets (PlasticsEurope, 2018). The majority of the global plastic production is made up of only five thermoplastic classes, namely: PE, PET, PP, PS and PVC (Andrady, 2015). The individual polymer classes are shown in Table 2.1, with PE being split into a high and low density fraction. In order to distinguish between the different polymer classes, the most common types have been assigned a recycling number or SPI code, that is imprinted on the product to provide information about the plastic material.

2.1.1 Advantages of Plastics

The rapid growth of plastic materials can be explained with the typical material properties and the associated advantages making plastics suitable for many applications. Plastic materials are of a relatively low density, resulting in light weight products while providing a relatively high material strength. Plastics are also known for their good insulating properties and durability (PlasticsEurope, 2019). Due to these properties, plastics can compete with traditional materials and even replace them in some of their applications.

Recycling number	Abbreviation	Polymer Name	Demand in Europe in %	Application
1	PET	Polyethylene Terephthalate	7,4	Bottles for drinks, cleaning detergents etc.
2	HDPE	High-Density Polyethylene	12,3	Shampoo bottles, toys, houseware
3	PVC	Polyvinyl Chloride	10,2	Pipes, window frames, garden furniture
4	LDPE	Low-Density Polyethylene	17,5	Plastic bags, wrapping film, trays and containers
5	PP	Polypropylene	19,3	Bottle caps, microwave containers, car parts
6	PS	Polystyrene	6,6	Plastic cups, packaging peanuts and styrofoam
7	Others	Miscellaneous Plastics	26,7	Multilayer films, medical implant, optical fibers

Table 2.1: Plastic polymer classification, distribution, and application based on PlasticsEurope (2018) and Rahimi and García (2017)

According to Andrady (2015) there are at least three aspects for which plastics are advantageous: 1) energy savings and carbon emission reductions, 2) material conservation, and 3) consumer health and safety.

In the transportation and building sector plastics can play a considerable role for energy savings (Andrady, 2015). In the transportation sector plastics can replace other materials, in order to reduce the weight of a vehicle. Due to a relation between weight and fuel efficiency, this can have a significant impact on the fuel consumption and carbon emissions of a vehicle. In the building sector the thermal insulation properties are used to reduce heat loss and increase the energy efficiency through insulation foams, pipes or window frames (Andrady, 2015).

Plastics are also widely used in the health and food sector. Especially valuable are the barrier properties provided by plastic materials. Plastic packaging can protect its content from chemical or microbial contamination (Andrady, 2015). Due to this, sterile medical equipment can be conserved and food contents can be preserved and stay fresh for longer, which also has an impact on our food waste.

2.1.2 Disadvantages of Plastics

The above mentioned properties, which make plastic an excellent material for a variety of applications, also come with some drawbacks. The production, use and disposal of plastic materials are related to both human health as well as environmental issues.

Though plastic polymers are generally not hazardous to humans, there are concerns of them having a negative impact on human health (Lithner et al., 2011). Chemicals and

additives that have been added during the production, could however cause problems. If the product is used in close contact to either food or the human body, these chemicals could leach out and enter the human body(Andrady, 2015; Lithner et al., 2011). Another possible threat with yet unknown effects, are plastic particles in the food chain (Harvey and Watts, 2018), which can occur if marine animals ingest plastics (Lithner et al., 2011) and get later eaten by humans with micro plastic particles inside them.

Another problem is the impact of plastic through the natural resources needed for its production. Though plastics can be made out of renewable material such as corn starch, the majority of plastics are made out of fossil fuels. Throughout its life time, plastic materials consume a large amount of energy during production or recycling and release greenhouse gasses (Andrady and Neal, 2009).

Though plastic is a very resilient and durable material, it does break down over time and turn into smaller and smaller pieces. However, this process can take decades or centuries and highly depends on the circumstances of the environment (Andrady, 2015). This means that plastic materials accumulate in the environment if littered or put into a landfill (Geyer et al., 2017). It is estimated that all plastic ever produced and not incinerated is still present in the environment today (Andrady, 2015).

2.2 Plastic Packaging - A rising Problem

Plastics are used in many different application sectors, such as building and construction, transportation, packaging, consumer products, etc. In 2017 the largest portion of the EU's plastic demand came from the packaging sector where 39,7% of the plastic production was used, followed by the building and construction sector and the automotive sector with 19,8% and 10,1% of the market respectively (PlasticsEurope, 2018). These numbers show that the packaging sector alone consumes far more plastic than the next two largest sectors. Data on the production and use of plastics from 1950 to 2015 reveals, that the packaging sector has, for decades, consumed a similarly significant share of the annual plastic production, as can be seen in Figure 2.2.

Packaging refers to products "used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to [...] the consumer" (European Parliament and Council of the European Union, 1994, Article 3). Once the goods are further processed, used, or consumed, the packaging normally becomes waste. Geyer et al. (2017) estimated that packaging products have a lifetime of less than one year. The high packaging demand in connection with the short lifetime means that packaging products are faster discarded than other products. In 2017, packaging products accounted for ca. 60% of the post-consumer plastic waste in the EU (PlasticsEurope, 2018; European Commission, 2018). The high amount of packaging waste requires an appropriate waste management system to prevent the plastic from entering and damaging the environment (Hahladakis and Iacovidou, 2018). Ideally

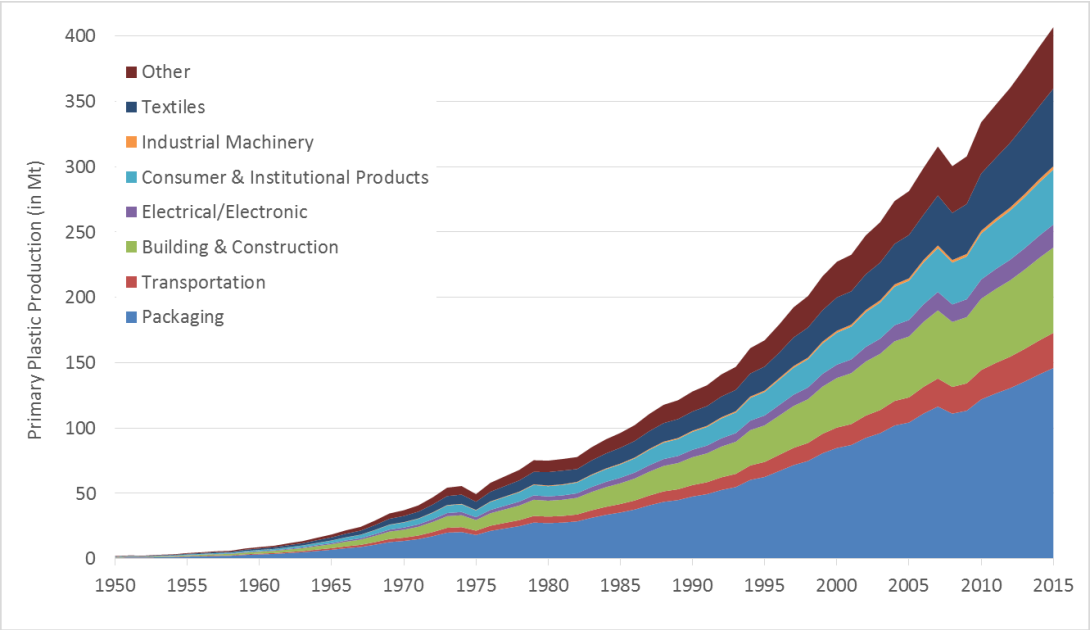

Figure 2.2: Plastic production by sector from 1950 to 2015 (Geyer et al., 2017, fig.S1)

the waste would be collected and recycled to recover the material and reuse it for the production of new plastic products.

2.2.1 Challenges in maintaining the Material Quality of Plastic Packaging

Plastic packaging is normally made out of one of the plastic polymers shown in Table 2.1 above. The majority of plastic packaging however, is made out of only three different polymer types, namely PET, PE and PP (PlasticsEurope, 2018). Products made out of these plastic types are theoretically more recyclable as they can be melted and shaped into a new product (Hahladakis and Iacovidou, 2018). Despite this, the recycling rates for packaging waste [1] remain low, as can be seen in Figure 2.3, reaching an average of 40,8% in Europe (PlasticsEurope, 2018).

The low recycling rates are often related to material quality aspects. In order to understand how the material quality is affected, it is important to look at different stages of the products lifetime. The rather short lifetime of plastic packaging means that degradation due to environmental conditions barely impacts the material quality (Hahladakis and Iacovidou, 2018), however, there are other aspects that affect the recycability of plastic packaging and determine whether the plastic can be reused for new production. These aspects are related to the *product design*, the *collection and sorting*, the *recycling technique*, and the *demand for recycled plastic*.

[1] From household, industrial and commercial packaging

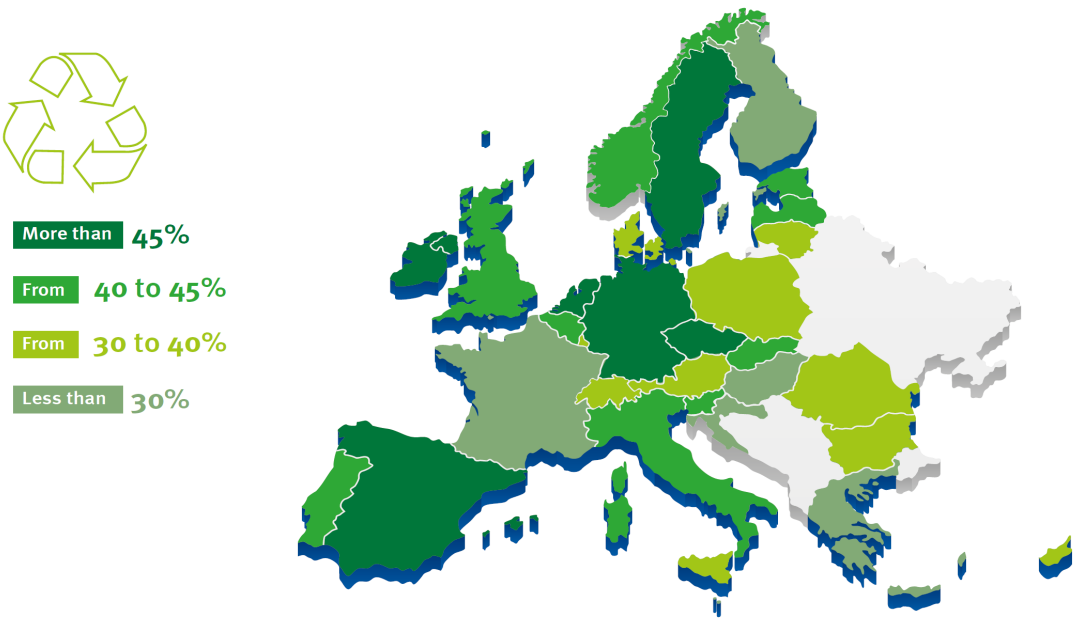

Figure 2.3: Plastic packaging recycling rates of Europe (PlasticsEurope, 2018)

Product Design

While almost all packaging products are made out of thermoplastics (PlasticsEurope, 2018), that alone is not enough to ensure their recyclability. The different polymer types provide different properties and provide different functions. Thus each packaging item can be designed with a customized plastic composition, which fits the needed function and marketing of the product. However, this can lead to a huge diversity on the market and later in the waste material, which poses a challenge for the recycling process, and can negatively affect the quality of the recycled material (European Commission, 2018). Especially problematic for the recycling process are colors and prints, additives and chemicals, or multilayered materials (Ragaert et al., 2017). As the first step in the life cycle of a packaging product, the material and design choices can have a huge influence on the retaining material quality at the end of its life.

Collection and Sorting

Another major factor for the material quality degradation can be found in the handling during the recycling process itself. In order to achieve high-quality recycling, it is necessary to separately collect and sort the waste in the different polymer types used in the packaging products. Especially the sorting is important to ensure clean recycling streams and avoid any type of contamination (Ragaert et al., 2017). The different polymer types are often incompatible and already small amounts can negatively affect the properties of the polymer mixture (Hahladakis and Iacovidou, 2018). While the waste management infrastructure plays an important role, it is also important to educate the consumers about separate collection and correct sorting of plastic waste. One example of high-quality separate collection of plastic is PET. The bottle deposit system incentivizes consumers to

collect and return PET bottles in a separate waste stream (European Commission, 2018; Andrady, 2015).

Recycling Techniques

In order to understand how plastic packaging can be recycled and how the products material quality affects this process, it is important to look at the currently available recycling techniques. In the waste treatment of plastics, there are generally speaking four different recycling techniques, referred to as primary, secondary, tertiary and quaternary recycling.

Primary recycling is a mechanical closed loop recycling for clean and uncontaminated single polymer plastics (Singh et al., 2017). Primary recycling often occurs in production factories with excess materials or in separately collected waste fractions such as PET bottles collected through a return system (Ignatyev et al., 2014; Rahimi and García, 2017). The recycled material is of high quality and can be mixed with virgin plastic or used as a secondary material (Kumar et al., 2011).

Secondary recycling also refers to a mechanical recycling process, however, the used waste material is often post-consumer plastic packaging, which first has to be sorted according to the different polymer types to get cleaner waste fractions for the recycling. The recycled material is of a lower quality than in primary recycling, as a result of contamination with other materials, moisture, or acids (Ignatyev et al., 2014). Due to the loss of quality, the material is normally not reused for the same purpose as the original product (Singh et al., 2017; Rahimi and García, 2017).

Tertiary recycling is a chemical recycling method that recovers the petrochemical molecules through a depolymerization process (Singh et al., 2017; Ignatyev et al., 2014). This recycling process turns plastic, which cannot be recycled through the previous means, into feedstock, oil products, combustible gas, and heavy residues (Arvanitoyannis and Bosnea, 2001).

The last technique is *quaternary recycling*, which refers to incineration and energy recovery. The material is burned and the released energy can be recovered as electricity or heat. Incineration is often used for mixed, contaminated or otherwise low-quality plastics, that have no other recycling options (Ignatyev et al., 2014; Kumar et al., 2011).

The quality losses throughout the plastics life cycle mean that the material cannot be recycled indefinitely (Andrady, 2015), as each cycle will further reduce the material quality. In order to keep up the quality, virgin material has to be added. Thus, recycling can slow the production of virgin material for a while (Geyer et al., 2017) but it does not replace it entirely due to the lower quality of the recycled material.

Demand for Recycled Plastic

As of today, the demand for recycled plastic is relatively low and is often only used in low-value applications (European Commission, 2018). Plastic recycling is often done in small and regional plants in rather small quantities and with different standards. Thus, producers are concerned about the quality and stable supply and fear that recycled plastic cannot fulfill their product requirements (European Commission, 2018). Additionally, the lack of information about the presence of chemicals and additives in recycled plastic can lead to unknown quality issues, which can pose a problem for production, such as varying viscosities. For example, blow-molding requires a higher material viscosity than injection-molding (Hahladakis and Iacovidou, 2018; Færch Plast, 2019).

2.2.2 Plastic Packaging Waste in Denmark

The Danish waste management system has traditionally had a strong focus on incineration. Especially in the case of post-consumer waste, which is often a mixed waste stream, a very large portion is sent for incineration (The Danish Government, 2013; Eurostat, 2019). In recent years, Denmark has started to reorganized its waste management system and has increased the recycling rates of packaging materials, but nevertheless, the recycling rate of plastic packaging remains behind the rates of other materials (Eurostat, 2019).

In 2016, Denmark produced ca. 215 tonnes of plastic packaging waste, of which 36% had been recycled (Eurostat, 2019). These numbers represent the total amount of generated plastic packaging from both households and industry. It can be assumed that the actual recycled post-consumer plastic waste is below the 36% and thus the large majority of this waste fraction still gets incinerated.

Recycability of Danish Post-Consumer Plastic Waste - Case Studies

A sample analysis of post-consumer plastic waste conducted in December 2017 by Edward Vingwe (2019) revealed that two of the aforementioned aspects are especially challenging, being the product design, and the collection and sorting of the post-consumer waste. For this purpose, 75 post-consumer plastic packaging product samples had been collected at the waste management facility I/S Reno Nord, which collects and sorts post-consumer waste from Aalborg Municipality. In order to determine their recyclability, the packaging was disassembled and the surface of each component was analyzed for its polymer type.

The results, as seen in Figure 2.4, showed that in ca. 50% of the cases the product was made out of homogeneous polymers, which can be sorted and recycled. However, the other half of the sample showed differences in the material composition.
In ca. 20% of the samples, the packaging was made up of two or more components that used different polymer types. Though these products could be recycled if separated into their individual components, they cause an issue for Reno Nord (Kirkegaard, 2019). The

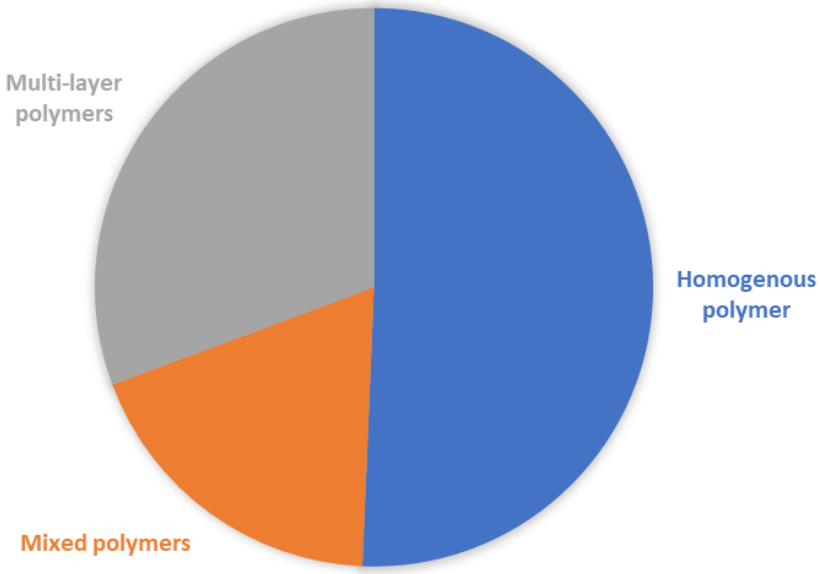

Figure 2.4: Polymer composition of post-consumer sample products based on Vingwe (2019)

products stay assembled during the sorting process and thus only one of the materials gets detected and the product is sorted accordingly. The problem is then, that the hidden materials do not belong into the same fraction and contaminate it.
The remaining 30% of the samples were made out of multiple layers of different polymers. The problem for the waste management facility is the same as in the previous case, however in this case it is impossible to separate the individual layers. The machine detects only one polymer type and sorts the product accordingly, but due to the presence of other polymer types, the waste stream gets contaminated and the quality of the recycled material gets reduced.

A similar study with the aim of analyzing the composition of Danish source separated plastic waste was conducted around the same time in Copenhagen municipality by Eriksen and Astrup (2019). Eriksen and Astrup (2019) used a sample of 460kg to analyze waste material in terms of polymer type, product type, design and separability, and color. The majority of the sample were food as well as non-food packaging products with more than 95% consisting of PET, PE and PP (Eriksen and Astrup, 2019). Further analysis of the sub-components of the packaging showed that approximately 50% of the analyzed products were made out of a single plastic polymer. The other half however, contained products that showed multiple polymer types, causing problems during sorting and recycling.

As can be seen in these analyses, product design and (correct) sorting are closely related. In order to improve the recycling rates, both the design of products as well as collection and sorting has to improve. The results by Eriksen and Astrup (2019) show high improvement potentials for plastic recycling with state-of-the-art recycling and initiatives to increase

the quality of recycling. Further, a case study on the circular economy potential of Denmark, found that Denmark could increase its recycling rate of plastic packaging to 75% by 2035, if adequate measures are taken in regards to design, collection and sorting (Ellen MacArthur Foundation, 2015a).

2.3 Actors related to Plastic Packaging

The problems outlined in the previous sections showed that plastic packaging is impacted by multiple actors throughout its entire life-cycle. In order to get a better understanding about the different actors and how they impact the packaging material, Figure 2.5 provides general overview about the different types of actors.

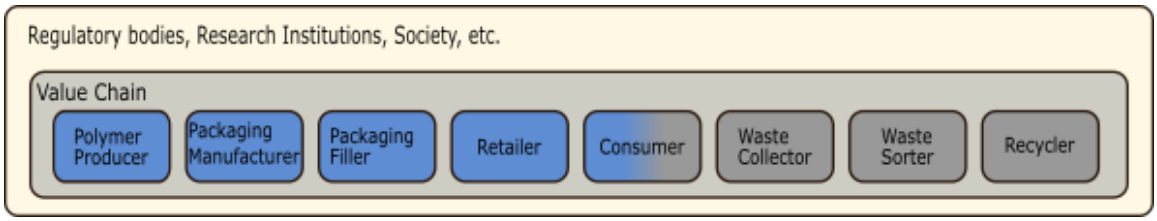

Figure 2.5: Actors related to the plastic packaging value chain. Blue actors are related to the production chain and grey actors are related to the waste chain, the consumer is the connection between these two chains where the product changes from the one side to the other

Each plastic item starts at the **polymer producers** who use raw materials and create the different polymer types described in Table 2.1 above. The producer has an influence on later plastic recycling and contamination through the use of chemicals and additives. However, the use of additives often depends on requests from other actors. The plastic is made into granulates or foils which are then used by the **packaging manufacturer** to produce the packaging products such as trays or foils. The manufacturers may request special plastic compositions to create a unique product portfolio or respond to a specific customer request. Another actor in the packaging value chain is the **packaging filler**. The filler takes the packaging products and fills them with his products. Fillers may have a varying amount of influence on a packaging design depending on their influence on the value chain. They can request customized design solutions from various suppliers which they then assemble when filling the packaging with their products (Færch Plast, 2019). However, customized designs are generally more work for the converters, thus they depend on the terms and conditions between the converters and the fillers.

The products are sold by a **retailer** to the **consumer**. Both can express desires about ideal packaging and ask the production chain to reply to that (Hanegal, 2019). The retailers can formulate requirements and wishes about the packaging design that should be sold at their stores, especially for their home brands (COOP, 2019a), and the consumers have the possibility to influence packaging design through their purchasing choices. As the end-consumer, they are also the intersection between the production chain and the waste chain. Once the packaging has fulfilled its service, it is generally discarded into the

waste bin. Here the consumer can have an impact on the recyclability by disassembling the packaging and sorting it according to the material.

The waste is then entering a waste management process which contains a **collector**, a **sorter** and a **recycler**. The waste fractions which are collected depend on the locally installed infrastructure and are often organized by the municipality. The collected waste is delivered to a sorting facility who sorts it into even cleaner fractions for recycling. The sorter depends on input collected from the consumer but has little to no influence on the packaging they are using and how they discard it (Kirkegaard, 2019). Finally, the packaging material is recycled into new granulates or flakes that can be used again by the converter in the production chain for new packaging products (Færch Plast, 2019).

While all of those actors were part of the plastic value chain, there are also some external actors who have an influence on the design and recycling of plastic packaging. External actors are **national governments** as well as the **EU** who put up regulations both for plastic production as well as for plastic waste management and thus set the boundaries for the industry. Other external actors can be **NGOs**, the **society** and the **media** who engage in the discourse about plastic packaging. This influences the consumers and can put an external pressure on the production chain.

2.4 Circular Economy Strategies for Plastic Packaging

The rising demand for plastics and the associated increase in plastic waste puts more and more pressure on the environment, both through resource consumption as well as emissions and accumulating waste. In order to reduce the pressure on the environment, the already existing plastic material needs to be recycled to offset the production of new material. This, however, requires a transition in the entire supply chain towards a circular economy model in which a product becomes a new product's resource at the end of its life. In order to pave the way for this transition, the European Commission developed a strategy for plastics in a circular economy which should ensure that all plastic packaging will be recyclable in 2030 (European Commission, 2018). The European strategy was soon answered with national strategies and action plans in relation to circular economy and plastic waste management. The following section first introduces the concept of a circular economy and then moves on to look into the details of recently released European and Danish strategies.

2.4.1 The Concept of Circular Economy

In recent years CE has gained more and more interest from policymakers and industry as a tool to address issues such as global resource scarcity or land use. The concept of circular economy originates from various schools of thought, e.g. "regenerative design",

"cradle-to-cradle" or "industrial ecology", which lead to a variety of different definitions and models (Ellen MacArthur Foundation, 2013; Kalmykova et al., 2018; Kirchher et al., 2017; Ghisellini et al., 2015; Geissdoerfer et al., 2017). In general, CE aims to increase the circularity of material flows, by maintaining the material in the economy on its highest material quality and utility level (Kirchher et al., 2017), which can be achieved through "long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017).

Though there are a variety of different definitions for CE, there are also some widely used commonalities among them. Kirchher et al. (2017) identified two core principles to CE, the *system perspective* and the *R framework*.

The system perspective highlights that the CE needs a fundamental change instead of incremental improvements of the system (Kirchher et al., 2017). This change needs to happen at three different levels: the macro level, the meso level, and the micro level. The macro level focuses on the composition and structure of the economy on a regional or national level (Kirchher et al., 2017; Ghisellini et al., 2015). The meso level focuses on the development of eco-industrial parks, where companies collaborate and form an industrial system (Ghisellini et al., 2015). Lastly, the micro level concentrates on individual companies, products and consumers, which includes the adoption of cleaner production methods such as eco-design and better material sourcing, as well as consumers consumption patterns and responsibility for post-use treatment (Kirchher et al., 2017; Ghisellini et al., 2015).

According to Kirchher et al. (2017), the R framework is often seen as a "how-to" guide for CE. There are different variations of the R framework with varying numbers of "Rs" ranging from 3R to 9R. The "R's" refer to different steps and strategies that keep products and materials in the market. A common theme among the R frameworks is the use of a hierarchy. Earlier "R's" with a higher "circularity" are preferred and prioritized over later "R's" (Kirchher et al., 2017).

The European Union has adopted a 4R framework for its waste framework directive which builds on Reduce, Reuse, Recycle and Recover, which are explained below (European Commission, 2016; European Parliament and Council of the European Union, 2018a). However, most legislation seems to focus more on recycling than the other aspects, but new strategies aim for a more radical change focusing on a wide range of aspects.

- Reduce: Reduction of material usage through redesign or a prolonged lifespan.
- Reuse: Reusing products either directly or through repair and refurbishment.
- Recycle: Recovery into non-virgin materials for manufacturing.
- Recover: Retrieval of energy through incineration.

(European Parliament and Council of the European Union, 2018a)

2.4.2 A Circular Plastic Economy in the European Union

In recent years the European Union has shown a rising interest in actions related to a circular economy, which were expressed in an action plan released in 2015 (European Commission, 2015). One of the priority areas for the circular economy is plastics. In order to address the issues related to plastics, the European Commission decided to both review the existing legislation on waste, especially packaging waste, and to set more ambitious recycling targets, and to develop a strategy for plastics in the circular economy, which addresses issues such as recyclability, the presence of hazardous substances, and plastic littering (European Commission, 2015).

Packaging and Packaging Waste Directive

Following the outlined measures from the action plan for circular economy, the Packaging and Packaging Waste Directive received an amendment in May of 2018. The purpose of the packaging and packaging waste directive is to prevent and reduce the production of packaging waste through reuse and recycling. The amendment contained new general recycling targets for packaging products and some targeted to specific materials. According to the targets, by the end of 2025, at least 65% of all packaging waste should be recycled and by the end of 2030, this target will increase to 70% (European Parliament and Council of the European Union, 2018b). The specific target for plastic packaging materials is 50% in 2025 and 55% in 2030.

The amendment also brought the concept of an extended producer responsibility (EPR) to the packaging and packaging waste directive and the member states are thus required to establish appropriate schemes for all packaging until the end of 2024 (European Parliament and Council of the European Union, 2018b). Packaging choices are normally made by the producers and thus the EPR is seen as a financial incentive for the producers to take the product designs end-of-life impacts on recyclability into consideration (European Commission, 2015).

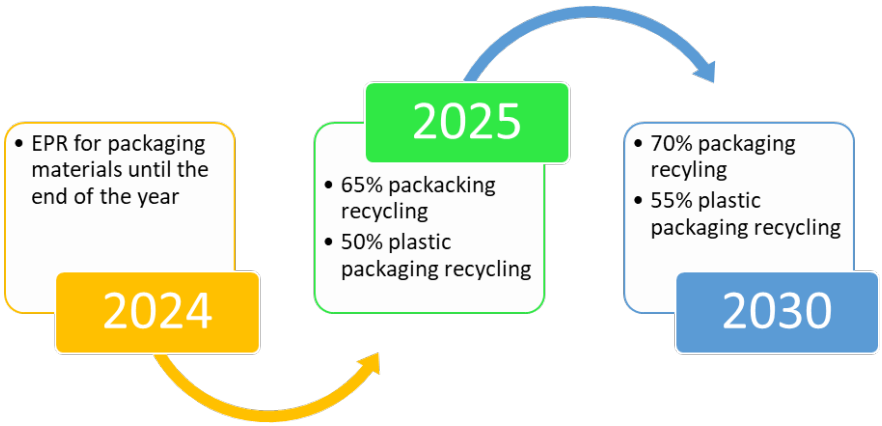

Figure 2.6: Summary of the targets from the packaging and packaging waste directive

Strategy for Plastics in a Circular Economy

The *"European Strategy for Plastics in a Circular Economy"* was released in 2018. It outlines a vision for a European "circular plastics economy" in 2030, in which design and production respect the needs of reuse and recycling, leading to more sustainable consumption and production patterns (European Commission, 2018). In order to realize this vision, the strategy outlines several actions that have to be taken by the different stakeholders. The measures are about improving the economics and quality of plastic recycling, curbing plastic waste and littering, driving innovation and investment towards circular solutions, and harnessing global action (European Commission, 2018). The European Commission wants to involve all actors in the plastic value chain for everyone to contribute and take action on this matter. It is suggested that more cooperation among the actors in the plastic industry and closer collaboration between the plastic industry and political authorities is needed in order to transition towards a circular plastic economy.

Though the strategy targets all kinds of plastic products, packaging products, and single-use items are especially important due to their short lifetime and large presence in the plastic waste stream (European Commission, 2018). The strategy calls for better plastic recycling through an improved product design that makes it easier to recycle plastic products. Furthermore, more plastic waste should be separately collected and better sorting and recycling standards should increase the quality of the recycled plastic material. Altogether this should lead to a rising market for recycled plastic and increase recycling rates (European Commission, 2018).

2.4.3 Danish Actions for Better Plastic Recycling

Following the EU's example, Denmark developed its own circular economy strategies in 2018. The Danish Government developed two strategies to move towards a circular economy, the first one being circular economy actions in general terms and the second one being particularly targeted at circular plastic consumption. Along with the development of the strategies by the government, the forum for circular plastic packaging (FCPP), an industry collaboration, developed its own recommendations and actions. The main findings from the three listed documents in relation to circular plastic handling actions are further described below.

1. *"Strategi for cirkulær økonomi - Mere værdi og bedre miljø gennem design, forbrug og genanvendelse"* (Strategy for Circular Economy - More value and better Environment through Design, Consumption and Recycling) by Miljø- og Fødevareministeriet og Erhvervsministeriet

2. *"Plastik uden spild – Regeringens plastikhandlingsplan"* (Plastic without Waste - The Governments Plastic Action Plan) by Miljø- og Fødevareministeriet

3. *"Forum for Circular Plastic Packaging - recommendations and actions"* by the Forum for Circular Plastic Packaging

The Governments Circular Economy Strategy

In Denmark, rising concerns about global resource consumption led to a more critical introspection on Danish consumption patterns. Through reuse and recycling, as well as better design and production, companies can get more value out of the same material and can contribute to reducing the pressure on natural resources while maintaining economic growth. Thus, the circular economy is seen as an opportunity for Danish companies to take a leading position in the development of new technologies and solutions that accelerate the transition towards a circular economy (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018). First steps towards a circular economy have already been taken. Many Danish companies and public institutions started to work with more circular business models and design innovations. Another step is the proposal to open the waste management sector for more competition, to allow for better access to the recyclable materials by private companies (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018).

In order to further accelerate the transition towards a circular economy, the government launched several initiatives in six focus areas, being:

1. Strengthen companies as driving force for the circular transition
2. Support circular economy through data and digitization
3. Promote circular economy through design
4. Change consumption patterns through circular economy
5. Create a well-functioning market for waste and recycled raw materials
6. Get more value out of buildings and biomass

(Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018)

In relation to plastic packaging point 1, 3, and 5 are of most interest. The strategy sees companies as the driving force for a transition towards a circular economy. Through the use of more circular production methods, companies have a high potential to reduce the production cost and save money. The production methods also have a high impact on the reuse and recycling potential and thus on the later value of a product. Hence, design for a circular economy is another way to increase economic growth. Besides that, the design also has a large influence on the impact a product has on the environment (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018). Nevertheless, even with better design and production as well as other consumption patterns, at some point, a product will reach

its end-of-life and enter the waste stream. Here the strategy describes the importance of high-quality recycling to maintain as much value as possible, however, that requires a functioning market for waste, and companies who want to use recycled raw materials (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018).

In order to support companies in the development of more circular innovations, the government wants to provide them with easier access to advice and funding for the implementation of circular business models. Furthermore, the government takes a proactive role in the development of product standards at the EU level. Another important initiative is to streamline the different waste fractions and collection systems currently used all over Denmark and to establish common sorting criteria and recycling standards, which is needed in order to produce high quality recycled raw material (Miljø- og Fødevareministeriet og Erhvervsministeriet, 2018).

The Governments Plastic Action Plan

The plastic action plan aims to move Denmark towards more circular plastic consumption, which means that plastic has to be both recyclable and recycled (Miljø- og Fødevareministeriet, 2018). It focuses on a variety of different aspects related to plastic production and consumption, such as fewer plastics in the environment, a better knowledge base for decision making, cooperation between actors in the value chain and across borders, and increased recycling and better waste handling. The government calls for responsibility from the actors in the entire value chain who should get into a dialog to find a solution together. The action plan highlights that there is no universal solution to solve all the issues related to plastic consumption, thus, the government has developed 27 initiatives, as seen in Table 2.2, which address a wide range of plastic related issues (Miljø- og Fødevareministeriet, 2018). Some of these initiatives are directly related to packaging production, use, and recycling, through design for recycling and a more standardized collection and sorting. Plastic producers should use fewer types of plastic, which further helps to improve the sorting and recycling (Miljø- og Fødevareministeriet, 2018).

The first initiative is the development of a national plastic center, which aims to bring the different actors from the value chain together, to speak to consumers and companies about plastic and inform them about advantages and disadvantages and how to handle them, and to develop design guidelines for plastic products. The plastic center will also play a central role in many of the other initiatives by generating and collecting knowledge and developing ideas and collaborations for a circular plastic economy.
Initiative two and three are about an in-depth data collection of the current situation by mapping the Danish plastic consumption and waste treatment and analyzing the business potential of investing in better sorting systems.
The fourth initiative wants to enable funding for research projects on reuse and recycling for more sustainable plastic consumption.
Other initiatives include specific actions for increasing the recycling rates of plastic wastes,

1.	National Plastics Center - gathering spot for the danish plastic operation
2.	Analysis plastic use and handling in Denmark
3.	Mapping of development and business potential for the danish plastic industry
4.	Prioritizing of research and technology developments
5.	Sector collaborations within eg. agriculture, construction, etc
6.	Extension of the return and deposit system on juice and soda bottles
7.	Extended producer-responsibility for plastic packaging
8.	Collection and sorting standards for plastic waste
9.	Denmark supports the EU directive on single-use plastic items
10.	National campaign to reduce waste in nature
11.	Pool for local initiatives to clean beaches for plastic
12.	Prohibition of non-degradable hail bowls
13.	Examination of ghost nets in Danish waters and methods for cleaning
14.	Ban of free plastic bags with handle
15.	Ban of thin plastic bags with handle
16.	Danes' plastic bag consumption must be halved by 2023
17.	Development of requirements to reduce disposable plastic consumption at large events
18.	Analysis of fee on single use plastic items to reduce plastic usage
19.	Ban of micro plastic in cosmetics
20.	National research and innovation network about micro plastic
21.	Knowledge about micro plastic in sewage sludge
22.	Knowledge about micro plastic discharge from artificial grass and alternatives
23.	Knowledge about pros and cons of bio-based and biodegradable plastic
24.	Survey of PVC products on the Danish market and substitution possibilities
25.	Collective European requirements for design for recycling
26.	Prioritization of Denmark's international commitment
27.	Strengthened efforts near sea areas

Table 2.2: Overview of initiatives from the danish plastic action plan based on Miljø- og Fødevareministeriet (2018). Columns marked grey are related to plastic packaging

such as initiative six, which aims to extend the already established bottle-return system to juice bottles. It is estimated that through this, another 52 million bottles can be recycled annually.

The seventh initiative is the implementation of the above mentioned and, by EU regulation, required EPR for packaging products, which should promote environmentally friendly packaging design and ensure appropriate reuse and recycling of the packaging material.

Another important initiative for a circular plastic economy is initiative eight, which will standardize the municipal collection schemes and sorting criteria on a national level. This will enhance the material quantity and quality and thus lead to a better market for recycled plastic. Further national standards on waste fractions will make it easier for the average Danish citizen to sort their waste accordingly.

The last relevant initiative is number 25, which calls for EU wide design requirements. The Danish market is open for international companies to sell their products, however, the

resulting waste is treated regionally. Thus it is important that imported products fulfill the same quality standards as the Danish products in order to retain an overall high recycling quality. EU design requirements for packaging materials can help to achieve better recycling rates in all European countries and ensure high-quality recycled material.

Forum for Circular Plastic Packaging

The forum for circular plastic packaging is an industry collaboration of various stakeholders[2] from the plastic value chain as well as external experts such as NGOs, researchers, and consultants. The stakeholders joined forces to develop solutions for a circular plastic economy and, together, they formulated the following vision as well as recommendations, which are shown in Figure 2.7, and actions necessary to reach this vision.

> *"**Denmark as a role model for circular plastic packaging***
>
> - *Where there is an incentive to use plastic again and again*
> - *Where we design plastic products that provide value for society, consumers and the environment*
> - *Where the global plastic packaging solutions of the future begin"*
>
> (Forum for Circular Plastic Packaging, 2018a, p.5)

The six recommendations cover aspects of the entire life cycle of a product, beginning with design and material considerations, and ending with initiatives for better recycling. The recommendations involve actions from both professionals and consumers in order to reach the above-mentioned vision (Forum for Circular Plastic Packaging, 2018a). The first recommendation is to design packaging for recycling. For that, the forum has developed a concrete design manual that guides producers to design for recycling. Another recommendation is to increase education about bio-based and biodegradable plastics. Due to complications in the recycling process, if conventional and biodegradable plastics get mixed, it is recommended that packaging should not be made out of biodegradable plastics. Additionally, the forum wants to initiate the creation of a platform for more transparency and discussions for consumers and professionals to make more environmentally correct decisions for design and consumption. The fourth recommendation is to open up return systems similar to the bottle collection system to collect cleaner waste fractions which are suitable for high-quality recycling. In line with this, is also the next recommendation, which aims to improve the waste sorting in households, as well as in municipal sorting and recycling stations. The last recommendation targets the retail sector and wants to enhance return systems between businesses for packaging articles that do not reach the consumer (Forum for Circular Plastic Packaging, 2018a).

[2]List of participants: https://plast.dk/deltagere-i-forum-for-cirkulaer-plastemballage/

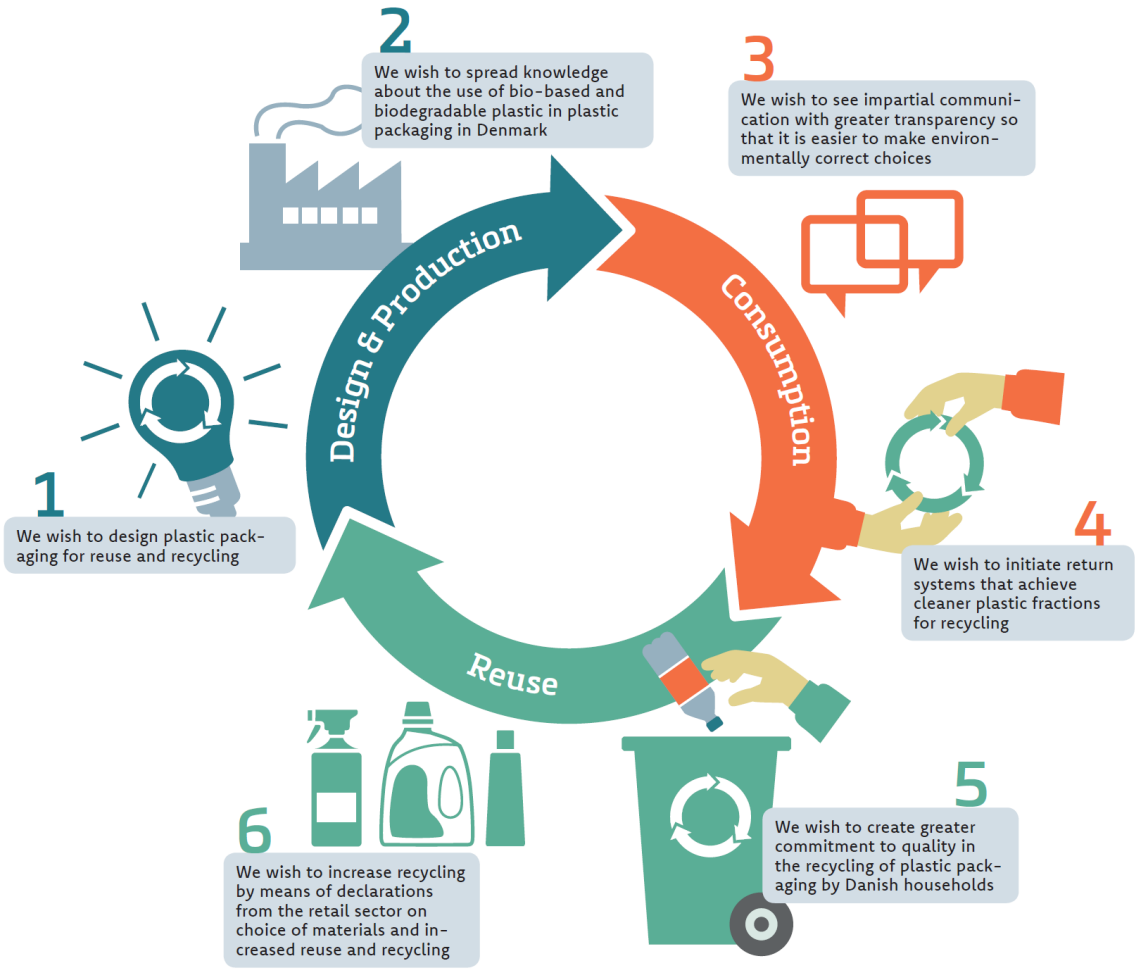

Figure 2.7: Recommendations by the Forum for Circular Plastic Packaging (2018a)

In a timeline, the forum represents when the different recommendations and measures should be realized by. Some of the actions such as the development of a design manual and some initial tests and pilot projects have already been done. Others, which require a change of legislation or depend on the results of the pilot studies, take more time. The last scheduled action is to have the design manuals be acknowledged in the legislation for the 2025 required EPR (Forum for Circular Plastic Packaging, 2018a).

While all the recommendations are relevant for a circular plastic packaging economy, the first recommendation was seen to be especially interesting, due to the high influence of the design on the products life cycle and its treatment at the end-of-life. Thus it was decided to mainly focus on the product design and to further investigate the mentioned design manual.

2.4.4 Summary of Actions from Politics and Industry

In order to keep a better overview over the different strategies and actions initiated and recommended by governmental bodies and industry, they are summarized in Figure 2.8.

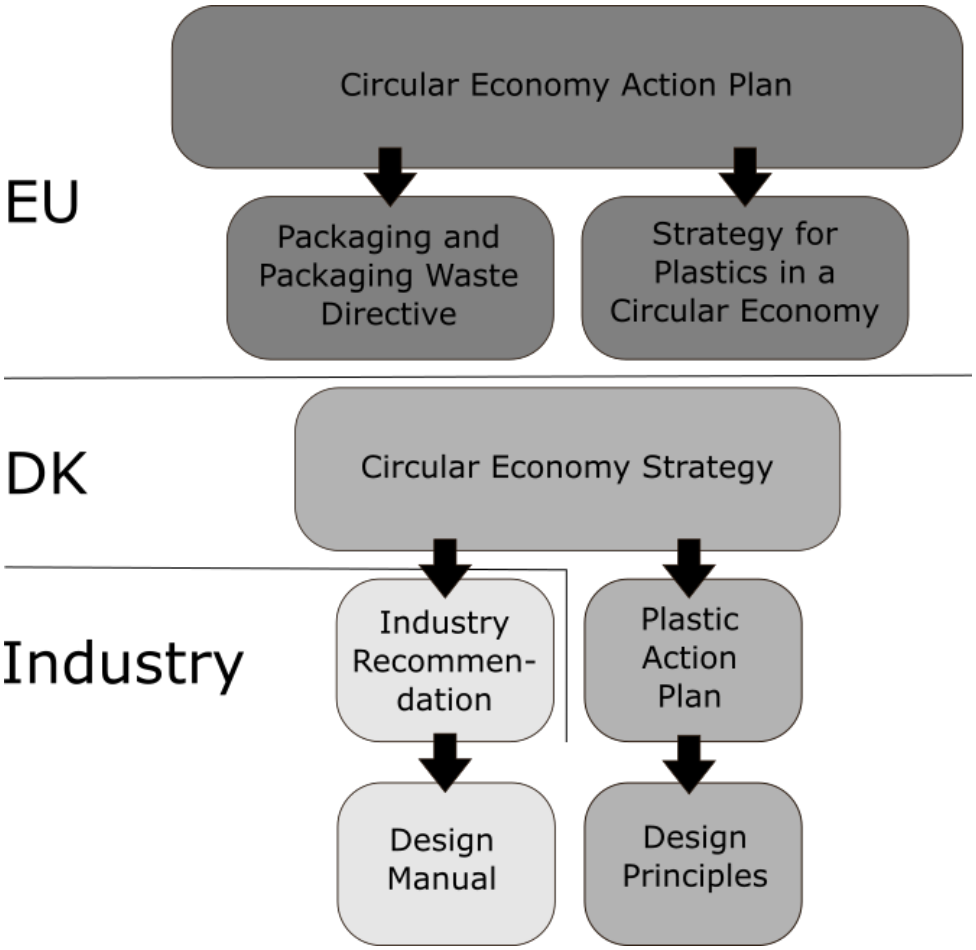

Figure 2.8: Overview of strategies and actions in the EU and Denmark

The strategies and actions are created by three different actors, who stand in a hierarchical order to each other. On the top is the EU who's strategies and legislation provide the minimum requirements and guidelines for its member states such as Denmark. In this case, the EU developed a CE action plan in 2015 which on the one hand led to an amendment of the packaging and packaging waste directive, and on the other hand, to the creation of a strategy for plastic material. At the national level, Denmark developed its own CE strategy which was followed by the government's plastic action plan. Building on the development in the EU, the Danish plastic industry formulated, simultaneously to the ongoing work at the national level, a set of recommendations that should be seen as input for the political work (Forum for Circular Plastic Packaging, 2018a). Both the political work and the industry effort then led to the development of design principles for plastic packaging.

2.5 Design Manuals for Plastic Packaging

Due to the previously mentioned issues related to plastics, and in particular, plastic packaging, it was realized that the design plays a central role in order to overcome those issues. Following the release of the circular economy strategy and the plastic action

plan, two independent design manuals were developed. One was created by the forum for circular plastic packaging in relation to the above-mentioned recommendations, and the other for the Danish Environmental Protection Agency (EPA). Both manuals were developed in a Danish context with the currently available technology in mind. They both aim to create a design for plastic which would be optimal through its life cycle, and enter the waste stream with a high potential of being recycled, and in the case of the EPA, it is focused on food packaging, which might result in some more specific principles. The design manuals used in this research are:

- *"Reuse and recycling of plastic packaging for private use"* made by the Forum for Circular Plastic Packaging
- *"Dogmeregler og designprincipper - Et redskab til at øge genanvendelsen af fødevareemballager i plast."* (Dogma rules and design principles - A tool for increased recycling of plastic from food packaging) made by Rethink Plastic

The design manuals provide a clear description of how plastic should be designed in order to close the circle in the plastic economy. A summary of the principles described in each manual can be seen in Table 2.9. The design manual from the forum for circular plastic packaging is supposed to be updated annually in order to be up to date with the newest technologies and other developments (Forum for Circular Plastic Packaging, 2018a). The design manual by Rethink Plastic is accompanied by a project report, which provides further background information about the process of the project puts the design principles in more perspective to the value chain (Hatch & Bloom and VE2, 2018).

In order to make the design principles more specific for the different components a set of packaging can contain, they are separated into individual components; the main component, sub-components, and decoration/labels. The main component refers to the largest element that generally holds the product. The sub-component refers to lids, sealings, or other additional components such as straws that are used to make the packaging complete. The label then refers to the component that holds the legally required product information. As seen in table 2.9, the designs are focused on using mono-materials for plastic packaging products, one manual proposes PET as the optimal polymer type for food packaging (Rethink Plastic, 2018). Another principle is to design the product in a way that the different components are easy to separate from each other and from their content (Hatch & Bloom and VE2, 2018; Forum for Circular Plastic Packaging, 2018a). The design of packaging plastic is one of the actions that needs to be taken to move towards a better recycling system, and thus the design principles provide an important contribution to that movement, however, the recycling of the products will only be possible if the system which they are embedded in supports it.

The implementation of the design principles is the first step in a long process towards a better recycling system. Afterwards, an appropriate collection system for plastic waste

		Mentioned by:	
	Design principles	**Rethink Plastic**	**Forum**
Maincomponent	Avoid surface treatment such as silicone and anti-fog, which makes it hard to categorize the used packaging	X	
	Work with monomaterial	X	X
	Prefer PET as material (can be used in an open circuit for food packaging)	X	
	Uncolored or clear plastic is prefered	X	X
	Hinge lid on containers for convenience food, so that the lid does not end in the environment	X	
	Breaking point in the lid hinge, so that the lid can be disassembled from the container, if the label can not be removed	X	
	Make rounded corners, also along the bottom, so it is easy to empty	X	X
	Wide opening for thick liquids, or possibility for it to stand on ist head, so the liquid can get out easier		X
	Make at least one big surface, to support a better grip in the sealing foil	X	
	Be concerned about the thickness of the product, to avoid bars and other strengtheners, which makes it problematic for empty and clean	X	
	No printing on the container, only on label		X
Sealing	Part-components in same material or completely removable	X	X
	As much as possible use foil-bags which leave a clean main-component	X	
	Make sure the sealing can be removed in connection with the lid	X	X
Label	Use plastic labels instead of paper, they are easier to remove	X	X
	Use glue, which easily gets off, if paper label is needed	X	X
	Prefer cardboard or paper cover, which leaves a clean packaging	X	X
	Design the label with a big rip-slip, which makes it easier to grab and remove	X	
	Avoid labels on other surfaces than the sealing-surface, so that only one label has to be removed	X	
	Provide information about correct disposal (separation and sorting)	X	

Figure 2.9: Summary of design manuals for plastic packaging based on Rethink Plastic (2018) and the Forum for Circular Plastic Packaging (2018b). This figure explains which design principles the different manuals include. The grey color indicates "Material choice", and the blue indicates "Product design".

suitable for recycling has to be established, which could be done by the industry itself, the municipalities or in a national scheme by the government. Possible ideas are return and deposit systems for businesses as well as consumers to return packaging, another option is community recycling stations for consumers to appropriately dispose of other products. The goal with this is to collect as many clean plastic material fractions as possible, so that it can re-enter the production of packaging (Hatch & Bloom and VE2, 2018).

The Forum also has initiatives to improve the recycling system, which were expressed in the above mentioned recommendations. They want to test the potential for an extended return system in the retail sector and want to research the advantages and disadvantages of such systems, which would also involve the consumers. Furthermore, they want a national waste fraction which only consists of plastic, in order to make it easier for the waste management to sort and recycle the plastic (Forum for Circular Plastic Packaging, 2018a).

Problem Formulation 3

3.1 Problem Statement

Plastics offer ideal properties for packaging applications, however, they also hold the problem of accumulating in the environment if not treated in a proper waste management process. Plastic packaging products make up ca. 60% of the post-consumer plastic waste, of which on average only 40,8% are recycled. The reasons for the low recycling rates are diverse and complex, but one important aspect is the design and production, which has an impact on the entire product life cycle. The EU and Denmark have recognized this problem and want to implement more CE aspects into the plastic economy. A recent development in Denmark was the creation of two design manuals for plastic packaging products, which want to create products suitable for reuse and recycling. In order to research the effects of these manuals on packaging designers and producers, the research question is as followed:

"How can companies producing and using plastic packaging overcome the challenge of designing and manufacturing plastic packaging for a circular economy?"

To help answer the research question the following sub-questions have been formulated:

Research Sub-Questions	**Aim**
SQ 1: How can the principles from the design manuals be implemented into the design and manufacture of plastic packaging?	Analyze the companies ability to adopt the individual design principles from Figure 2.9
SQ 2: What are the barriers and opportunities to implementing the design manuals?	Identify factors (company internal or system related) that affect the implementation of the design principles
SQ 3: How is the packaging fillers ability to design plastic packaging affected by other actors?	Analyze the interrelations between different actors and their effect on "circular" packaging design

3.2 Delimitation

Due to the limited amount of resources, it was necessary to clearly define the scope of the project. For this, the following delimitations have been made.

Food packaging belongs to the so-called 'food contact materials' (European Commission, 2019), which must comply with the European legislation on food safety and therefore put up stricter requirements for the packaging products. However, if the principles from the design manuals are applicable to food packaging, they should also be applicable to non-food packaging.

Though the project had already focused on Denmark due to the location and the background of the researchers, the design manuals gave this focus another reason. The manuals have been developed in a Danish context, taking into account the available technology and infrastructure in the Danish waste management. Though international trade brings a lot of foreign packaging to the Danish market, it was decided to only focus on Danish companies, who are more closely related to initiatives happening in Denmark.

Analyzing the different actors in the value chain and their influence on the recycling of packaging products, showed that design decisions have a high impact on the later value and are primarily taken by the early actors in the value chain. Therefore, it was decided to focus the research on the plastic packaging manufacturers and packaging fillers who seem to have the most influence on the packaging design.

Until now, several decisions that narrowed the research area were taken. The following figure provides an overview of the process and shows the scope of this research.

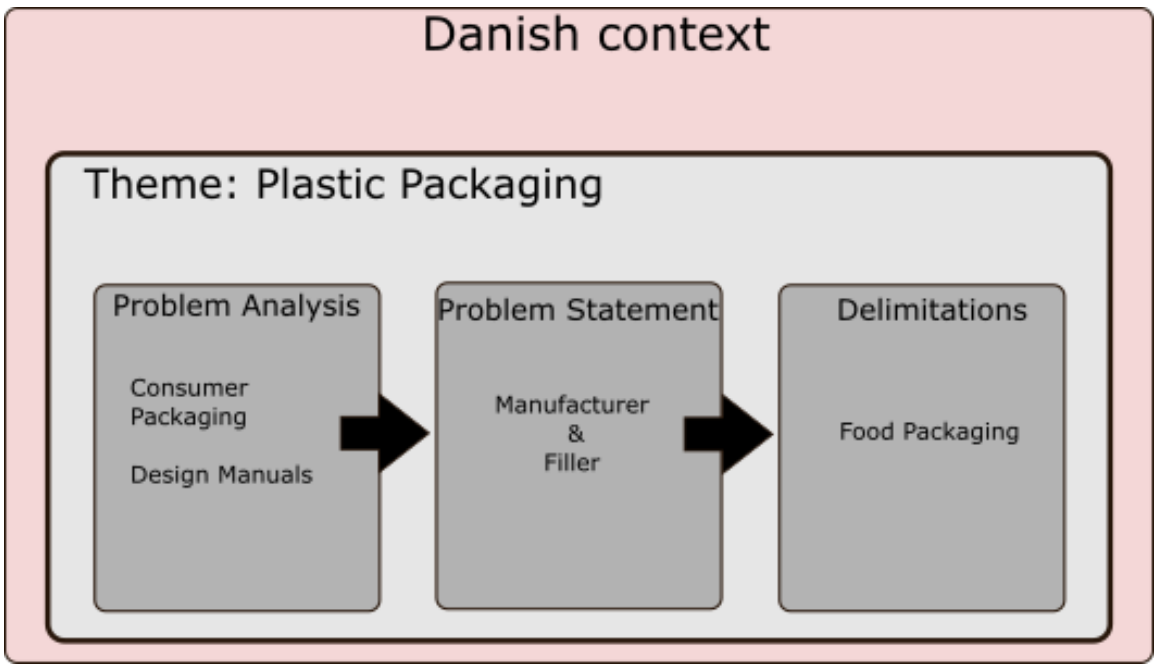

Figure 3.1: Narrowing process of the research topic to the design manuals for manufacturers and fillers of consumer food packaging

Research Design & Methodology 4

In order to answer the research question, it is necessary to obtain empirical data from relevant industry stakeholders about the design of plastic packaging and the system surrounding it. The information is expressed through personal opinions from the individual stakeholders, which makes it important to choose an adequate research approach that can handle such kind of data.

To make sense of the gathered data, the researcher has to apply certain philosophical assumptions. For this research, the assumptions are based on phenomenology, the study of the structures of experiences and consciousness. Phenomenology is based on an ontology that states that there are multiple realities, which are developed through human perceptions (Moustakas, 1994). In accordance with phenomenology, the epistemological understanding is that peoples knowledge is subjective evidence, whereas the context of this subjective knowledge has to be understood by the researcher. For the analysis, however, the researcher has to interpret the obtained data and express presumed biases, power balances, and other effects that can influence the understanding of the data. According to Moustakas (1994), this is possible because in a phenomenological understanding the researcher can add his reflections to the analysis, as long as the context and the arguments for the reflection are stated.

The project contains of an iterative research process, which has caused the research question and design to change and evolve over the project period. Based on the chosen philosophical assumptions, the research methods have been qualitative and inductive in order to reflect the subjective nature of the data. To extract data from this knowledge pool, qualitative research methods are needed due to their ability to bring forth the subjective understandings of reality. The research used Literature Studies and Document Analysis to collect initial data for the problem analysis. Later Interviews were used to gather empirical data from selected stakeholders in the plastic packaging value chain. This data is analyzed using a SWOT analysis, which is used to understand each stakeholders opinion and idea on the design manuals as well as to compare them if there are collective understandings of the phenomenon by multiple stakeholders which would indicate a common reality (Creswell, 2017) and could be used as a recommendation for the next generation of the design manuals, as well as the design responsibility in the value chain.

4.1 Literature Studies

The literature studies are used to gain a fundamental understanding of the project background in terms of plastic production and recycling methods as well as state-of-the-art examples of plastic waste management. This is done to better understand the current problems related to plastic waste and to put them into perspective with the current possibilities available in Denmark. The literature studies are also used to gain a theoretical understanding of the research design and to develop an analytical framework for the analysis. However, due to the recent developments in the research topic, the amount of scientific literature is currently limited, and non-scientific literature had to be used.

4.2 Document Analysis

The document analysis is mainly used to collect data for the problem analysis. It is used to analyze non-scientific literature, such as EU directives and strategies, national strategies, industry recommendations, and the Danish design manuals to get an understanding of the circular economy agenda and state-of-the-art solutions concerning "design for recycling" offered by the industry.

4.3 Interviews

The majority of the data used in this research has been gathered through interviews. In the problem analysis, interviews are used to obtain background information on, **1)** the design principles of the two design manuals and, **2)** the waste management concerning plastic recycling. Furthermore, interviews became the main method of extracting data from the field, because of the ability to retrieve data from socially constructed phenomena, which is important when individual opinions are the main focus (Creswell, 2017). Interviews were conducted with experts on plastic waste and representatives of different companies that manufacture and fill plastic packaging. When doing qualitative research like interviews, the data collection is often based on a relatively small sample size, thus it should be based on some selection criteria. These criteria and the selection process of the interview participants are further described in section 4.3.1 below.

All the interviews for this research are conducted as semi-structured interviews in order to enable the interviewees to convey their knowledge about the subject unobstructed, and to bring up points which were not considered by the researchers when creating the interview guide. The interviews were structured for each specific group of stakeholders, so that the answers gathered are comparable. However, some of the interviews were more openly structured than others, the reasons for this are explained below. The interviews were structured in an interview guide as outlined by Brinkmann and Tanggaard (2015, p.39), which consists of research questions and interview questions. The research questions represent the knowledge that is intended to be collected through the interviews, and the

interview questions are rephrased versions of the research questions, split into multiple questions which address the different elements of each research question but can be easier answered in separate questions (Brinkmann and Tanggaard, 2015). An example of an interview guide can be found in Appendix A.

The interviews were recorded and then transcribed through a meaning condensation. Meaning condensation is used to make concise statements from the statements given during the interview, which then get categorized to create a platform for arguments that are being used in the analysis (Brinkmann and Tanggaard, 2015). The meaning condensation involves a certain level of interpretation by the researcher on the meaning of the interviewee's statements (Kvale and Brinkmann, 2009, p.227). This is necessary in order to understand the opinions expressed during the interviews and for them to make sense in the context of the research. This interpretation process can to some extent be affected by the prioritized categories used in the analysis. The interviewees have been contacted, after the analysis was finished, and to be sure that their opinions have not been misunderstood, were given a chance to read through and provide feedback if they disagreed with any statements used.

4.3.1 Stakeholder Selection

This research primarily collected information on what affects the possibility of designing plastic packaging for recycling, by conducting interviews with relevant stakeholders from the value chain. There are multiple ways to ensure the collection of representative data. One method is to have a large sample size, in this case, a large variety of companies have been included in order to secure a majority of the stakeholders in that value chain. Another way is to choose relevant stakeholders through a strategic selection process, to narrow the relevant stakeholders for answering a specific question. Due to the delimitations made in section 3.2 the research scope focuses on food packaging, which is subject to stricter requirements than non-food packaging. This delimitation was made as, according to Flyvbjerg (2006), food packaging can be seen as a critical case, which means that, if the designs for recyclable plastic can be used here, they could be used in all other plastic packaging designs.

The companies were selected by **A)** backtracking "problematically designed" packaging samples collected from the waste stream, and then following them back to the companies which were accountable for the designs, and others were selected because **B)** they participated in the creation of the design manuals, which would indicate an interest in circular plastic packaging design.

The backtracking process used the sample data provided by Vingwe and analyzed in section 2.2.2. It focuses on products that contain mixed and multi-layer polymers, which make up approximately 50% of the samples as shown in Figure 2.4. The products identified through this method serve as a point of departure for initiating contact with the producing companies. It is assumed that companies identified through this method, might

have a harder time to implement the design principles. Thus they can provide better information about the barriers and challenges in changing the product designs. However, the sample contained a lot of unidentifiable products, which are not used for this project, due to missing information. Further, this research is focused on Danish producers as legal requirements, collection, sorting, and recycling of waste might differ from country to country, and it is assumed that Danish companies are more willing to participate in this research, due to the design manuals being focused on Danish infrastructure.

4.3.2 Conducted Interviews

This section explains the purpose of the conducted interviews, along with the considerations made in the interview design to get a qualitative outcome. An overview of the different interview stakeholders and the role their organization plays in the plastic value chain are summarized in Table 4.1.

Organization	**Role**
Hatch & Bloom	Author of design manual
The Danish Plastics Federation	Author of design manual
Aalborg University	Waste management researcher
Reno-Nord	Waste sorter
Færch Plast	Plastic manufacturer
Sky-light	Plastic manufacturer
Arla	Packaging filler
COOP	Packaging filler
Atria Danmark	Packaging filler
Hanegal	Packaging filler
Tulip	Packaging filler

Table 4.1: Overview of the interview stakeholders

Interviews with the creators of the design manuals

Part of the initial research for this project was to examine the design principles laid out in "Reuse and recycling of plastic packaging for private use" and "(Dogma rules and design principles - A tool for increased recycling of plastic from food packaging", see section 2.5. Two administrative participants in the creation of the reports were interviewed to clarify some of the details and to get a better understanding of the underlying principles of the design manuals. The interviews also served to assist in understanding of the methodology behind the development of the design principles and recommendations.

Interview with plastic waste experts

The design principles give several guidelines on how to design plastic packaging in order to make it better suited for recycling and resolve some of the problems with today's plastic packaging. Two experts on plastic waste, one from Reno-Nord and one from AAU, were

interviewed in order to ascertain which problems are most prevalent in the plastic waste stream. The interviewee from Reno-Nord I/S is their Environmental and Development Manager, and information was gathered on the daily problems encountered with plastic waste sorting. The interviewee from AAU is a PhD-student with a focus on plastic waste who, in interviewing, elaborated on his waste management research. Their knowledge was also used to identify relevant stakeholders for the core data interviews, which is further described in the Stakeholder Selection. The interview with the AAU PhD-student was less structured than the other interviews, in order to allow him to explain some of his findings used in section 2.2.2.

Interview with plastic packaging fillers

The companies were interviewed with the purpose of getting a better understanding of a company's packaging design, as well as the design requirements of the different companies. Furthermore, they were asked to assess the design manuals with the intention of investigating the readiness of the companies in applying the design principles to their products and for identification of potential barriers. However, this often leads to a discussion about external factors that influence how much a company can, or is, willing to do. In preparation for the interview, the participants were provided with the two design manuals, as well as the summarized table which is seen in Figure 2.9 in section 2.5 to have the opportunity to review the recommendations and build their own opinion about them if they had not already seen them.
Arla and COOP, both participated in the FCPP, were specifically asked about their input to the creation of the design manual, and if the participation has impacted how they design their products.

Interview with plastic packaging manufacturers

From the analysis of the design manuals and the value chain, it became apparent that the design is mainly influenced by the early actors in the production chain. Thus it is important to not only focus on the packaging fillers, but also to include the packaging manufacturers, because the manufacturers can provide additional information about design requirements, and express how they can help to implement the principles expressed in the manuals.

4.4 Reflections on the Research Process

4.4.1 Validation through Triangulation of "Better Recycling" as a Concept

In this research, the design manuals have been treated as boundary objects, meaning that they are artifacts that secure a common understanding on a given subject. These objects are always placed on the borders to other social worlds and function as communication

between them (og Griesemer, 1989). In this case, the communicated subject is the design of plastic for recycling, and the different social worlds spawn from the different actor-categories in the value chain. The validation in the research is based on the scope of the research, which is to understand the companies opinion on these design manuals, and hopefully, develop ideas to how they can be optimized in relation to the boundary object (Creswell, 2017). In order to investigate the phenomenon from different dimensions, the interviews were conducted with three different groups: the manufacturing companies, filler companies found through the backtracking process, and filler companies who participated in the design of the manuals.

4.4.2 Limitation with Interviews

This project period was from February to June 2019, which influenced the amount of data, and the data collected with the interviews. The rather short time frame meant that the interviews with the packaging manufacturers and fillers all had to be conducted in short succession. However, missing contact information, lack of replies, lack of time and a vacation period, and hesitation from the companies were some of the encountered challenges when arranging the interviews with the different stakeholders. Other limiting factors were related to the execution of the interview. Though all interview stakeholders were located in Denmark it was not possible to arrange personal meetings all the time and thus the majority of the interviews had to be conducted via phone or Skype. This sometimes caused some difficulties with understanding and provided some challenges for the transcription. While the first interviews were conducted in English, it was soon realized that some actors felt a bit uncomfortable, and had problems to express themselves, thus it was decided to conduct the rest of the interviews in Danish, though it resulted in more work for the data processing afterwards.

Other factors that could influence the data from the interviews are biases and restrictions. In some of the interviews, it became apparent that the stakeholders were at first resistant and hesitant to open up and talk about the topic. This could have been due to missing knowledge and confidence in environmental decisions. This might also have been the case for other stakeholders who, to some extent, seemed to just repeat the arguments of their suppliers. Other stakeholders, however, seemed to know more than they wanted to reveal, which could mean that there might be more opportunities than talked about in the interviews.
One bias, which is important to highlight, is that the interviews were made with a small part of the whole value chain, which makes it impossible to know what a stakeholder, which have not been included would have to say of a matter where they are being the discussion subject. But this is a by-product of the delimitation which states that our data consists of data from filler companies, and not the entire value chain.

Analytical Framework 5

In order to make sense of the data gathered through the interviews, a framework which can translate this data is needed. Through the interviews it became very clear that the relations between the actors, embedded in the network of plastic packaging, have valuable information for the problematic circumstances with designing plastic for recycling. The analytical frameworks chosen in the report are a **SWOT Analysis** and a **Network analysis**. This helped administrate the analysis, by mapping the data into barriers and opportunities in the implementation ability, with the SWOT. With this categorization of data the relations showed importance, and therefore a Network analysis was used to group the relations and elaborate on how this affects the companies. Theories, which can provide explanatory power, have not been used, because of the pragmatic approach which have been the core of the research. With these frameworks it has been possible to structure the data, and from there conclude from the relations which these frameworks provided.

5.1 SWOT Analysis

This project focuses on identifying the barriers and opportunities for designing and manufacturing plastic packaging in a circular economy. In order to analyze this, a SWOT-framework is used in this thesis. This framework is used to highlight the internal and external factors for implementing the previously outlined principles from the design manuals into the interviewed companies' product design.

A SWOT analysis identifies and evaluates **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats. It is conventionally used by individual businesses, to assess internal and external factors, which can impede or assist a company (Valentin, 2001). In this project the SWOT analysis will instead be applied to the group of companies identified in the Stakeholder Selection, all of which are identified as Danish packaging fillers companies, who have products in the Danish waste stream. This means that internal factors in this analysis should be understood as factors these filler companies can influence directly, by changing either production or business habits within the company. External factors should be understood as factors filler companies cannot influence directly, such as legislation or other stakeholders in the value chain.
The SWOT analysis will be used to answer the second sub question. This will be done by analyzing the filler companies ability to implement the design principles from the design

manuals about how to design recyclable plastic packaging.
The SWOT-analysis is based on the qualitative data collected through interviews with the selected filler companies.

	Internal factors	External factors
Favorable factors	**Strengths** The companies ability to change to more recycleable packaging	**Opportunities** Opportunities that can use to increase the recycling of packaging
Unfavorable factors	**Weaknesses** The disadvantages the companies have that inhibit their ability to change the packaging	**Threats** Inhibits the companies from being able to make more recyclable packaging

Table 5.1: Definition of SWOT factors adapted from Valentin (2001)

5.2 Network Analysis

In this thesis the network analysis is used to understand how the external factors identified in the SWOT-analysis about how actors affect a the filler companies ability to design plastic packaging for recycling. One has to understand that a company can not operate in isolation. Companies are related to several different actors, which create a network of relationships around the company (Håkansson and Ford, 2002). Within the network analysis both the social and the technical content in the network relations related to a company play a role in its ability to change. The relation in these networks can be described by four different features: **1)** reciprocity, **2)** interdependence, **3)** loose connections and **4)** power relations (Søndergård et al., 1997; Grabher, 1993).
Reciprocity is a feature that covers the expected relation and action between two parties. It relates to the trust that arises from continued work between two parties or more, which over time creates an expectation of benefit to the parties, not necessarily for the individual exchange but for the overall sequence of exchanges (Søndergård et al., 1997).
Interdependence is created over time as actors build a long term relationship. The relationship creates mutual adaptation, which influence how they both evolve (Grabher, 1993). The interdependence manifests in the mutual knowledge and alignment for each others resources, which makes it hard to exit these relationships. Benefits have been developed over time, such as common codes, which eases communication and other exchange of information. These represent an investment, which will be lost if the connection is broken, making the companies hesitant to break the connections and to make any radical changes (Søndergård et al., 1997).
Loose coupling refers to how actors are bound together in the network. The connections between actors in networks are loose, unlike the connection there might be between different departments in a company. Meaning that the actors have some autonomy, preventing

them from being locked into to specific exchange relations by sunk cost (Grabher, 1993). *Power relations* consists of control over resources, which can be products, production equipment, knowledge etc. (Søndergård et al., 1997). In the network model asymmetries in power are what allow some actors to exploit the interdependence in the network. An example of this could be a large customer influencing its suppliers, the larger the customer is the more it can influence the suppliers (Grabher, 1993).

The network consists of actors that have an influence on or are part of the network, by having control over resources or by doing productive activities (Søndergård et al., 1997). The actors within the network can be described from three dimensions: Business network, Development network and Regulatory network (Figure 5.1). The networks represent an expansion of the activities and resource base which the actor/company has. Expanding on this network or gaining more control over it will therefore enable companies to have a bigger influence on how the network can develop.

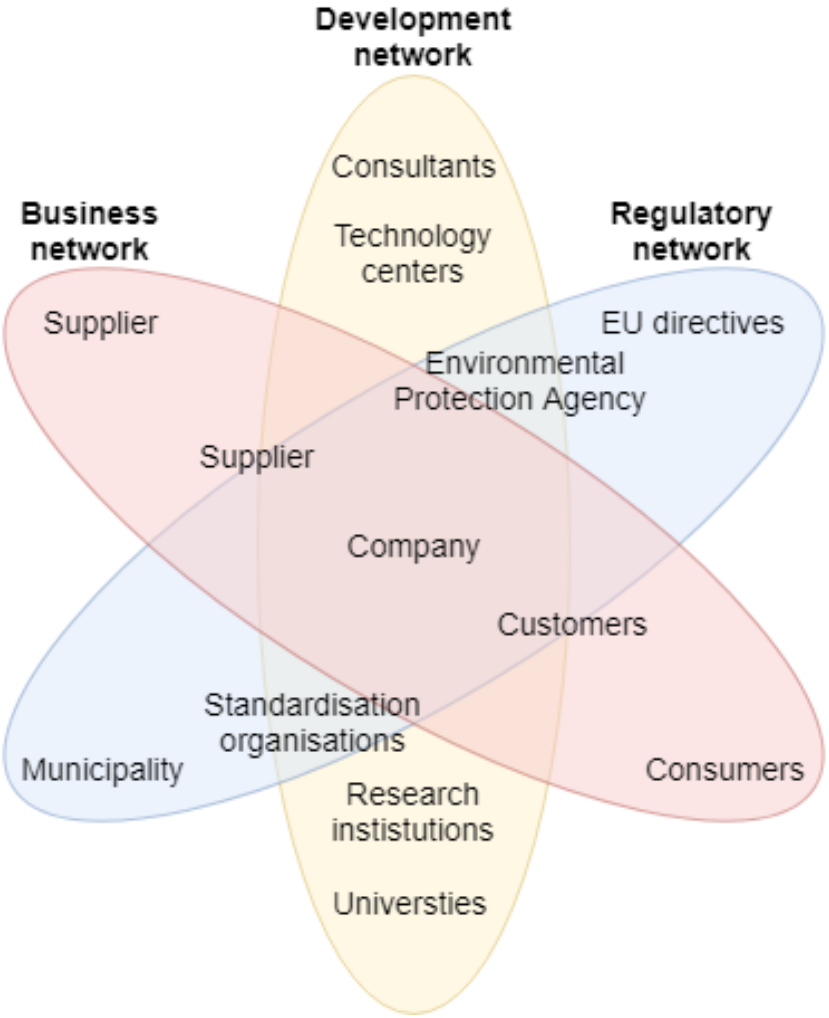

Figure 5.1: The three network dimensions, based on Søndergård et al. (1997)

Each of the three dimensions of the network is characterized by having different influences on the network. The **business network** is comprised of company to company relations and relates to the supply chain of a company, where the exchange of money,

experience, products and product requirement happens. All four features of the network are especially pronounced in the business network. *Reciprocity*, representing the mutual expectation that goes with a business agreement, such as payment, product quality and quantity etc. The *interdependence* between companies can manifest as shared accumulated knowledge and dependence on certain activities such as delivery of packaging for a companies products. *Loose coupling* represents a companies ability to change for example their suppliers. *Power relation* represents a company's ability to influence the rest of its value-chain, through various means.

The **development network** is comprised of sharing and adding new knowledge to the network, for example, information from a supplier that finds a new solutions. Depending on how the knowledge network intersects with the other networks an actor in the knowledge section can have various amounts of the four features. A University giving general idea about new solution, would for example have less reciprocity and interdependence with a company in question, than a supplier to the company. Each of which could affect how the solution is received at in the company in questions and how tailored and easy to implement that given solution would be.

The **regulatory network** is comprised of actors such as the EU, national government or agencies that set regulations and requirements which the company needs to comply with. This gives these actors an unbalanced power relation with companies. Their generally low level of interdependence with the company means that the company can do little to change these requirements.

Analysis 6

Designing and manufacturing packaging for a CE is a challenging process. Different interests and dependencies among actors can inhibit the transition towards a more circular economy but there are also opportunities for the actors to collaborate and push together for a radical system change. One of those opportunities is the development of the design manuals, which should help the producers to create more sustainable packaging. Sustainable packaging is essential for the transition towards a CE. In order to better understand how the packaging producers can take part in this transition, this analysis is set up in accordance with the three sub-questions laid out in section 3.1. It starts with the investigation of the actors ability to implement the design principles into their production, which afterwards leads to an investigation of the different barriers and opportunities for implementing the design manuals, which includes internal company factors, as well as system related factors. Finally, the entire network is taken into account and the effects of other actors on the packaging fillers are investigated in relation to the product design.

6.1 The possible implementation of the design principles and the internal effects related to that process

During the interviews, it became apparent that most of the companies had already taken steps to use more sustainable packaging. Some of the companies had been involved in the creation of one, or both, of the design manuals while others had only heard about them. Thus, many of the design principles described in the manuals were already known to the interview participants. Nevertheless, none of the companies had yet found sustainable packaging solutions for the entirety of their product portfolios, which led to discussions about the implementation of the individual principles and the challenges that arise from them.

Discussing how the companies could comply with the design manuals in detail was not possible due to the large variety of products the companies produce. As a compromise, it was discussed how the companies could comply in a more general perspective to the design principles. Due to the differences between the companies, the products they produce and the packaging they use, not all the principles were relevant. Figure 6.1 shows the design principles that were discussed with the different companies. While the first four

companies are relatively similar to each other, there are larger differences in the last three companies. The main differing company is COOP, who is seen as both a producer and a retailer, and during the interview it became clear that they have many suppliers who produce in their name and thus COOP only sets the packaging requirements but does not have to implement them. Therefore, the interview was used to discuss how the design manuals have affected the company, and how they aim to proceed with them. The last two companies from Figure 6.1 are packaging manufacturers, who do not fill and seal the packaging, thus they were only interviewed about the main component and how they view these design manuals. In order to provide a coherent structure for the following sections, the design principles are grouped into main component, sub-component and labels.

	Design principles	Hanegal	Atria	Tulip	Arla	COOP	Faerch Plast	Sky-Light
Main component	Avoid surface treatment such as silicone and anti-fog, which makes it hard to categorize the used packaging							
	Work with monomaterial	x	x	x	x		x	x
	Prefer PET as material (can be used in an open circuit for food packaging)	x	x	x	x		x	x
	Uncolored or clear plastic is prefered	x			x			x
	Hinge lid on containers for convenience food, so that the lid does not end in the environment							
	Breaking point in the lid hinge, so that the lid can be disassembled from the container, if the label can not be removed							
	Make rounded corners, also along the bottom, so it is easy to empty							
	Wide opening for thick liquids, or possibility for it to stand on ist head, so the liquid can get out easier							
	Make at least one big surface, to support a better grip in the sealing foil							
	Be concerned about the thickness of the product, to avoid bars and other strengtheners, which makes it problematic for empty and clean							
	No printing on the container, only on label				x			
Sub-component	Part-components in same material or completely removable		x	x	x			
	As much as possible use foil-bags which leave a clean main-component							
	Make sure the sealing can be removed in connection with the lid		x	x				
Label	Use plastic labels instead of paper, they are easier to remove	x	x					
	Use glue, which easily gets off, if paper label is needed		x		x			
	Prefer cardboard or paper cover, which leaves a clean packaging	x	x		x			
	Design the label with a big rip-slip, which makes it easier to grab and remove				x			
	Avoid labels on other surfaces than the sub-component, so that only one label has to be removed		x	x	x			
	Provide information about correct disposal (separation and sorting)			x				

Figure 6.1: Overview of the discussed design principles in the individual interviews

6.1.1 Hanegal - Packaging Filler

Hanegal is a small independent Danish company, which has produced organic meats and ready-meals for more than 35 years. Sustainability has been an important aspect for the company since its establishment as they believe that one should produce sustainably. The interview was conducted with the co-founder of the company, who calls herself the chief ideologist. Together with the CEO, she is in charge of all important decisions such as

which packaging material and design should be used. The interviewee was already familiar with the design manuals prior to the interview and presented multiple possibilities of how Hanegal could implement some of the principles outlined in the manuals.

Main Component Design

Hanegal acquires some of its packaging from Færch Plast, who mainly creates food trays with a high amount of recycled material. The decision to use Færch Plast as the packaging supplier was made in order to use more recyclable products. The trays are made out of carbon black PET, which is possible to recycle, however not in the current sorting system in Denmark. Though Hanegal is a bit in doubt about the packaging solutions provided by Færch Plast, especially about them being black PET, they are in the situation of not being large enough to customize their design, which makes it problematic to request specific design preferences.

> *"We are such a small company, that we can not go to Færch and demand to have a triangular pink tray."*
>
> Hanegal (2019, 00:08:18, translated)

Another type of packaging used by Hanegal are foils, which are used for their sausage products. They have asked their supplier to produce these foils in a recyclable material, but Hanegal was told that their criteria were too high compared to the rest of the market - *"We could take what was on the market or not."* (Hanegal, 2019, translated). Following this, they had considered to pack the sausages in trays as well, however, that would have resulted in an "over-packaging" which was, in Hanegals eyes, not a better solution in terms of sustainability (Hanegal, 2019).

Label Design

In regards to the design of labels, Hanegal mentions that they currently use cardboard sleeves for their ready-meals. They were previously considering to switch towards plastic labels for their cold-cuts, however the change would increase the production cost of the products so they would become too expensive as they are under price pressure from the downstream value chain. Thus, they are now researching the effects of using cardboard sleeves for the cold-cuts as well. In relation to labels, Hanegal was also worried that a new design would not be supported by their current machinery and that they would have to invest in a new machine. This would again result in extra cost and could cause interruptions in the production line (Hanegal, 2019).

> *"We have talked about the cold-cuts[...] Instead of changing the paper labels into plastic, then be thinking of using sleeves. What would this then mean, and we are not done researching that"*

Hanegal (2019, 00:58:49, translated)

All in all, Hanegal is interested in the development happening within the Danish waste system, and want their packaging to match what the waste system supports (Hanegal, 2019). They would like to hear a second opinion about the advantages and disadvantages of black plastic to get a better understanding of the matter. Furthermore, Hanegal would like a solution to its foil-packaging, but due to the costs of changing the production they can not promise to change it immediately when a new solution presents itself (Hanegal, 2019).

6.1.2 Atria Danmark- Packaging Filler

Atria Danmark (further referred to as Atria) is part of the Finnish company Atria Plc, who produces food products in the Scandinavian countries, Russia, and the Baltic region (Atria Plc, 2019). In Denmark Atria stands behind the brands 3-Stjernet and Albæk Specialiteter. The company operates two production plants in Denmark but the headquarter is located in Finland. The two people participating in the interview were a procurement manager for packaging for the Atria group, and the Danish quality and laboratory manager. Atrias' main concern is their consumers safety and thus food safety is of the highest priority for them, but of course sustainability is also a huge topic for them.

"The challenge [...] is to [...] reduce packaging, shift to homogeneous types of plastic and still have a product, with high product safety."

Atria (2019, 00:30:41, translated)

Main Component Design

Atrias main focus in regards to packaging is on reducing the amount of plastic overall used in their own products and, alongside, running different projects on sustainability, as reduction is the one aspect whose sustainable effect can not be denied. Changing the packaging is then taken step by step (Atria, 2019).

"[...] the main concern in these projects [...] is reduction. Reduction works no matter how it is twisted and turned."

Atria (2019, 00:47:59, translated)

Most of Atrias products use a packaging which consist of a top and a bottom part e.g. a tray with a foil. Normally the bottom and top part are both made out of PET (Atria, 2019). This means that Atria uses mono material packaging products, but in order to seal the packaging they have to use a non-PET layer to weld the bottom and top part together. This has to be done with a foreign material, which has a lower melting point

as otherwise the materials would melt together and it would not be possible to open it again later.

> *"Yeah, if you look at it now then you could say that when we weld it together, that is where the critical component is when talking about consumer safety."*
>
> Atria (2019, 00:23:22, translated)

In order to transition towards a more circular economy and discover new sustainable solutions, they are searching for other solutions that work with their currently installed machines, as, similarly to Hanegal, it would be too costly to have to change the production set-up (Atria, 2019). In regards to the sustainable projects on the side, Atria has started a pilot project about using mono material plastic foils which contain 60-70% recycled PET from plastic bottles and can be sorted and recycled afterwards (Atria, 2019).

Sub-component and Label Design

The packaging units described above have labels both on the top and on the bottom, where the top label is made out of plastic and the bottom label is made out of paper. The reason for two labels is that they communicate different information, and thus it is not possible to remove one of them (Atria, 2019). A solution for this could be to change the paper label to a plastic label, which would help to improve the recycability of the entire packaging unit. However, this could pose another problem, as it would result in a larger plastic consumption, which would affect the results of a corporate social responsibility (CSR) report, as it would lead to an overall larger plastic consumption. Nevertheless, plastic labels might be the overall best solution because they also increase the recycling possibilities and thus might counteract the increased consumption. In order to make the decision to change the labels, however, all the different effects on the company have to considered.

> *"[...] So if we get measured in a CSR report somewhere, on how much plastic we use, then we would have to reconsider the effect of switching to plastic labels. But it might be that it is the overall best solution. So it is hard to find the right solution."*
>
> Atria (2019, 00:38:26, translated, modified after follow-up talk with company)

Atria also pointed out that there might be some conflicts between the design recommendations by Rethink Plastic and Danish food safety legislation. In the design manual it says that easy removable labels or cardboard sleeves are preferable, but according to Atria the Danish legislation says that the label may not be removable in the store Atria (2019).

Looking through the legislation Atria refers to, it was not explicitly said in the main text that easy removable labels are forbidden, however it said so in the Commissions Q&A.

> *"Mandatory food information must under no circumstances be hidden, covered or divided by other inscriptions or images or other materials. The labels must therefore not be easily removed for the sake of the availability or access to the compulsory food information to the consumer."*
>
> miljø og fødevareministeriet (2018, p.11, translated)

Thinking about the design principles, this would mainly affect the use of sleeves as they can be removed in the store. When the design manuals talk about easy removable labels, it can be understood that the label should be possible to remove without leaving traces or that the glue is dissolvable so that the label can slip of the packaging if it is for example washed, thus it is believed that the easily removable labels are not as much of a problem in comparison to the sleeves. Nevertheless there are already products on the market that use sleeves (e.g. see Figure 6.2 below) so it is not believed to be a major problem. Furthermore, the products that do use a sleeve often use a mechanical folding design so that the sleeve does not slip off during transportation or handling. With a bit of freedom of interpretation, this might be seen as a way to prevent the label from being removed from the packaging and thus comply with the legislation. Nevertheless, in case of a conflict between food safety and sustainable packaging, the food safety should always be given a higher priority.

> *"Then there is some which could be contradicting to these design manuals are this with the labels. Its says something about that you should make them so that they are easily removable, but it says directly in the food legislation that the label which is being put on the product, should not be able to be removed. So you must not be able to tear it off in the stores. Because if you find a product in the stores without expiration date then we have to take it back."*
>
> Atria (2019, 00:40:26, translated)

In general, Atria sees these design manuals as a description of an ideal world. They point out that the manuals lack discussion of how a packaging that follows the outlined design principles may affect a products shelf life (Atria, 2019), which could cause an increase of food waste or have an effect on the transportation as new batches have to be send out more frequently. Additionally, Atria mentioned that it can be challenging to select the ideal packaging because there are many different aspects to consider, such as CO_2-emissions, recycability, and biodegradability, and there is no common understanding about these aspects. For example, the carbon footprint is sometimes calculated without including transportation or energy, which would lead to lower CO_2-emissions and make a product look more attractive than others.

6.1.3 Tulip - Packaging Filler

Tulip is an old Danish company that belongs to the Danish Crown group. Tulip is known for its bacon and cold-cuts, but also produces sausages, meat balls, and ready-meals. Tulip is a quite consumer oriented brand, which is driven by its consumer interests (Tulip, 2019). Their consumers are often very concerned about the climate and sustainability, and always look for solutions that help them live a sustainable lifestyle. For many consumers it is hard to relate to some invisible CO_2 emissions, however, plastic is easier to relate to, thus packaging is of great interest for Tulip.

> *"[..] What is important to the consumer at the moment is climate, and climate can be hard to relate to with CO_2 and CO_2 quotes and how many flight travels is that compared to the other, but what is, in relation to climate, easier to relate to is plastic and accumulation of plastic in nature and in the oceans."*
>
> Tulip (2019, 00:05:06, translated)

The interview was conducted with the category director for fresh meats. The interviewee was not familiar with the design manuals prior to the interview and took a lot of his knowledge about plastic packaging from his previous experience with consumers. When talking about specific design principles, he seemed to refer to products from both Tulip as well as Danish Crown, which has to be taken into account when reading the following statements.

Main Component Design

Tulip purchases parts of its plastic packaging from Færch Plast. Through this they gave a large part of the responsibility of finding sustainable packaging solution to Færch Plast. So far, they have made their trays recyclable by changing to PET trays, but for the future they want to do even more. Some at the company want to work with bio-degradable plastic next, though they should know that bio-degradable plastics are problematic as they can not be recycled together with normal plastic.

> *"[...] the first step, we felt was the right one was to move toward a recyclable type of plastic, and that is also the common thing to do as the first step towards a longer packaging journey or strategy, is as the first thing to get it into a circular process [...] which was also a quite big step to make, with the volumes we are dealing with, to go from not-recyclable to recyclable plastic."*
>
> Tulip (2019, 00:09:29, translated)

One way that Tulip made it easier for themselves to change from PP and PE to PET, was to change all of their packaging trays to PET at once(Tulip, 2019). This makes sense

if one has a large amount of different containers, because, through that, it is possible to reduce the variety and to create a new standard for the company. Furthermore, this ensures that all packaging containers are compatible with the production equipment and thus it is not necessary to invest in a large number of different production lines.

> *"[...] So we have not fx. been able to continue with PP and PE, so it was necessary for us to make a clean cut and change the whole market to PET, because, production wise, we cannot handle both.[...] make the foil stick to the PET trays has not been easy, it has taken quite a bit of work."*
>
> Tulip (2019, 00:23:17, translated)

Sub-component and Label Design

Tulips trays are sealed with a non-recyclable foil. Though they looked for alternative solutions, they so far, could not find a foil that provides the same function as their current solution (Tulip, 2019). Nevertheless, Tulip has thought of other ways to make their products more recyclable. For example they are working on a short guide that gets printed on the labels in order to make the consumer aware and inform him about correct recycling.

> *"[...] furthermore there is consumer information, so we practically can get the consumers to sort these trays and also take the foil of [...]. We are starting to use the pictograms developed by the Danish waste association, which we also will apply on our new packaging, when we will implement it, and it consist of a sorting guide."*
>
> Tulip (2019, 00:20:00, translated)

The interviewee explained that Tulip does not always have the power to decide the specific packaging and label for the products they produce. This is because a large part of their products are sold under different private labels, such as the brand princip which is sold by Salling group (Tulip, 2019). However, for those products that are sold under the Tulip brand, they can influence the design of the label. Most products contain a main component and a foil that seals off the top and at the same time acts as the label. But among the large variety of Tulip products there is also an outstanding example that uses a cardboard sleeve (See Figure 6.2).

Figure 6.2: Packaging example with clear sealing and cardboard sleeve

"Rema [salling group] has their own private labels in this category, where we basically work as the producing unit, [...] an example could be princip in Salling group [...]. We produce and pack, but it is their labels on there."

Tulip (2019, 00:29:55, translated)

6.1.4 Arla - Packaging Filler

Arla is a big Danish dairy company, which produces a wide variety of different products. Arla strives to take the lead with all of its actions pleasing their consumers needs. This mindset is visible by Arla being one of the few interviewed companies who published sustainable packaging targets. The first one being a 30% reduction in CO_2 production by 2030 and to become carbon neutral by 2050 (Arla Foods, 2019). The second target is to aim for 100% recycability by 2025.

"Our biggest CO_2 impact we have is from our products, or the milk. It is the cows in their stables, the gas they emit, the food they eat, the whole process accounts for, I think it is above 80% of our CO_2 impact. [...] This is where the CO_2 is, and that is also why food waste is so important to us, packaging is important because we need to preserve, we need to make sure we don't waste, so this 80-90% of the CO_2 emission is not wasted. So the packaging is very important in that relation."

Arla (2019, 00:09:47, translated)

The interview was conducted with two packaging innovation managers, who work with the design of packaging for fresh products. Due to its size, and impact of their products, Arla has a dedicated department which is responsible for the packaging design development. Furthermore, Arla is a member of the FCPP and has participated in the development of the forums Design Manual, which has been an advantage for them (Arla, 2019) and gives them a different perspective compared to Tulip, Hanegal and Atria.

Main Component Design

Arla says to have already made improvements to its products toward sustainable solutions. As seen in the following quote, Arlas main goal is to **a)** reduce material usage on their products, **b)** reduce CO_2 emissions, and **c)** make recyclable packaging from preferably renewable sources (Arla, 2019). However not every step is ideal yet. For example, the milk cartons have been changed to be 100% made out of renewable material, which means that the PE plastic layer is made out of sugarcane. However, they express that sugarcane might not be the most sustainable choice in the long run and they are working on finding other solutions, nevertheless "it is a beginning" (Arla, 2019).

"We have a whole portfolio with products which we are working on improving, we are trying to make material reduction, which is something we work with a lot, [...] so we have gone from normal PE on our milk cartons, to biobased PE, so now milk cartons are 100% renewable based."

Arla (2019, 01:03:44, translated)

While Arla has corporate packaging targets, the interviewees also mentioned that it sometimes can be challenging to argue for a new packaging design, as, before sustainable packaging was a concern, it was often just seen as a necessary additional cost. The packaging is needed to handle and sell the product to the consumer, especially for Arla who produces a large number of liquid products.

"Well packaging is just seen as a cost of sales [...]"

Arla (2019, 00:24:50, translated)

Arla however has changed from using PS in many of the trays to now using PP because PP has better recycling possibilities, and smaller carbon emission (Arla, 2019). Thus, this change is in line with their overall packaging targets, but recycling should not be the only focus area. One interviewee is as well a supporter of reuse solutions and would like to have a functional return system for reuse instead of recycling.

"Does the system have to be recycling? Why not reuse? Why should I not have a one liter packaging, which can be reused, and if I am a bit smart I would make it so that Rynkeby[3] can also use it[...] We could standardize the one liter packaging [...]."

Arla (2019, 00:17:45, translated)

He believes that reuse would require lower energy consumption than recycling and thus such a reuse system would be the ideal solution for him. However, he also points out some challenges related to the reuse system.
He thinks that Arla itself is not large enough to establish such a system on its own. In order to set up a functional reuse system, Arla would have to invest in a large number of reusable bottles and a logistics system to get the bottles back from the consumers to the production facilities. Due to the high investments, he thinks that it would be better to collaborate with other companies. Through this, it would be possible to share the bottles and the logistic systems and, as a result, reduce the costs for the individual company. The more companies take part in a single reuse system, the easier is it for the consumer to return the product after use and the more might be willing to do it. Furthermore, the

[3] Company: Rynkeby Foods A/S

more bottles are reused, the higher the environmental benefits if the initial assumption is correct.
Another problem that he points out, is that he thinks the marketing department would not be happy about such a system as a uniform bottle design leaves less room for individual design and thus it would limit their available options to differentiate their products from others (Arla, 2019). Nevertheless, the interviewee thinks that this nothing to worry about, as already now, one liter milk cartons seem to have a more or less standard physical design (at least across Denmark), differences can be seen in some using a screw cap and others a tear technique to open it. Furthermore, the print, which can be seen as the label, differs among the different brands and types of milk. The interviewee himself pointed out that if working with such a reuse system, the labels are of more importance and need to be used to personalize and cover up signs of usage, thus there should not be any big problems in the way of a bottle reuse system, as long as the involved companies agree with each other.

Sub-component and Label Design

A large amount of Arlas products are liquid, such as milk and yogurt, many of which are put into cardboard composite cartons or plastic bottles. The labels are then either directly printed on the carton or on an extra foil which gets wrapped around the plastic bottle and creates a shrink sleeve (Arla, 2019). When speaking about shrink sleeves, an example was brought to the table at Arla. They have a bottle of chocolate milk, as seen in Figure 6.3, in a white PET bottle with a colored PET shrink sleeve (Arla, 2019). Due to the easy flow and the positive environment at the interview, a little experiment was started. Looking at the bottle it was tried to apply some of the design principles (see Figure 6.1 above) and develop alternative design solutions. The result was a transparent PET bottle that would be entirely covered with a PET shrink sleeve. The shrink sleeve would have to act as a protection against sunlight, as the UV light could damage the product, and should be easy to remove after finishing the chocolate milk by using a tear strip. However, the interviewees pointed out that such a tear strip might cause confusion for the consumers as in the past it was experienced that consumer sometimes did not understand innovative design solutions and rather get annoyed by them (Arla, 2019). In this example, the consumer should separate the bottle and the sleeve afterwards and it is questionable how many consumers would first of all notice it and then act accordingly. Consumers might either unknowingly or out of convenience discard the packaging as a whole.

Figure 6.3: Mathilde Kakao bottle - Example of a PET bottle with a PET shrink sleeve on

> *"It depends on how far they will go and also how far they can manage to go. We have tried to make different innovative solutions to avoid fx. straws, and so that the consumer should open the packaging in a new way, but it didn't work. [...] if it does not work they will get a scissor [...] So you have to be careful trying to be innovative"*
>
> Arla (2019, 00:04:15, translated)

Another example for labels and sleeves can be found in the Kærgaarden and Lurpak butter trays. The Kærgaarden design has changed from a mixed-plastic tray to a PP tray and a cardboard sleeve, which leaves cleaner fractions for recycling when separating the packaging. For the Lurpak tray, Arla is trying to create a label that dissolves in water so that it can be washed off in the waste treatment process (Arla, 2019).

Participating in the Forum for Circular Plastic Packaging

As already mentioned above, Arla is participating in the FCPP and took part in the development of one of the design manuals. Through this, Arla could not only share its own knowledge about sustainable packaging but also learn from the other participants. However, when talking about the impact of the design manuals to Arlas packaging design, it became evident that the manuals barely influenced the design because the process of changing to more sustainable packaging already began earlier with a project called "Plastic Zero" in the Copenhagen municipality. This project shaped the knowledge about sustainable packaging and started a process in the company which led to taking part in the FCPP and developing criteria for optimal design solutions (Arla, 2019)

> *"[...] we started back in 2010 where our environmental manager had written in our strategy about having 100% recycable packaging [...] that was the first step and in relation to that we started a project with Copenhagen municipality called 'Plastic Zero' and developed the first model of a design manual. [...] and now we are part of the 3. generation of the design manuals"*
>
> Arla (2019, 01:02:09, translated)

6.1.5 COOP - Packaging Filler & Retailer

COOP is a Danish retail company which also produces its own brands, thus COOP takes a double role in the value chain and is both a packaging filler and retailer. COOP does not only sell their own brands, but also buys products from other brands to sell in their own stores (COOP, 2019a). Due to this, it was challenging to talk about specific products because the product design is something that is negotiated between COOP and their suppliers (COOP, 2019a), and thus the interview was more focused on the design manuals in general and how they can be communicated to the suppliers.

> *"We have it produced from one of the producers which is not ours, but the brand on the product is ours. Here we have the muscles to change what we want to change. Of course with respect for the commercial and economical decisions we make, but also to respect the consumers, but there we can change it as we see fit. In regard to this packaging strategy we have said that [...] we want to change around 5000 of our own products, we have dedicated us to change radically sustainable."*
>
> COOP (2019a, 00:07:39, translated)

The interview was conducted with the project manager of the CSR development. Same as Arla, COOP is participating in the FCPP and took part in the development of the forums design manual. Thus the interviewee was very familiar with the design manual from the FCPP.

Possibilities in comparison with the design manuals

COOP is in the situation where their products are produced by other producers but get sold under the COOP brand name. This changes how COOP can influence a products packaging design. Though they have the power to set the overall packaging requirements, they have to talk with each supplier to implement the requirements. Due to the high number of different products and suppliers, as highlighted in the quote above, they have to change the design requirements step by step. For this, COOP takes inspiration from the design manuals and develops their own product-specific manuals for all of their product categories. The problem is that the manuals only talk about the general design principles but in order for their procurers to apply the principles, they need to be more product specific (COOP, 2019a)

> *"It is going to be much more product specific for us. Because the planners or procurers buy goods, [...] and one procurer might be specialized into berries. [...] And a person sitting with this can't just take this design manual and work with it from A to Z, because they don't have the competences to "translate it". [...] So what they need is the easiest and most applicable version."*
>
> COOP (2019a, 00:28:05, translated)

In order to contribute to a CE, COOP has developed a new ambitious packaging strategy for their own brand products to review and optimize the packaging design to a more sustainable solution (COOP, 2019b). This packaging strategy builds up on six measures which they systematically try to implement through the specific design manuals for their own product categories (COOP, 2019a).

1. All packaging should be recyclable
2. Use recyclable materials where possible
3. Use renewable materials if recyclable materials are not an option
4. phase out harmful chemicals
5. Protect products and prevent waste
6. Reduce amount of conventional plastic consumption

(COOP, 2019b)

Participating in the Forum for Circular Plastic Packaging

As mentioned above, COOP is participating in the FCPP and and took part in the development of the design manual. They say that due to this contribution, the design manual does not give them anything new, as many aspects are based on their input to the work group that developed the manual. However, they do implement the design principles in their own packaging requirements, and had begun the process before the release of the design manuals. Furthermore, COOP talks about the advantage of the FCPP, because it creates a dialogue between the different actors and helps to gain an understanding on the design of sustainable packaging. Thus, the FCPP contributes to the knowledge building about sustainable packaging design.

> *"I think they [the design manuals] are fantastic because they are also an expression of the collaboration that start in conjunction with when the plastic federation came to us, relatively early in this, and asked us not to just sit in each our silo and talked about what should happen and what we want. So the manuals where one of the many work groups, where we were working with all kinds of things."*

COOP (2019a, 00:20:33, translated)

6.1.6 Færch Plast - Packaging Manufacturer

Færch Plast is a manufacturer of plastic packaging, which primarily produces food trays and containers out of PET, however, they also use other types of plastic such as PP which makes up around 30% of their profits (Færch Plast, 2019). An interview was conducted with the group technology development director, who though they do not develop new designs, works with new material compositions (Færch Plast, 2019). The interviewee has been a stakeholder in the creation of the Rethink Plastic manual and currently is participating in the next generation of the design manual by the FCPP, thus he had been familiar with the principles outlined in both manuals. As Færch Plast is just a

manufacturer of food containers, they were not asked about sub-components and labels, because they are not in charge of them.

Material Selection for Packaging Design

The interviewee pointed out that for him there are three important aspects to consider when selecting a packaging for a specific product and targeting it to fit a circular economy: **1.)** reduced food waste through extended shelf life, **2.)** food safety, and **3.)** recyclable packaging for more CE.

> *"The real reason for packaging is to reduce food waste[...] Then you have to look at your packaging about food safety, and when these two works then you can look at can you recycle it. It is important to remember these, I call them the three major columns in a circular discussion."*
>
> Færch Plast (2019, 00:13:39)

The interviewee liked to differentiate between a CE and what he called a spiral economy. In a spiral economy, the product can be recycled for the same purpose a limited amount of times before it looses enough quality that it has to be down-cycled to a purpose with lower requirements (Færch Plast, 2019). He explained that PET is the only real circular plastic material because the industry uses a "de facto standard" PET composition due to the large amount of PET bottles, thus the properties of the recycled material are well known. Furthermore, PET can be recycled several times without losing much of its quality as long as it is not contaminated, and it is even possible to regenerate the material and upgrade its quality to comply with the high food safety requirements (Færch Plast, 2019). PP however, only supports the spiral economy because there is a larger variety of material compositions which leads to more variability in material properties. Additionally, PP irreversibly degrades during the recycling process which leads to quality losses and requires the use of additives to compensate for it, thus it should only be used for less demanding applications.

> *"When you melt polyolefins[4] it creates free-radicals, it means its impact strength and the properties are lost a little every time it is being melted. So polyolefins, no matter what everybody says, polyolefins can never be circular."*
>
> Færch Plast (2019, 00:09:12)

When speaking of polyolefins, Færch Plast too, offers the possibility of customizing the plastic material if the customer buys more than 1000 tonnes of packaging a year. This means that the customer can change the standard composition, which contributes to a

[4]Polymer produced from olefins e.g. PE and PP

wide range of different plastics on the market. As it was already pointed out above, this provides uncertainty about the quality of the recycled material and thus can be problematic for a CE system. In the end, Færch Plast does not say that PET is the only plastic material which should be used, as all plastics have their purpose and application area, but when talking about CE then PET is the most suitable material (Færch Plast, 2019). In order to make it easier to select the right plastic type for an application and to understand how it relates to a CE, the interviewee expressed the idea of application based design manuals which differentiates between PET and polyolefins as well as food and non-food applications.

> *"We need a design guide per application, so we need one for PET and we need a design guide for polyolefins food applications, and we need a design guide for the non-food polyolefins."*
>
> Færch Plast (2019, 01:01:55)

6.1.7 Sky-light - Packaging Manufacturer

Sky-light is a plastic packaging manufacturer, who specializes in trays and foils for food packaging. For Sky-light, the customer needs are most important. Thus they have committed themselves to produce high quality packaging solutions, which are made with a high amount of recycled material. The interview at Sky-light was conducted with two participants. One is working with communication and marketing and a participant in different industry networks, such as the Rethink Plastic consortium, which created the design manual for the Danish EPA. The other interview participant is a factory manager, and has responsibility over Sky-lights products, the maintenance of the machinery, and technical development. Due to Sky-light being a packaging manufacturer, the interview only focused on the material and the design of their packaging trays, which can be seen as main packaging components.

Main Component Design

The interview participants did not remember the original reason why Sky-light started to manufacture PET products, but the reason for them continuing to use PET is that PET, unlike polyolefins, can be produced using renewable resources. Additionally, PET's barrier properties are ideal for food products, and according to Sky-light they are better than those of polyolefins.

> *"Well PP is clear oil product, and there is no alternative way to produce it. It doesn't have the same good barrier qualities as PET has, when speaking food. In the beginning of 2015 people started to recycle PET, many of our competitors on the market today, they still only produce from virgin material, and we almost exclusively make our products from recycled plastic."*

Sky-light (2019, 00:07:52, translated)

Sky-light uses primarily recycled PET material, which they acquire from returned PET bottles as well as leftovers from their customers production. Though these sources of plastic are generally of a quite high quality, Sky-light has invested in machinery that can further increase the quality if necessary and, through that, assure a constant material quality. This gives an insight into the actions Sky-light has taken in order to make recycling a possibility for them (Sky-light, 2019).

"[...] to make PET recyclable the plastic needs to be treated. So we have bought plants for this treatments over time, and in these plants we can raise the IV[5], to better the quality of the PET."

Sky-light (2019, 00:25:59, translated)

Sky-light often develops its products in collaboration with their customers, so they can customize the physical design. This gives Sky-lights customers the possibility to create their packaging in accordance with the design manuals, and further it would be possible for Sky-light to provide their knowledge about sustainable packaging and recyclable plastic material in the form of guidance for their customers.

"The design of many of our packaging is made in collaboration with our customers."

Sky-light (2019, 00:02:07, translated)

However, for smaller companies this practise could be a disadvantage, as they buy smaller quantities and thus it is less profitable for Sky-light to customize the design (Sky-light, 2019). As a reaction to this, some of Sky-lights customers have made collective purchases and through that raised the quantity over the required amount for making a customized design. Nevertheless, for smaller companies to make this kind of purchase-collaboration, the group has to agree on a common design for the packaging unit (Sky-light, 2019).

"They need to have a certain size before the customer can customize their products, but we have examples of that some of our units are being sold to multiple customers, or that the customers have a collaboration, and through that have agreed that others can buy that product."

Sky-light (2019, 00:38:58, translated)

[5] Intrinsic Viscosity

Possibilities through Design Manuals

Sky-light has a positive view on the design manuals, because they call for the use of mono-materials and express a favor for PET, which is the material Sky-light uses to produce its products (Sky-light, 2019). However, Sky-light does not see that the design manual has influenced how they manufacture plastic packaging, as they have been working with the same design criteria for some time now. Nevertheless, the design manuals support their previous decisions and help them to further develop in this area.

> *"Don't know if they [the design manuals] radically have affected our production, basically they support the development which we support ourselves, we work with PET, exclusively [...] And this is being highlighted by the manuals, and it is a really good idea to move in that direction, especially for the food packaging, which is the industry we work with a lot."*
>
> Sky-light (2019, 00:04:48, translated)

Furthermore, Sky-light thinks that the design manuals are an important tool in the creation of a circular plastic packaging economy and see them as a boundary object that connects different stakeholders and creates a common understanding among the industry through communication. The manuals can also be used to reach out to politicians in order to make them understand the system and change the infrastructure to enable a CE. For this, Sky-light has previously invited politicians to their company to introduce them to the plastics economy and explain to them how a system suitable for a circular plastic economy would look like.

> *"I see the design manuals as a way to focus on the solutions, and also a way [...] to affect the politicians, and say 'that this is what we need to do, and we need to make some systems, which supports this development'. So it is a tool to enlighten and make nuances and make attention on the possibilities we have which we can just as well get into action and work on."*
>
> Sky-light (2019, 00:52:45, translated)

Similar to Færch Plast, Sky-light does not believe in a 100% circular economy for plastic. They argue that the energy consumption for recycling will, in the long, run be higher than that of a balanced system which used both recycled and virgin material (Sky-light, 2019). The reason for this, is that the plastic loses small amounts of its quality in each recycling process iteration and that the regeneration process for reversing this can be quite energy expensive, and the more often the material gets recycled, the higher the quality losses are, and the less suitable is it for high quality recycling. Sky-light calls this a *slow down-wards spiral*. The spiral model wants to make decisions based on several environmental criteria such as CO_2 emissions, and not just on the amount of plastic being

recycled (Sky-light, 2019). In this model, the plastic properties would also be considered, which lead to polyolefines also being used for food-packaging. However, due to the higher quality losses, recycled polyolefines are more suitable for non-food packaging (Sky-light, 2019).

> *"[...] but we also work with other business models, we work with the circular and something we call spiral recycling. Everything can not be totally circular, and to make all circular does not even make sense, because of the demanded resources on some parameters. Therefore we need the debate about the spiral-business model."*
>
> Sky-light (2019, 00:19:42, translated)

6.1.8 Summary of Implementation Possibilities

This section explored the possibilities in applying the design principles to the products of the interviewed companies. As mentioned in the beginning of the section, it was not possible to elaborate on all the design principles due to the large variety of products produced by the interviewed companies. Nevertheless, the topics most elaborated upon were the material of the *main component*, and the removability of *sub-components and labels*.

Main Component

All the companies have packaging products which are made out of PET, thus in these examples, PET is is an option as a mono-material. Some companies have almost their entire product portfolio packed in PET because it provides ideal capabilities for meat trays and similar products. Other companies also use PP and PE as a mono-material. When talking about the material choices, Arla questioned whether PET is as sustainable as it seems when reading the design manuals, because its CO_2-emissions during production are twice as high as those of PP, which is the reason why Arla prefers PP (Arla, 2019). Tulip and Hanegal however, decided to use PET and in order to be more sustainable and use recycled materials, have chosen Færch Plast as their designer and supplier of packaging solutions.

Both plastic manufacturers produce primarily with PET, and say that it is possible to create a large variety of shapes and quality-grades for it. Both offer customized design solutions for their customers, however this is only possible if the purchased quantity exceeds a certain amount each year, for Færch Plast this is a minimum of 1000t.

A common problem among all packaging filler companies are foils. Some products need a combination of certain barriers and flexibility for their packaging, which, according to the interviews, can only be provided by foils. In order to address this problem, Atria started a pilot project focused on using 60-70% recycled PET in their foils, which they see as

the only possibility to make them more sustainable. Hanegal mentioned that they had considered using trays for their sausages, however that would increase the overall consumption. The total consumption is also a main concern for Atria, who focuses on plastic reduction as its sustainable effect can not be questioned (Atria, 2019). Furthermore, one interviewee from Arla would like to see a functional reuse system because it could save more CO_2 than recycling, however it might be hard to organize the logistics and change the current system.

Sub-components and Labels

When it comes to disassembling the packaging, which often is necessary to separate the different types of plastic used in a product, all companies had some ideas of how it could be accomplished. Tulip thought of printing a recycling guide on their packaging products, in order to inform the consumer of the correct preparation for recycling. A little experiment with Arla showed that it would be possible to change the design and make it easier to separate and recycle while maintaining its functionality, however Arla previously tried to create innovative design solutions to enable better disassembling methods for the products, but they experienced problems when the new design was not understood by their consumers, thus they are a bit reserved towards doing something new and innovative.

Hanegal uses sleeves for their ready-meals, which creates an easily removable label. Furthermore, they have thought of using plastic labels on their foils though this had not been implemented yet as they just began researching the effects of it. Atria has also looked into using plastic labels on their products, however, this leads to an overall larger quantity of plastic usage in the CSR report, and this effect would need to be considered because it would increase the usage of plastic which then would be considered if it is of concern to Atria or if it has little to no effect. Additionally, Atria raised concerns about sleeves and easy removable labels, as they understand the food legislation to demand that labels have to stay attached to the product until it is sold to the consumer.

6.2 Barriers and Opportunities for Circular Packaging Design

In relation to the practical implementation of the design manuals the companies were also asked how the manuals could influence the plastic packaging system. In order to better understand how the plastic packaging system works, it is important to look into all the different actors in the value chain and investigate their role and responsibilities. Through this it is then possible to identify important factors that affect the implementation of the design manuals and which have to be addressed for a successful change of the system. However the interviews were only conducted with some of the actors from the value chain thus this section also relies on barriers and opportunities identified by Hatch & Bloom and VE2 (2018) in the additional report to the Rethink Plastic design principles. At first

the outlined value chain in the additional report was used to collect information about the various actors and afterwards the interviews were used to identify more specific barriers and opportunities.

6.2.1 Barriers and Opportunities identified in the Design Manuals

For the development of the Rethink Plastic design manual, the authors conducted a wide range of interviews with different stakeholders (Lyngsted, 2019). This was done in order to map out the value chain and get an understanding of how and why the actors behave as they do (Hatch & Bloom and VE2, 2018). For this they not only looked into the barriers for each actor to implement better design standards but also looked at the drivers and opportunities for each actor and how they would benefit from a transition towards a more circular plastic economy through circular plastic design (Hatch & Bloom and VE2, 2018). The findings help to better understand the problems throughout the value chain and identify the related actors, as well as, enabling a communication about common goals; they are summarized as barriers and opportunities in Table 6.1.

Actors in the value chain	Barriers	Opportunities
Polymer Producer	Lack of high quality recycling system in DK that complies with strict food safety requirements	Better recycling in DK would require fewer imports of recycled material and impact the price
Packaging Manufacturer	Price is important, multi-layers are used to lower cost while meeting the regulatory requirements	Influence customers to use mono-materials and phase out multi-layers
Packaging Filler	Market pressure makes companies see packaging as an extra cost	Great interest in sustainable packaging (ideology & future legislation)
Label Supplier	Impact of the label is often neglected but it can cause problems for sorting and recycling	Influence customers to use labels that can be removed or are compatible with the sorting system
Retailer	Price driven, higher production/purchase costs mean less profit	Can set packaging requirements as incentive to better design
Consumer	Limited knowledge about sustainability, often price conscious not everyone sorts plastic waste (missing knowledge, ignorance)	Many consumers want to be environmental friendly, symbols and information can educate about correct handling
Waste Collector	Different collection systems across DK (plastic is only sorted in some places), sorting mistakes from consumers	Higher quantity of recycling material as incentive to invest in new technologies, consumer awareness about sorting and recycling
Waste Sorter & Recycler	Contamination through sorting mistakes or mixed plastics	High demand for recycled plastic, clean fractions from closed loop systems are better to recycle

Table 6.1: Barriers and opportunities of actors in the value chain (Hatch & Bloom and VE2, 2018)

The Cost of Packaging

From the different actors it is evident that the price is of a major concern. A closer look shows that it is a factor for all actors related to the production chain. Considering that the value of a product increases the further it gets downstream, it can be assumed that the price pressure originates at the lower end, the consumers or retailers, who might will be unwilling to pay a high price, or want to increase their own profits. However the producers are reliant on the retailers to take their products into the stores, but also reliant on the consumers to buy their product in order to make profits. Thus the actors might

be reluctant towards investments into new designs, production, and materials, as it would increase their costs, which they would have to explain to the retailer and the consumers.

Sustainability as a Driver

A strong emphasis is also put on the interest of sustainability by both producers and consumers. Producers have an interest in sustainability in order to live up to their own requirements and stand out from their competitors, as well as being ahead of possible future regulations. Consumers are concerned about global problems, such as plastic waste in nature, and thus want to behave environmental friendly and search for solutions that allow them to do this. However, many consumers have a limited knowledge about sustainability and might want to do good, but do not know how. Thus it is important to provide a common understanding about state of the art packaging and help the consumers understand this through symbols and information on the packaging.

Production Requirements

Most important in the production of packaging is that it complies with the strict food safety regulations (Forum for Circular Plastic Packaging, 2018b). Thus, not all plastics are suitable for food-packaging. Recycled material for example does not always fulfill these requirements due to contamination and thus might not be allowed to get in contact with food. In order to comply with the requirements, the producers often use a thin layer of food approved plastic inside the packaging, and create the rest of the packaging out of a cheaper material. This however can cause problems for the recycling if the layers are made out of different polymer types. Thus to maintain a good recycability it is important that the layers are made out of the same type of plastic.

Impact of Recycling System

In order to achieve a circular system it is also important to take into account the connection between the recycling and the production. In Denmark there is currently no appropriate system for high quality recycling. This means that companies who use high quality recycled material in their production have to import it from other countries. While there is no supply of recycled material in Denmark there is a decent demand for it. This small supply of recycled material and the large demand can lead to high prices, which would further increases the price pressure on the producers if they want to use recycled materials. In fact the demand can be so high that the price of recycled material can even exceed that of virgin plastic (Hatch & Bloom and VE2, 2018).

6.2.2 Barriers and Opportunities identified in the Interviews

In the interviews the companies were mainly questioned about their ability to implement the principles from the design manuals into their own product design. It soon became clear that all the companies saw it theoretically possible to produce plastic packaging

which would contribute to a circular economy. However the companies' responses to what actually is feasible were often more diverse and elaborated on the entire system and how it affected them. Thus it was decided to categorize the companies answers as SWOT factors, which are defined in Table 5.1 to identify the barriers and opportunities of implementing the design manuals to enable a circular packaging economy. The categorization of the companies responses can be seen in Table 6.2.

Sustainability as a Driver

One of the first things that was mentioned by all the companies was that sustainability is an important consideration for their packaging choices. Many actors saw sustainability as a core value of their companies and recognized that it is getting more important for their consumers. Thus some companies such as Arla and COOP have developed specific targets related to packaging (Arla Foods, 2019; COOP, 2019b) and another has included it into its CSR strategy (Tulip, 2019; Danish Crown, 2018).

The Impact of Size

An interesting aspect was that there were noticeable differences between companies depending on their size. The size of the company determines how much influence the company has on the supply chain. Large companies such as COOP can make requirement to their suppliers and demand them to make changes to their designs or change their supplier in search for the solution they asked for (COOP, 2019a). Smaller companies however experience opposite effects. They often have to compete with larger competitors on a tight market and get turned down by their suppliers when they ask for specific requirement because their purchase is too small (Hanegal, 2019; Sky-light, 2019; Færch Plast, 2019).

Also related to the size of a company are the available resources that can be dedicated for packaging. Larger companies have a team or department working with packaging applications and requirements (COOP, 2019a; Arla, 2019). In other companies it was a bit more unclear of who was responsible for decisions regarding the packaging; the interviews were conducted with a procurer, a quality manager, a category director and an owner of a company. At Hanegal for example the interviewee together with the CEO made the decisions about packaging design without having a profound knowledge about packaging and they relied on the information provided by the supplier to make the decision. In general small companies seem have a harder time to develop their own design solutions and to get them custom made, hence they depend much more on their suppliers.

The Cost of Packaging

During the interviews there were several times mentions of the price as an important factor (COOP, 2019a; Hanegal, 2019; Tulip, 2019). The companies said that it is a hard business, and that they are under pressure by their customers and the consumers to deliver same quality for a stable price. This marked pressure hinders the companies from implementing

Strength	Opportunity
	Large actors have a responsibility
	German EPR system is a role model that can promote sustainable packaging
Sustainability is a core value, good for branding	Market and industry collaborations to share knowledge and development
Corporate goals related to packaging (e.g. in CSR strategy)	Consumer awareness: plastic problem is visible and sustainability is an important aspect, might accept higher prices for better solutions
Large size creates power over suppliers	
Dedicated team/department working with packaging	Appealing politicians for system change and more common infrastructure
	Combination of design manuals would give more specific guidelines
	Investments can turn into a business
Weakness	**Threat**
Small size makes actor dependant on value chain	Unknown EPR system in DK creates uncertainty
High costs for implementation and technical challenges through change of design and production	No consensus about best solution
	Lack of knowledge from consumers
Market pressure, price is an important criteria	Consumer habits (e.g. best price)
Packaging is seen as a necessity and extra costs	Too general design guidelines, lack of product specific requirements
Lack of knowledge for judgment about different packaging solutions, have to rely on supplier	Conflicts of design principles with regulations (food safety, expiration date)
	Lack of common infrastructure for high quality sorting and recycling
Sensitive products demand high quality packaging with specific properties	Risky investments if system is unknown
Complex brand structure with different labels and varying amount of influence	Lack of EU wide standard, risk of incompatibility with other countries

Table 6.2: SWOT categorization of interview responses

alternative packaging solutions, because for those the companies often have to invest in expensive machinery and solve a variety of technical issues to get the production running with a new packaging. For example changing the plastic type requires not just a new input material but often requires a new physical design and new equipment because the material behaves differently, which was the reason why Tulip decided to make a clean cut when changing to PET packaging (Tulip, 2019). It can be seen that the implementation of new designs is a long and costly process which especially for smaller companies can be hard to afford. As a result packaging is often given a low priority and sometimes seen as a necessary extra cost (Arla, 2019), which should be as low as possible.

The Impact of the Consumer

In accordance with the findings by Hatch & Bloom and VE2 (2018) the consumer is seen as an important factor. The companies expressed that many of their consumers are concerned about environmental issues, such as CO_2 emission and plastic waste, but in contrast to the CO_2 emissions, it is easier to relating to the plastic problem as it is visible in the oceans, and in close surroundings and it is a popular topic in the media (Tulip, 2019; Atria, 2019). Nevertheless most consumer do not act accordingly and select products based on the habits, for example the price (Tulip, 2019). This goes along with the fact that many consumers do not know what constitutes sustainable packaging or simply cannot identify it and thus cannot distinguish between the different packaging options. For example bio-degradable plastics are seen as a positive thing by the consumers (Atria, 2019; Hanegal, 2019) though the industry says that bio-degradable plastics cause an issue for recycling and can only be incinerated (Sky-light, 2019; Forum for Circular Plastic Packaging, 2018a). Thus it is important to not just increase the consumers awareness about the problem but also to educate them about the different materials so they can make better purchase choices in the stores.

> *"Some try to convince us that bio degradable materials are the best choice. [...] I'm still being bombed with mails questioning why we need to have our pates in plastic, because plastic is a no-go, and why we are not using bio-degradable materials, I mean there is a lot of questions of that caliber, which indicates that a communication task from the government or other interested, is needed."*
>
> Hanegal (2019, 00:35:02, translated)

Lack of Standards

Another factor that was talked about was the lack of industry standards and agreements. A problem is that there is no industry wide consensus about the best solution. Many believe that PET is the best option, when others think that PP is better. In the design manuals this uncertainty can also be seen, while the Rethink Plastic manual clearly prefers

PET (Hatch & Bloom and VE2, 2018), the FCPP does not declare a preference for any of them, however they point out that PET can be recycled into food packaging application while PP and PE can only be used for non-food applications (Forum for Circular Plastic Packaging, 2018a).

Along with the missing standards in the industry there are also missing standards in the waste management. At the moment there is no common waste collection scheme across Denmark as it is handed by each individual municipality, further there is no high quality sorting and recycling infrastructure that could provide recycled material suitable for food applications. In regards to the recycability of the material the waste management has expressed that they barely have any impact on it. The waste management does not get involved in the design and production of the plastic packaging and in the end has to make the best out of the waste material they get as input to their company site (Kirkegaard, 2019). Though the danish government has agreed to streamline collection and sorting standards for plastic waste (see Table 2.2), Kirkegaard (2019) had not seen that they had decided on how to streamline the waste management yet, thus for far it is just a promise without a solution. However it would be an important decision to make and it would not only help the waste management but also the industry to work towards the same direction.

The Unknown Effect of the Extended Producer Responsibility

Besides questions regarding the implementation of the design principles, the companies were also asked for their opinion about the future EPR legislation, with some companies raising this topic on their own initiative. The majority of the companies had already heard of the EPR and either knew that the legislation has to be implemented until 2024 in Denmark or that it is already in place in other European countries such as Germany. All agree that the EPR potentially is a good policy and that it hopefully will create an incentive for more sustainable packaging designs. Some companies referred to the German EPR system and that they could imagine a similar system being implemented in Denmark (Arla, 2019), however, at the moment it is unknown how the EPR will be implemented in Denmark. Some companies also expressed fear for an EPR tax that will increase the price resulting in them having to pay for it themselves and not getting it redistribute to the other actors also being part of the value chain. Another fear was that there might be discrepancies among the different EU countries, of which recycling system to apply. Arla for example exports a large amount of their products to Germany and England, therefore they fear that each country could end up with a different material preference and then an ideal packaging for Denmark could be categorized less recyclable other countries (Arla, 2019). All of this leads to uncertainties in the value chain, which prevents the companies from further developments and investments if they do not know where to go (COOP, 2019a).

"What I fear a bit is, that we in Denmark with a very small population,

actually decided upon only using PET as plastic material, and then around in our core markets Europe, they decided PP or PE or mix of different plastics as their only plastic material, which would cause us to suddenly have to make a custom production for Denmark, which isn't the same as all the rest we also make."

Arla (2019, 01:21:06, translated)

6.2.3 Summary of Barriers and Opportunities

In general it can be seen that there are several factors that are related to each other. The system creates a loop where the barriers enforce each other. This can be seen when connecting the waste management with the production chain. In order to use recycled material it is necessary to have high quality recycled material but to get that, companies have to use recyclable materials which later ends up as input waste material at the recyclers, and there needs to be a good waste management system in place. The question then is where to start changing the system. During the interviews it was experienced that companies said that, they do not know how to change because there has not been a decisions about the waste management system change yet. At the same time the waste management said that they are also limited in what they can change because they do not have an influence on the materials they receive as input, and therefore are powerless.
In order to implement changes and break up the loop of the system, the opportunities might play a major role. Especially the rising consumer awareness about plastics and their demand for sustainable products as well as the EPR might help to make space for a system change. Nevertheless it is important that this system change is carried by all actors, and that especially larger players with a lot of influence are aware of their responsibility and take a leading role.

"We need to have focus on how we get the plastic material back again and create some more circular stream from the consumers and back again. So we can get this material input back into the industry. That link we have to solve"

Sky-light (2019, 00:40:21, translated)

6.3 Plastic Packaging Network Relations

In order to further understand how the filler companies ability to design plastic packaging for a CE is affected by other actors, a network analysis is used to identify the relations of the different actors to the packaging filler companies. The filler companies are embedded in a complex network structure, that makes it challenging for them to successfully implement changes without considering how they are affected by the other actors in the network (Håkansson and Ford, 2002). Therefore it is important to understand how the different

actors from the three networks are related to the filler companies and how they affect the implementation of the design manuals and thus impact the creation of a circular plastic packaging economy.

> *"[A] company seeking change is always dependent on the approval and actions of others to achieve the change, when introducing a new service, altering a logistics pattern or developing a new product.*
>
> Håkansson and Ford (2002, p.135)

Figure 6.4 shows the business, development, and regulatory network which contain the various actors. All the networks affect the packaging fillers in in their own way, however the networks also overlap and thus some actors can be related to more than just one network. For example suppliers to the filler companies are part of the business network but they might also participate in the development network. Another example is the FCPP, which contains of actors of all three networks.

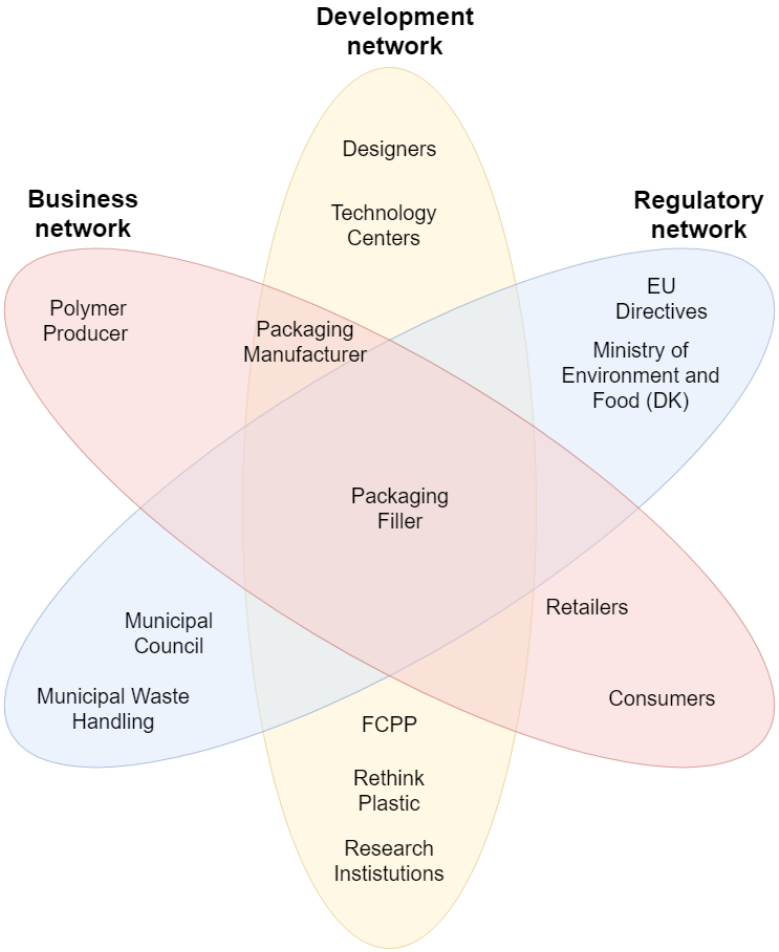

Figure 6.4: The actors that influence the filler companies ability to implement new packaging design, based on Søndergård et al. (1997)

The business network consists of the value-chain, which is connected through exchanges of materials and services. The packaging filler companies are directly connected to their

suppliers such as the plastic packaging manufactures and their customers, the retailers, who sell their products. Through their direct connection they are also indirectly connected to sub-suppliers such as the polymer producers and the end-consumers. However an actor can also take multiple roles such as COOP, who is both produces products under its own brands (Änglamark, Xtra) and sell them in its own stores (Brugsen, Fakta, Irma and Kvickly) (COOP, 2019a).

The development network is comprised of actors that develop new production methods and packaging solutions or come up with guidelines for state of the art solutions. These actors could be designers, engineers, and researchers, who either work for the packaging filler company, one of its suppliers, or an external third party. The design manuals, made by Rethink Plastic and the FCPP, can be seen as an attempt to make guidelines for state of art plastic packaging solutions, build on knowledge from the Danish industry.

The regulatory network which affect the filler companies through various levels of regulations. These regulations are made by both the EU and the national Government. In recent years legislation and strategies related to the use of packaging had been developed which set targets and requirements for the upcoming years (see section 2.4). Besides this there are also quality requirements related to the plastic material which the packaging has to comply with, examples for this are requirements for food safety or the use of chemicals and additives. Other actors in the regulatory network are the municipality and the municipal waste collection. Despite their lack of direct regulatory power over the fillers, they are still important actors for the entire system. The municipalities manage how the municipal waste system is set up and thus have an influence on the collected waste fractions and the waste treatment.

The following sections are going to look at the connections between the different actors and the packaging filler companies. For this analysis the focus is put on the packaging filler companies as they are the actor where all the actions from the production come together and the product is finished to be put into the retail stores and sold to the consumer. The regulatory actors whose relation to the packaging filler is analyzed are the EU and the municipal council who is related to the municipal waste handling. The business network contains the actors which the packaging filler companies have the most interaction with as they are directly connected through the value chain. The actors that are analyzed here are the packaging manufacturers, the retailers and the consumers. Lastly the development network is looked at with focus on the knowledge exchange from the experts in the network to the packaging fillers. The remaining actors that are present in Figure 6.4 are referred to throughout the analysis but they are not directly put in relation to the filler companies.

6.3.1 Relation to regulatory network

The EU and National Government on Extended Producer Responsibility

As stated in section 2.4.2 the EU has recently released an amendment of the *packaging and packaging waste directive*. This amendment contains two major changes being the release of new recycling targets and the introduction of the EPR for packaging waste. While the packaging fillers are not directly affected by the first change, the second one relates to them all the more.
The EPR is a binding EU regulation which has to be implemented into national law at the end of 2024. While this piece of legislation is already implemented in other EU member states, it has not yet been implemented in Denmark, in fact the Danish Government still works on this legislation and for the packaging filler companies, and the entire value chain, it is yet unknown how the EPR will be implemented in detail, and therefore unknown how it will impact them. The relation with the Danish Government is mainly one-sided, while all the companies are affected by the governments decisions, most of the companies have no influence on the governments decisions. While the packaging filler companies generally think that the EPR can bring a change to the current system they also expressed their dissatisfaction about the Danish Governments progress with the EPR. In their eyes the Government takes too long to decide how to implement the plan, and does not involve the industry enough in the process. This waiting for a decision, which would provide a direction for the packaging design, makes the companies unwilling to commit to an given solution because they fear to have to change again once the government has made a decision.

> *"Actions need to be done, and especially political actions, and not just on a national level but also on an EU level."*
>
> Sky-light (2019, 00:29:32, translated)

Another problem that the packaging fillers have with the implementation of the EPR is that it is only explained in general by the EU, which leaves the member states a certain amount of freedom to adjust the legislation. This however can lead to different packaging preferences within the EU member states. As was previously expressed in a quote by Arla, it could happen that the Danish parliament prefers PET and another country PP and PE (Arla, 2019). This example is seen in Sweden, where they now prefer PP and PE (Færch Plast, 2019). As the EPR will be some kind of tariff has to be paid by the producer, Arlas products could be classified differently in different countries, which might lead to extra costs for the company. Alternatively Arla could produce different types of packaging for the different markets, however that is also related to additional costs. Thus the filler companies who also sell their products outside of Denmark are worried that the national EPR might be incompatible.

Municipal Waste Handling

The last actor in regulatory network is the local authority, the municipality. Under the Danish environmental protection act the municipalities council are responsible for the management of waste, whit the minister of environment and food being responsible for establishing the general rules about municipal waste sorting (Miljøbeskyttelsesloven, 2019). Thus, each municipality is alone responsible for the collection and treatment of the waste generated by the households within its borders.
It is up to the individual municipal councils to make a 12 year municipal plan for waste handling, in accordance with the executive order for waste (Affaldsbekendtgørelsen, 2019). These municipal plans specify the sorting and treatment requirements for the different municipalities and describe how the waste has to be collected (Affaldsbekendtgørelsen, 2019). The result of this is that the treatment details are different from municipality to municipality and thus the waste management system varies greatly across the country (Ingenøren, 2019). These differences are an annoyance to the interviewed companies, as it does not support a circular packaging economy.

> *"As long as you have x number of different sorting plants in Denmark and not even the municipalities know what to do and every municipality does it in their own way. It has to start somewhere and it should probably be the government that makes the starting point."*
>
> Atria (2019, 00:45:48, translated)

Through the varying waste management systems some filler companies might have a harder time to commit to a new packaging design that can be recycled, if the sustainable advantage for the society is uncertain because neither the EPR nor the recycling infrastructure is fully established yet, and therefore the product most likely will be incinerated. While the lack of an appropriate recycling system might not stop the companies from developing and using sustainable packaging, it at least does not encourage the companies to take that step. Nevertheless the companies can still improve their packaging design and be above what is currently possible to handle by the municipalities, then they would be ready once the municipal plans get renewed. Tulip, who changed its entire packaging to use PET trays explains the struggle with the sorting system like this:

> *" when we started this, about 30 municipalities where able to collect household waste [...] and then there is the problem with many of the sorting plants they have can not scan these trays, many of which get incinerated. So just switching to recyclable, felt a bit like, that we were a few steps in front of the development"*
>
> Tulip (2019, 00:10:09, translated)

A problem could be that filler companies do not have a direct connection to the municipal waste management and thus they do not have the possibility to influence how the municipalities collect and sort the waste. However the filler companies not only want to know that their packaging material will be recycled, they often also want to use recycled material in their own packaging design and by that involve the recyclers into their supply chain (Tulip, 2019; Atria, 2019; Færch Plast, 2019; Sky-light, 2019). The challenge then is to communicate and coordinate solutions between both the industry and the waste management in order to create a system where plastic material is recycled and reused in high quality. An example for such a connection from recycling to production can be seen at Færch Plast. Færch Plast started to use a large amount of recycled plastic to produce meat trays, however they can not get the necessary amount of recycled plastic, which is needed for their production, from the Danish waste stream. Thus Færch Plast has to import the material in order to keep the production running.

> *"[...] but we have a plastic industry that needs to keep up. So with changing our entire assortment of meat trays in Denmark into recyclable plastic, made it necessary for Færch plast to buy a company in the Netherlands, who collects this plastic. Because we don't do them well enough in Denmark yet. So they haven't been able to get the necessary plastic amounts."*
>
> Tulip (2019, 00:15:33, translated)

This shows that the waste management and the packaging fillers are technically depending on each other, however due to the lack of direct interaction neither of them seem to benefit of this relation at the moment. The packaging filler companies are annoyed that their investment into recyclable packaging is not paying off, if the waste management can not recycle it appropriately and thus they have no incentive to further improve the packaging design other than for their own interest (e.g. Arla with its target)(Arla Foods, 2019), and the municipal waste management, that do recycle, lack the input of recyclable waste to establish a stable supply of recycled material and sell it back to the producers of the packaging materials.

6.3.2 Packaging Manufacturer Relations

Actors in design process

The packaging manufacturers primary function in the supply chain is to produce plastic packaging for the filler companies, however during the interviews it became apparent that they also possess an advisory role in the business network, in terms of physical design and material choice. The interviewee from Tulip says that the solutions they have found to packaging typically came from the packaging manufacturers (Tulip, 2019). The interviewed filler companies have generally expressed that their solutions to packaging are primary created in collaboration with the packaging manufacturer, who reciprocate

the investment in their production service with know-how, about the available solutions for a specific application. The general concerns about plastic from the consumers, made the filler companies focus more on the sustainable and recyclable packaging designs. In order to work towards their goal, the companies can use their relationships to their advantage (Håkansson and Ford, 2002) as shown by an example explained by one of the representatives from Atria that shows how they as a packaging filler have made use of their connections to various plastic packaging manufacturers.

> *"We have big varity of foil producers as suppliers at the moment, and all are working on finding the right solution, and if you ask all about it, they there is many different solutions to that question. [...] Out of the suppliers, I have chosen some strategic suppliers and they give us the bulk of our supply."*
>
> Atria (2019, 00:16:25-00:33:20, translated)

This example above illustrates how different answers to sustainability can be when a filler company asks for solutions from their suppliers, but also that this provides a possibility for tailoring ones sustainability profile. If packaging filler companies use their opportunity embedded in loose coupling, they can choose to collaborate with those companies who provide solutions compatible with the design principles. Through this choice the filler company can create an incentive among the plastic manufacturing companies to work on finding solutions that are in line with the design manual.

Lack of Design Standards

To find a collective solution to standards in sustainable plastic packaging design, the filler companies need to have a well formulated idea about their own packaging requirements. Without such clear requirements, for example some of the design principles, it can be difficult for the company to select the ideal solutions out of all the offered packaging examples, mentioned above. This variety can overwhelm the filler companies, especially those that do not have expertise knowledge about packaging, and can in the end lead to frustrations by the companies.

> *"That is simply a jungle. Also because all these producers in Europe, they don't go in the same direction. [...] Some say that green PE is the way forward, while others think it is mono, other again think it is all about minimizing the amounts of plastic used [...] there are solutions all depended on what you are looking for."*
>
> Atria (2019, 00:35:57, translated)

This lack of consensus in the industry about the focus in what sustainable packaging is, has made it difficult for the fillers to get a clear answers from their suppliers. This means

that the interviewed filler companies generally had to do their own research, which is carried out by the design department of the companies. Without a consensus on what constitutes sustainable packaging within the value chain, it can be hard to make progress. In the example of Atria above with various suppliers the company could simply chose between multiple manufacturers and negotiate from there.

Power Dependency through purchase agreements

Through the purchase of packaging material the filler companies make an economical contribution to the manufacturer and thus have gained some power in that relationship, through which they can pressure the manufactures to work on certain solutions. However, both Sky-light and Færch have expressed that they only work on customized packaging for companies with relatively large orders Sky-light (2019); Færch Plast (2019). Though this also means that if a company only wants to have made a relatively small order of new packaging, either because the company produces relatively few products or it is a new type of product, then there is a barrier of negotiation with the manufacturer, who has higher cost for a new production line and thus might gain less from starting a new small packaging line. An example of this is seen in a quote by Hanegal above in section 6.1.1, where the interviewee said that their packaging order size is under the limit of that which they have to have to be able to customized the design (Hanegal, 2019).

However the different filler companies could also agree on a common goal and through that put pressure on the rest of the business network, especially the packaging manufacturers who are in their supply chain. In that way the filler companies are not only dependent on their suppliers but also have some influence and power. This can be seen in an example provided by Færch Plast, which shows how they came about to focus their production on recycled PET. Færch Plast was pressured to change their production because the packaging fillers, their customers, were asked to adapt to a new design requirement from the retailers.

> *"In 2007 we had no recycled material and branded our product on high quality, we don't compromise on food safety. Then the supermarked said we want recycled material, then we started the development, we were forced into it because the marked started to ask for recycled material. [...] So we started to work with it"*
>
> Færch Plast (2019, 00:53:20)

6.3.3 Retailer Relations

Power and Dependencies

The relation between the filler company and retailers is influenced by the size of the filler, as outlined in section 6.2. The smaller filler companies seem to have are high dependency

on their retailers, while the retailers in return are rather just loosely coupled with the filler companies. This is because the companies need the retailers to sell their products while retailers have more options and could replace a product from one filler company with that of another company. This is well exemplified with an anecdote from Hanegal, which a few years ago started buying PET trays, which are recyclable and made from recycled plastic. However it was not possible to convince all their customers that the PET trays were a better choice, and Hanegal was faced with the choice of either losing their customer, or to keep some of their products in the former aluminum trays (Hanegal, 2019). Changes of the production however could also affect the products price, which is another area where the retailers can demonstrate their power.

> *"We can't necessarily just pass forward a higher prices to the retailers and the consumers. Then the procurers might very well say, that we are free to change, but it must not cost more. That is not uncommon, put a little bluntly"*
>
> Hanegal (2019, 00:15:13, translated)

An example from COOP shows just how much power and influence the large retailers have. COOP wanted to have some changes made to a product they sold in their stores. At first this did not seem to be possible but after they refused to continue selling it in their stores the producers were able to change the product and could reestablish to collaboration.

> *"We were some of the first to have product demands on fluoridated substances, also on products where we are told it is not possible. Fx. with popcorn [...] we simply could not get those without the fluoridated substances. And then we made a statement saying 'we simply do not want it then', and then suddenly they found a solution."*
>
> COOP (2019a, 00:04:00, translated)

These examples shows the power imbalance between the retailers and the producers. However, one should remember that Hanegal is the smallest example of the interviewed companies and a larger actor who has far more products such as Arla might have a stronger position for negotiations, but nevertheless they are still dependent on the retailers to sell their products.

Influence on Packaging Design

This imbalance in dependency can pose a problem for the filler companies, if their visions for sustainable plastic packaging does not aligned with the retailers interests. All of the interviewed filler companies express their frustration about the lack of agreement, which

there is in relation to sustainable packaging solutions. Across the different filler companies, there is an agreement, that recycling is of a high priority, right after food waste and food safety. However the involved actors have different ideas of what the best idea consist of and how it should be achieved.

> *"There are a lot of different retail chains that have their own design manuals"*
>
> Arla (2019, 01:24:52, translated)

This lack of agreement, poses a challenge for the filler companies if they collaborate with different retail chains and they have different design requirements. This was something that was experienced by Hanegal where they ended up using two packaging solutions. However the retailers can also use their power to make the packaging fillers shift towards their requirements, which is what happened with PET.

> *"It is the supermarkets that put pressure on the fillers. The fillers were not really interested in adjusting to PET when it was first mentioned and not really interested but when the supermarkets showed interest, then the fillers suddenly became interested and want to convert."*
>
> Færch Plast (2019, 01:14:29)

Another way the retailers have an influence over the packaging design is through private labels. In that case the product is produced and packaged by the filler companies however the brand it is sold as is owned by the retailers, thus the retailer is in charge of the packaging design and can enforce his packaging requirements. The only way the packaging filler can contribute to the design is through getting in a dialogue with the brand owner and negotiate the design requirements. Examples of this could be seen by Tulip and COOP. Tulip said that they could not freely decide on the label which is used on some of the products, because they are sold under another company's name (Tulip, 2019) and COOP works on the development of category specific design requirements as a baseline to negotiate the design of their home brand products with the producers (COOP, 2019a).

6.3.4 Consumer Relations

The consumer is the last actor in the business network. He/she is the link between the production side of the product and the waste treatment. The consumers have not been interviewed as part of this thesis, but they have been mentioned several times by the interviewed actors, which made it clear that the consumers interest has an influence on the network. The consumers are analyzed by examining the perception that the interviewed actors have expressed.

Purchasing Power

The consumers represent by far the largest amount of people in the business network, as every person in the country can be considered a consumer. Through the sheer number the consumers have quite some power over the network, which they can apply through their purchase choices. The consumers buy products from the retailers, and through that, affect all the actors upstream the value chain, and provide power through economy. They are especially impacting the retailers by choosing a certain retail chain, and also packaging fillers by choosing to buy a certain brand. Nevertheless, in order to have a choice and apply their purchasing power, the consumers also depends on the choices that have been made in the value chain and provide them with different product options.

Consumer Interest

Through the above described power the consumers can express their interests and buy product that are relevant for them. As already mentioned in section 6.2 the filler companies have realized that the environment and especially plastic packaging is of a rising concern among their consumers (Tulip, 2019; Atria, 2019).

> *" [...] So there is no doubt in my mind, that we will see that the next generation and the following one, will have much more focus on [the environment], than we have had for the last few generations. So the pressure will come no matter what, if it doesn't come from the government or the EU, then it will come from the consumers."*
>
> Atria (2019, 00:27:27, translated)

Though the consumers are concerned about the environmental impact of their consumption many do not have a thorough knowledge about plastic and do know know how it related to the environmental problem. This leads to a lot of different opinions about sustainable packaging among the consumers. When Hanegal changed their packaging from aluminum to recycled PET the company was confronted by some consumers about this choice. It seemed that the switch to plastic is in itself controversial for some of the consumers, moreover an interest in making the packaging out of degradable material instead seems to grow (Hanegal, 2019). While bio-degradable plastics might sounds great to the consumer, the industry has its problems with them. Bio-degradable plastic can not be recycled together with conventional plastic. In fact it contaminates the waste stream and needs to be sorted for incineration, thus it was recommended by the FCPP that packaging should not be made out of biodegradable plastic (Forum for Circular Plastic Packaging, 2018a) However this is not widely know by the consumers, thus many still believe bio-degradable plastic to be a good alternative. In general it can be a problem that the public and with that the consumers have different opinions about sustainable packaging solution than the industry, because it could hinder the filler companies from

making the necessary changes and contributing to a system change, if the consumers do not support their packaging choice

"bio-degradable, the consumers think that it means that you can throw it into nature and they believe that a week after it is gone"

Atria (2019, 00:15:56, translated)

Consumer Habits

While the filler companies know that many consumers are concerned about the impact of the plastic packaging, they are not sure how much that would be noticeable in the stores when the consumers select a product. They fear that the consumers would rather follow their habits, such as picking a certain brand or choosing the cheapest price instead of evaluating the sustainability of every product (Tulip, 2019). Further, sustainability has its price, be it the material itself or an investment in a new machinery that has to be paid off, the product is most likely going to be a bit more expensive than the current packaging solution. Thus the companies wonder how much the consumers are actually willing to pay more for sustainable packaging solutions.

" there also need to be a economy in the things [...] nobody here is doing volunteer work, no matter how much we believe in more environmentally friendly packaging in our society. So there needs to be a zero-cost or a minimal bill for the overall value chain, unless the consumers are willing to pay for the entire price increase. [...] how much of that are the consumers actually willing to pay for"

Tulip (2019, 00:26:28.17, translated)

If the recyclable packaging is going to cost more, than the less recyclable packaging and both options are on the marked, then the consumers needs an incentive to buy the more expensive version. The interviewee from Tulip believes that sustainability could give this incentive. Of course the consumers have to be interested in buying sustainable products but when sustainability can be a good marketing factor that can counteract the higher price (Tulip, 2019).

"I actually think that sustainability have actually become the parameters that is used to convince the consumers to buy your product. [...] Recycling, sustainability, low CO_2 impact has become a parameter on line and possibly higher than many of the traditional in the grocery stores"

Tulip (2019, 00:34:35, translated)

6.3.5 The Impact of the Development Network

The development network contains of actors who are rather loosely connected to the packaging fillers. The network is mainly comprised of a knowledge exchange from the actor in the development network to the packaging fillers in the value, thus this interaction is rather one-sided unless the companies actively take part in the network for example in research or in the FCPP.

National Plastic Center for Information

As outlined in the governments plastic action plan in section 2.4.3 the danish government wants to establish a national plastic center, which should be a hub of information related to plastic and communicate advantages and disadvantages as well as state of the art solution to the public and the industry. Such a center is seen to be needed by some of the companies to provide a common understanding within the industry but also to educate the consumer. Hanegal expressed that it is hard to find out what the best solution for sustainable packaging is, and would like to get support from such a center where they could refer to when speaking about sustainable plastic packaging (Hanegal, 2019).

> *"I would like to have a impartial information center which one could link to and say 'here you can find the information which would answer exactly the question you have' [...] there can be different interests, which can make it hard to see through which interest there is in the different manuals"*
>
> Hanegal (2019, 00:42:43.00, translated)

The guidance provided by this center could consist of explanations of the infrastructure for recycling in Denmark, the latest development in packaging design principles, and what there would be recommended in a danish context. These manuals could work as a common ground for creating guidelines for the industry to base their design on. As seen in section 6.3.3 one of the interviewees from Arla mentions that there can be some major differences in how sustainable plastic packaging can be understood by the industry and it is also being mentioned by Hanegal in 6.2.2 that there can be misunderstandings of sustainability from the consumers too, which shows a lack of communication and education for the public.

Impact of Rethink Plastic and the Forum for Circular Plastic Packaging

The problem of many actors having a different opinion about how to produce packaging for a circular economy was also realized by the Danish Plastic Federation (Plastindustrien). That is why they called in actors from all three networks, including politician, recyclers, researchers, NGO's, consultancies, and various actors from the production chain, and created the FCPP, which works on the development of future solutions for sustainable development. A similar initiative was taken by the authors of the Rethink Plastic design manual who founded the Rethink Plastic consortium in relation to the development of

the design manual. These initiatives create a knowledge exchange of the different actors similar to what is planed with the plastic centers and could not only help the industry to get a better understanding about the system but also address the politicians to decide on a direction where the system should go.

The relation of the interviewed filler companies to the FCPP and the Rethink Plastic consortium is twofold. Some of the companies, Arla and COOP, were actively participating in the initiatives and could gain first hand experiences as well as express their own ideas about sustainable design and through that influence the other actors participating. The outcome of the initiates were the two design manuals which, though not binding, can influence a designers opinion about packaging design. COOP calls the design manual a fantastic expression of the collaboration that happened at the FCPP, however, not all the companies talked this positive about the design manuals. The other companies, who were not participating in the initiatives, could not influence the recommendations and design guidelines and as a result they might feel overlooked and a bit pressured having to change their design without being able to have their own interest taken into account. In order to influence the development of the design recommendation the companies would have to participate in the FCPP, however the results are available for everyone so that also those who did not participate can relate to them and include them in their design solutions.

6.3.6 Summary of Network Analysis

Regulatory Network

In the regulatory network the filler companies are influenced by the decisions taken by the EU or the national Government but often do not have an influence on these bodies themselves. Thus the companies expressed concerns about the upcoming implementation of the EPR. The EU member states are responsible for implementing the EPR themselves, but so far it has not been communicated how the government plans to implement the EPR, which makes it hard for the filler companies to decide themselves on a design for sustainable packaging if they do not know what design will be supported by their own country's EPR.
The waste handling is managed at a municipal level. This mean that each municipality has their own waste management system and there are no common waste fractions on a national scale. This does not motivate the filler companies to create sustainable packaging, because most of it can not be sorted and could easily be incinerated. Solutions to this is communication between the industry and the waste management together with a streamlines management system for all municipalities.

Business Network

In general it could be seen that there was a power imbalance in the value chain between the actor who sells a product and the actor who buys the product. The power always arises from the actor who gives the money and then moves up-stream along the value

chain. In the business network this means the power arises at the consumers and from there moves from actor to actor until it reaches the suppliers.

The relation between the packaging manufacturers and the filler companies are of crucial importance. The design of packaging often happens in collaboration between these two, as the packaging manufacturers also act as designers and advisor. This can provide the filler companies with a variety of different design solutions, because their suppliers may have different opinions about sustainable packaging, which can provide an opportunity but also be an inhibitor as it might create chaos and overwhelm the filler companies to make a decision.
In this relation the power is often in the favor of the filler companies as they are the customers of the packaging manufacturers, however this power might be weakened when the filler company is a customer who only makes small orders. Nevertheless, if the filler companies would make agreements among each other on what they would want from the manufacturers, they together could benefit from the power the larger companies already have.

The retailers are in more powerful position than the filler companies. Not only do they buy from filler companies, which already provides them with power, but there is also a smaller variety of retailers (e.g. COOP and salling group) than there are filler companies (e.g. Danish Crown, Arla, Hanegal, etc.), which further increases the power imbalance. As some filler companies produce very similar products the retailers have multiple options to buy a specific product and do not depend as much on a specific filler company. Though the size of the filler company can have a say in the power relation.
Another problem for the relation of retailers and packaging fillers, is that many retailers make their own design requirements, which makes it harder for the filler companies to design a packaging that complies with each retailers requirements. Further if the retailer buys products for their private labels, the filler company have very little to no influence over the packaging design. Through these design requirements the retailers can reach out to a large amount of actors push them to shift towards more sustainable packaging which can also lead to a changing effect for the entire industry.

Due to the power relations explained above the consumers opinion are of high importance to the filler companies. Even though the consumers are concerned with sustainability, this does not mean that they have a large knowledge about it. This can lead to disagreements between the consumers and the packaging fillers in relation to sustainable packaging designs and unfavorable material demand from the consumers, such as the demand of bio-degradable plastic. Hence the filler companies are concerned about whether the consumers would buy their products and for that change their habits or accept a higher price.

Development Network

One of the filler companies expressed their interest in a center for information, to be able to refer to this as the information to use for sustainable plastic packaging. This information center should communicate the latest knowledge of sustainable plastic packaging, put it into relation of the danish infrastructure and help tailor a designs for the different filler companies. The creation of the FCPP and the Rethink Plastic consortium to some extend fulfill the needs of such a plastic center. They combine various actors and create a knowledge platform that should help the industry to get a common understanding and work in the same direction. Nevertheless, not every ones interests seemed to be heard in the FCPP, which might lead to companies feeling overruled. In order to avoid potential conflicts of interest between those companies who participated and those who did not, it might better to have a national plastic center which provides equal opportunities for every actor and can also be used to communicate with the public and conduct further research. To make such a center all the actors in the value chain have to have a say, and the design of the products have to be tailored to a waste management system, which will be agreed upon and then pushed to the politicians. This could also provide the politicians with a plan for how to make the EPR.

Discussion and Recommendations 7

In order to discuss how the companies can overcome the challenges identified in the analysis, this discussion first evaluates to which degree the concepts from the design manuals contribute to making plastic packaging that corresponds to the concepts of circular economy, as defined by the R framework, Bocken et al. (2016) and Ellen MacArthur Foundation (2015b).

Afterwards the findings from the analysis are mapped and then translated into recommendations for the development of a circular plastics economy. These recommendations can be useful for several of the actors from the value chain, and can be understood as possible actions. The recommendations, and the discussion of their circumstances and possible effects, are presented in the bottom of the discussion.

7.1 Design Manuals versus Circular Economy

As described in section 2.4.1 there are many different definitions of CE, which generally focus on the circularity of material flow, by keeping the material in the economy at its highest quality level. In order to explore if and how the principles from the design manuals can contribute to the different facets of CE, they are compared to the prioritization of the R framework. The R framework approach is a well known and widely implemented method of focusing on CE in legislation. As described in section 2.4.1, the EU waste framework directive builds on a 4"R" framework consisting of *Reduce, Reuse, Recycle* and *Recover* although there are also other interpretations of the R framework with up to 9 "R's" depending on the author. Looking at legislation related to waste and packaging waste it is apparent that the highest focus is on increasing recycling by setting higher and higher targets, however they often lack to provide measures for reduce and reuse, which might be because it is harder to legislate as it can not be measured on the same parameters as recycling.

The design manuals are also primarily about how to design packaging for recycling, however the design manual, created by the FCPP, also touches upon some of the different aspects of CE. The FCPP introduces four concepts of CE that should be considered in order to design the packaging for "optimum use and circularity" (Forum for Circular Plastic Packaging, 2018b, p.3). These concepts are *Refuse, Reuse, Reduce* and *Recycle*. While

refuse has not been previously mentioned in this report, it is also often a constituent of the R framework (Kirchher et al., 2017). The concepts of Refuse and Reduce are not explored in depth in the manual, but outlined with a few points. Refuse is described as a direct delivery from the production without the use of any packaging and reduce is described as a reduction of the material quantity used for packaging, which can also be done at the individual packaging level (Forum for Circular Plastic Packaging, 2018b). From a CE perspective these concepts makes sense, though strictly speaking, they do not increase the "circularity" of a packaging. Nevertheless, they help to slow down the production of new packaging material. Putting less plastic packaging on the marked ultimately resulting in less plastic waste being generated. However, the manual does not provide any further information on how to refuse and reduce plastic packaging beyond these points.

The remaining two concepts are much more prominent in the design manuals. However, only the FCPP explicitly refers to the concept of Reuse; the design manual by Rethink Plastic only focuses on recycling. The following two sections elaborate in detail how Reuse and Recycle are understood in the design manuals, and how they could contribute to a circular economy.

7.1.1 Design manuals on reuse

Reuse is a subject that has been outside the scope of the analysis, and thus it was not investigated to which degree Reuse can be addressed by the actors in the various networks. The manual does not describe how reuse strategies should be implemented in detail, it provides a non-exhaustive summary of four concept ideas for reuse, which can be seen in Figure 7.1. The outlined concepts for reuse are "**To go**", "**Sold loose**", "**Packaging for carrying**" and "**Return system**". These concept are targeted at different product categories and specific applications.

The Concept of "To go"

The concept behind "To go", aims at packaging for beverages like coffee, where single-use paper cups could be replaced by a coffee mug or reusable plastic cup. In order to reuse the packaging, the cup should be easy to empty and wash and either stay at the retailer or be handed over to the consumer with the purpose of being reused.

Such a concept would be implemented as an individual adaptation (Ellen MacArthur Foundation, 2015b), where a single company implements these reusable cups, which their regular consumers could use in order not to buy a new cup for every coffee they buy. This could be a useful way of *"slowing resource loops*" as defined by Bocken et al. (2016). In other words, this would be a way to reduce the amount of new material that is put on the marked. It is however, not clear from the concept whether this is intended for a single company or if it is meant for multiple companies, which would have different effects.

A single company, employing this concept, could use it to create an incentive for its

	Input materials	Main component	Sub-components (Closures, lid, inserts, seals)	Decoration (Cover, print, glue and labels)	Emptying/ washing	Examples
To go 	Shall tolerate washing to a suitable degree.	Sold by a shop and taken away by the customer from time to time	Lid should be separable but kept together with the container	Shall not be possible to wash off label/ printing	Easy to empty and wash	Coffee mugs, e.g. at Circle K and Starbucks
Sold loose 		Customer takes along the packaging. Or packaging can be bought in the shop			Easy for the user to empty and wash	Packaging-free supermarkets
Packaging for carrying 	Shall have sufficient thickness and reinforcement of handle to be used again and again	Customer takes plastic bags back to the shop - used bags are taken back by the shop or collected by the municipality	The same type of plastic as the main component	The same type of plastic as the main component	Not relevant	Plastic carrier bags
Return system 	Shall tolerate washing to a suitable degree.	Packaging is dropped off in the shop. The shop washes it or sends it back to the food producer, which handles washing.	Lids should be separable Eventually lids shall also be collected and a minimum recycled	Shall be washable up to 65°C	Easy to empty and wash	Return system

Figure 7.1: Concept for reuse made by Forum for Circular Plastic Packaging (2018b) as shown in Reuse and recycling of plastic packaging for private use.

consumers to come back to their store, for example through a discount when they bring back the cup. However, being company specific could also have a constraining effect on reuse. If the reuse-cup could only be used at one specific store or at stores of a specific chain, then the consumer would be reliant on this one store, or chain, to reuse the cup, if the company refuses to reuse a competitors cup, or if the incentive is then not given anymore. This could be avoided if for example all coffee stores fill cups, regardless of where they come from, and possibly give a discount for not using a single-use cup, which would also benefit consumers who bring their personal reusable cup.

One way how this concept could play a larger role in a circular economy would be through what Ellen MacArthur Foundation (2015b) calls "*single-industry pooling as a service*", where the industry creates an industry wide standard, through which it could be possible to establish a system, such as a return system, that makes it more viable for the consumer to support the reuse concept. An example of this can be seen in various cities across Germany, where a company has established city-wide return systems based on a deposit scheme for all coffee-shops to participate (rec, 2018).

The Concept of "Sold loose"

The sold loose concept is based on the consumers taking their own packaging along or buying it separately at the stores. In contrast to buying individual packaged food, the consumers would fill up their own packaging, with the amount of product they wish to purchase. A side-effect of this is that the consumers buy as much as they need and might have less leftovers that could go bad and end as food waste. This concept has the potential to eliminate a lot of single use packaging, as the items are not individually packaged and the consumers could reuse their packaging multiple times. The concept in itself would be a good idea from a CE perspective in terms of *Slowing resource loops* by minimizing the amounts of plastic used for packaging and having the plastic that is used for packaging last longer.

However, the sold loose concept also comes with some obstacles in terms of logistics, handling of items, and food safety. Simply applying this concept to all products might not be possible for a large retailer with several thousand different products. Further packaging is often needed to preserve the food, ensure food safety and increase the shelf life. Dry foods and vegetables, might not significantly have their shelf life affected from being stored and sold in this fashion, but theinterviewed packaging fillers all have foods, which rely on the packaging to seal the food from contaminants and some of their products.

Thus this concept often focuses on niches. For example it is used in packaging-free supermarkets which have a smaller product portfolio than COOP, but it can also be used in specialty stores that sells fresh products for early consumption such as vegetable stores, bakeries, and butchers. Nevertheless, in order to sell loose products the retailers are reliant on the active participation of the consumers, as they have to bring their own packaging with them, which can be an effort in some situations or for some consumers. The consumers might also have to change their habit in relation to how long a product last, because without packaging there are no barriers that preserve the product. Further it is also not enough to just sell the products loose to the consumers, the retailers also need to acquire the product loose or at least in bulk from their suppliers, as else the packaging saved at the consumers could arise at the retailers.

The Concept of "Packaging for carrying"

The concept of packaging for carrying refers to shopping bags that are widely used by the consumers to carry their purchase. Many bags only get used once and often show signs of wear and tear afterwards and get discarded. To avoid this and make them reusable the bags should be made out of a stronger material that withstands multiple uses. Further all components should be made out of the same material. In order to increase the reuse potential of plastic bags they should be taken back to the store or the municipality, however the concept in the manuals does not explain what exactly should happen to them. An incentive for returning the bags could be deposit system, similar to how it is done with bottles. An example could be COOP, who has implemented a 1 DKK deduction when coming back to the store and using a COOP plastic bag from a previous purchase (COOP, 2019a).

The Concept of "Return system"

The return system concept is a circular system for packaging, where reusable packaging takes the place of single-use packaging. The packaging needs to be durable, easy to wash, and should be returned to the store or collection spots after use. Just like the "to go" concept this could slow the resource loops as it would mean that the plastic material is used for longer. Depending how often the packaging is reused and how much materials is needed in comparison to single-use packaging, this could significantly reduce the amount of plastic waste, although it is not possible to predict how much as not concrete example was provided by the FCPP. An example that was previously outlined in section 6.1.4 and that would fall into the return systems is the reuse system that was talked about by Arla. Nevertheless, this system is reliant on the involved actors to adapt their business model and the consumers to play their part and return the packaging, though this should not be a problem as consumers are already using return systems for soda bottles just that those are recycled and not reused. In order to implement a functional return system might require the industry to collaborate in a multi-industry pooling system (Ellen MacArthur Foundation, 2015b). So while the system may initially require some will from the actors in the network, or maybe even some legislative initiative, it could potentially be a working closed resource loop, system for packaging, but only if the packaging is manufactured in a way that is sustainable for recycling.

7.1.2 Design manuals on recycling

Both design manuals are focused on increasing the recyclability of plastic packaging, however it is interesting to elaborate on how the individual design principles can contribute to a circular economy. For this the design principles from Figure 7.2 were to compared to slowing and closing the resource loops as described by Bocken et al. (2016) in "Product design and business model strategies for a circular economy".

The focus of the principles, which the two design manuals have in common, are to make

		Mentioned by:	
	Design principles	**Rethink Plastic**	**Forum**
Maincomponent	Avoid surface treatment such as silicone and anti-fog, which makes it hard to categorize the used packaging	X	
	Work with monomaterial	X	X
	Prefer PET as material (can be used in an open circuit for food packaging)	X	
	Uncolored or clear plastic is prefered	X	X
	Hinge lid on containers for convenience food, so that the lid does not end in the environment	X	
	Breaking point in the lid hinge, so that the lid can be disassembled from the container, if the label can not be removed	X	
	Make rounded corners, also along the bottom, so it is easy to empty	X	X
	Wide opening for thick liquids, or possibility for it to stand on ist head, so the liquid can get out easier		X
	Make at least one big surface, to support a better grip in the sealing foil	X	
	Be concerned about the thickness of the product, to avoid bars and other strengtheners, which makes it problematic for empty and clean	X	
	No printing on the container, only on label		X
Sealing	Part-components in same material or completely removable	X	X
	As much as possible use foil-bags which leave a clean main-component	X	
	Make sure the sealing can be removed in connection with the lid	X	X
Label	Use plastic labels instead of paper, they are easier to remove	X	X
	Use glue, which easily gets off, if paper label is needed	X	X
	Prefer cardboard or paper cover, which leaves a clean packaging	X	X
	Design the label with a big rip-slip, which makes it easier to grab and remove	X	
	Avoid labels on other surfaces than the sealing-surface, so that only one label has to be removed	X	
	Provide information about correct disposal (separation and sorting)	X	

Figure 7.2: Summary of design manuals for plastic packaging based on Rethink Plastic (2018) and the Forum for Circular Plastic Packaging (2018b). This figure explains which design principles the different manuals include. The grey color indicates "Material choice", and the blue indicates "Product design".

the composition of the main component, sealing and label out of materials that can be recycled in separate plastic fractions. For those materials that can not be recycled, the principles proscribe that the design should be made in a way which the components, that aren't compatible with specific recycling methods, or consist of multiple mono-materials, are possible to separate from the components that are recyclable.

The goal of the principles is to make plastic packaging products, which ends up in the waste stream, suitable for recycling, because of their mono-material design and component seperation possibilities. This strategy, if implemented, could be part of the solution to solving the challenge of making packaging suitable for a CE, that can be recycled through secondary recycling processes. And it would also eliminate "monstrous hybrids" as Braungart and Donough (2002) calls products which consists inseparable components that needs to be recycled in biological and technical processes respectively.

One of the core principles of CE is to ensure a high material quality that it can be used for production again, after its functionel periode, as briefly described in section 2.4.1. In order to repeat this process as much as possible, the aim is that *"the "waste" resources are to be recycled into material having properties equivalent to those of the original mate-*

rial" (Bocken et al., 2016). This is not possible to do with secondary recycling, as even after municipal sorting, some sort of contamination will remain, if it have been soiled in chemicals household waste.
The plastic material will over time lose its quality per recycling process subjected to. Adding the effect of degradation to the plastic material, means that it will eventually be necessary to use the material for other purposes than packaging for food (Andrady, 2015). The material might still be useful for production of other products, with less restrictive requirements. This process is called downcycling and will eventually result in the material being of unusable quality, where best option for material use could be incineration. In this way the recycling of plastic packaging cannot become a closed loop, but a slowed and narrowed loop, as the same material is used several times.
One way of slowing the loop, which is implied but not explicitly stated in the design manuals, is to make the packaging from recycled material, having principles for how recycled material could be used could be used in the packaging. An example of how this could be done is, using rPET for trays and making an internal lining of virgin PET on the inside (Færch Plast, 2019). Guidelines like this would open the possibility for companies to consider how they can use recycled plastic in their packaging, and through that add more circulation or loops to the plastic materials lifetime.

7.2 Recommendations for the plastic packaging value chain in order to increase a sustainable use of plastic packaging

During the analysis a few elements of recommendable points were illuminated. These recommendation are generally meant for the authors of the design manuals, in order to optimize the information given in these manuals, however the recommendations can also be useful for other actors related to plastic packaging (see Figure 2.5). This section consist of three recommendations presented in the list below, following the list each recommendation is discussed in relation to sustainability.

1. If possible, use PET (virgin/recycled) for food products, if PE or PP is needed, then only use virgin material. Use recycled PE and PP only for non-food products. If not possible to comply with mono-material design, use other resins than PE, PP and PET, to keep waste fractions clean, see Figure 7.3.

2. Create a collaboration in Danish plastic industry to streamline design, utilize resources and create national state-of-the-art.

3. Include reuse as a possible system for better sustainable packaging, and elaborate on what companies would have to do in order to implement such a system. Provide examples of how systems like this would function.

7.2.1 Product Category Standards

From the interviews it was understood that the design manuals are not specific enough in some areas. One of the areas were it was kept too general was related to the use of mono-materials. The interviews discussed that different plastic types have to be used for different applications, but that this does not become clear from reading the design manuals. From both the interview with Sky-light as well as Færch Plast ideas of how to innovate the recommendation to use mono-material had been developed.

Færch Plast mentioned that they had created their own design manual (Færch Plast, 2019)[6]. When talking with the interviewee about the recommendations made in that manual, it became clear that mono-materials alone are not everything, moreover, it also needs to be distinguished between different application purposes. He explained that it is a problem that PET, PP and PE are all being used for both food and non-food packaging products, because plastic that was formerly used for a non-food applications could absorb chemicals that are not allowed to get in contact with food. Therefore the plastic has to be not only separated by polymer type but also by application type in order to achieve a high-quality recycling, and reuse the material in the food chain. The interviewee also explained that due to the recycling properties (see more in section 6.1.6), PET should be preferred for the set-up of a high-quality recycling stream. Separating between the different polymer types to get a clean PET fraction is theoretically possible with the right machinery, however those machines are not possible to distinguish between food and non-food application. In order to reach this clean PET fraction and have it be usable for food application after recycling, he suggest to use PET only for food application. PE and PP can still be used for food products, however, when being recycled their application should be restrained to non-food products, due to the quality issues occurring during the recycling. Figure 7.3 shows how this idea should be look like. This idea is also supported by Sky-light, who argues that this system represent a spiral system instead of a complete circular system, which is a realistic alternative for a circular economy in a danish context (Sky-light, 2019).

Research on product design and source separation of danish household plastic waste by Eriksen and Astrup (2019) showed that plastic waste in Denmark is contaminated with various chemicals and is currently not undergoing high-quality recycling due to its exposure to chemicals in the waste stream. Eriksen and Astrup (2019) argue that this causes problems for a circular system because of the high requirements regarding food packaging, which is the same argument used by Færch Plast an Sky-light.

This research further recommends that if a packaging has to be made out of multiple layers of different plastic types, it should be made out of plastics other than PET, PP and PE (Eriksen and Astrup, 2019). This is recommended in order to keep the waste fractions for PET, PE, and PP, the recyclable plastics, clean and avoid accidental contamination

[6]The direct citation to the Færch Plasts design manual can not be made because it has not been published

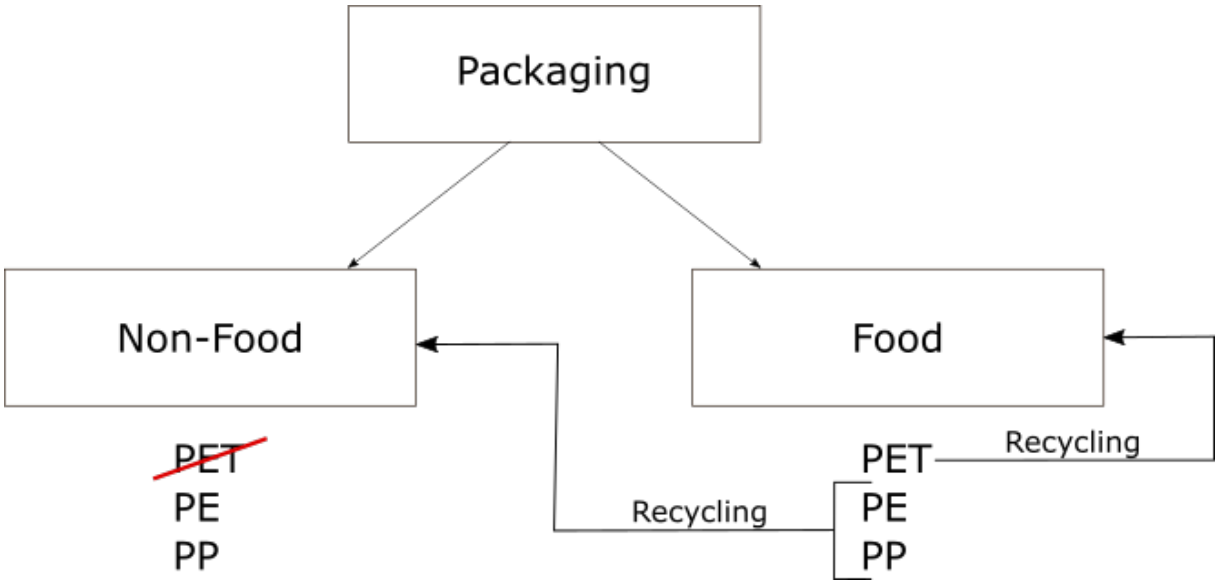

Figure 7.3: Caption

due to only scanning on surface of the product and thus sorting it accordingly (see section 2.2.2). Multi-layered plastic is unsuitable for recycling and by using a polymer type that is not separated for recycling the multi-layered plastic will end up in incineration. Though incineration is not a desirable option for a circular economy it might lead to cleaner fractions of the other plastic types and thus could lead to a better recycling of those.and possible to incorporate into a circular system.

> *"[...] In cases where packaging products cannot technically be produced with a single polymer, due to specific functionality requirements, the product should be produced in polymers other than PET, PE and PP, so that they will not end up in the recyclable PET, PE or PP stream and contaminate the plastic going to recycling. However, this should only be allowed when strictly necessary, so that the packaging producers do not just shift from PET, PE and PP to other polymers."*
>
> (Eriksen and Astrup, 2019, p. 171)

This leads to the first recommendation:
If possible, use PET (virgin/recycled) for food products, if PE or PP is needed, then only use virgin material. Use recycled PE and PP only for non-food products. If not possible to comply with mono-material design, use other resins than PE, PP and PET, to keep waste fractions clean, see Figure 7.3.

7.2.2 Collaboration in the Plastic Industry to achieve better National Recycling

In this report the opportunities and barriers for better recyclable plastic packaging were identified from the perspective of the design responsible. During the interviews it was mentioned that there is a trend for companies to create their own design manuals, both by companies that where interviewed for this research as well as companies who were not.

> *"There are a lot of different retail chains that have their own design manuals and solutions"*
>
> (Færch Plast, 2019, 01:24:52)

One example This example lead to the presumption that there exists many different design manuals in Denmark. Another example of unofficial design manuals are those developed by Færch Plast and COOP. Færch Plast is doing its own design manual, because they experienced that they needed scientific answers for their costumers when defending PET being a good recyclable material (Færch Plast, 2019). COOP is making more product specific design manuals to give to their purchaser and hand out to their suppliers to translate the rather general design principles from the FCPP into specific design requirements for each product. If there are differences between the different design manual it could potentially harm the success of creating a streamlined plastic packaging design.

> *"Our customers are starting to read this design manual or design guide and they have started to ask questions, because the design guide tells them that PP is one of the best material to use [...] So it was actually to have a more serious answer to our customers that we started to work with our own design guide."*
>
> (Færch Plast, 2019, 00:57:39)

Færch Plast is participating in the FCPP, and contributed with their knowledge to the creation of the design manual(Færch Plast, 2019). The interviewee mentioed that the manual he is working on for Færch Plast, has a lot of the data which is going to be used in the revision of the manual by the FCPP, which shows that more research is conducted in order to back up the arguments they stand for (Færch Plast, 2019). The examples of making own This example of making ones own design manual, is understood as a tool to retrieve more knowledge on the area, to argue for ones own case. This knowledge could then be brought to the table of the FCPP with companies who have other interests to be discussed among them. If this is the case, it is an example of a design manuals which does not harm the streamlining of plastic packaging.

COOP is making a design manual as well, but this one is not for the industry but only for internal usage. The reasoning behind this manual comes from how the current design

manuals look, which is being referred to in 6.1.5. The COOP interviewee said that the design manual from the FCPP is not specific enough for him to give to the different procurer, which they have in COOP. He mentioned that knowledge about sleeves and the regulation on packaging is not necessary something that they possess, and therefore these manuals have to be translated into their language, which is going to be very product specific (COOP, 2019a). This example of making a company design manual seems to be justified because it is for internal use, and based on the knowledge from the design manuals.

As seen above the reasoning for making ones own version of a design manual can differ, and when asking the companies why they thought companies were creating their own versions of a design manual for plastic packaging then Sky-light had some ideas. Their idea on this matter is that either, the companies want to be credited for coming up with the right solution on the recycling problem, or it shows that there is some disagreement in what the design manuals are prescribing (Sky-light, 2019).

> *"It is almost like it has become a trend in this industry, that it is all about who comes first with something new about sustainability."*
>
> (Tine Brødegaard Hansen, 2019, translated)

That the companies create their own design manuals does not have to be considered as something that is affecting recycling negatively. It shows that the companies are considering how circular plastic packaging could be designed, and further, it also shows that resources are being spent on development and it creates a platform for finding new undiscovered solutions. If the goal of streamlining the plastic designs to create better recycling of plastic packaging, should be taken into account, the trend of making one's own design manual, as a company, should be changed into something which would benefit the overall goal, and not disrupt it. The bad effect of making a lot of different design manuals is, first of all, that a lot of resources are scattered into many different small projects, secondly it makes it hard to make any agreement on what these plastic packaging designs should consist of, and thirdly it makes it almost impossible for politicians to create an infrastructure to support the plastic packaging design, which is inhibiting recycling development in itself. This problem was discussed in the company interviews, and some ideas were developed.

In the recommendations and actions (see section 2.4.3), the FCPP mentions a plastic center, which should become the epicenter of plastics in Denmark (Forum for Circular Plastic Packaging, 2018a). Hanegal talks about the benefits to have a center in Denmark which would be able to give recommendations on plastic packaging based on state-of-the-art knowledge and focused on that specific companies plastic usage and barriers (Hanegal, 2019). A center for plastic in Denmark provides the possibility to host a forum for a collective national design manual. This forum should merge with the FCPP and the

companies included in the Rethink Plastic consortium. All the stakeholders interested in creating design manuals should be invited to defend their design ideas, and become member of the forum. This would create a forum which would streamline the design principles for plastic packaging, it would possibly collect the different resources used in creating these design manuals and it would with this danish design manual create a danish state-of-the-art in circular plastic packaging design. If the national design manual was to be followed by most actors in Denmark, it would also be easier for the packaging fillers to implement its design principles, as the greatest obstacle to implementing the design principles, is the different priorities of design principles through out the supply chain.

This leads to the second recommendation: Create a collaboration in Danish plastic industry to streamline design, utilize resources and create national state-of-the-art.

7.2.3 Higher Incorporation of Reuse in Design Manuals

During the interview with Arla the topic of reuse instead of recycling had been raised. Reuse is a concept which is also mentioned in the design manual by the FCPP, but the information provided about it is rather limited as was seen in section 7.1.1 above, and non-existing in the Rethink Plastic design manual. How a reuse system could prove beneficial is not elaborated in detail, and from the look of the design manuals it looks like the reuse concept is not taken too seriously yet.

Speaking with the two innovation managers from Arla, it was discussed whether the focus on recycling is the right solution and if reuse should be more incorporated into the design manuals (see also section 6.1.4). It was mentioned that for a functional reuse system Arla would have to collaborate in a "single-industry pooling as a service" system as described in section 7.1.1 above.

The interview with Arla it is also mentioned that the government was involving the recyclers in order to develop a new national waste management system (Arla, 2019). Though the recyclers are a valuable stakeholder in this discussion of possibilities for a more circular economy. Not including other actors from the business networks, may fail to include the interest from the production and use side, as an example implementing a reuse system for different packaging products may not be a solution that is thoroughly considered by recyclers as it does not interact with their business. It can not be confirmed that the lack of reuse is caused by this, but it could be interesting to investigate how a reuse system could benefit the sustainable factor in comparison to recycling,and which possibilities a mix between the two systems would provide.

This leads to the third recommendation: Include reuse as a possible system for better sustainable packaging, and elaborate on what companies would have to do in order to implement such a system. Provide examples of how systems like this would function.

Conclusion 8

This project was conducted to research *how companies producing and using plastic packaging can overcome the challenges of designing plastic packaging for a circular economy.* This was done in two parts. First, the three sub-questions were used to form the analysis, and afterwards, the discussion was used to discuss how the design manuals contribute to a circular economy and formulate recommendations based on the previous findings. In the following each sub-question and the main findings are presented again.

1.) How can the principles from the design manuals be implemented into the design and manufacture of plastic packaging?

In relation to assessing the companies ability to implement the principles from design manuals, created from *Rethink plastic* and *Forum for Circular Plastic Packaging*, there was a common understanding that mono-materials are implementable in many product relations, and when it comes to separation of components or sealing, this is being researched by most the actors.
All the interviewed filler companies produce some products in PET, but some of the actors choose PE and PP, where they argue for either the higher CO_2 emissions connected to PET production, or because PET would complicate the design. Foils, made from mix-plastic, is hard for some of the filler companies to replace with mono-materials, because of the barriers and properties these mix-plastics provide. Solutions on this matter is wanted in the industry.
All are investigating the best options for making their products components easy disassembling. At Arla there was a few examples of innovative designs, which was not understood by the consumers, therefore this is being done with care. Some research is being done on the use of plastic labels, in order to produce them in mono-materials. However the usage of plastic labels can to some extent be influenced by CSR reporting on the usage of plastic. Therefore evaluations on priorities is being done in some companies. Some companies are experimenting with sleeve designs, others do not think that these are corresponding with danish regulations, and have therefore not chosen this solution.

2.) What are the barriers and opportunities in implementing the design manuals?

Barriers and opportunities, from the perspective of the filler companies and packaging manufacturers, are identified in table 6.2, followed by a description of the connection between the different barriers and opportunities to create a coherent understanding of

them.
In general, the barriers seem to enforce each other, which can become a problem for the different actors in the value chain. Communication between product design and waste handling is not being accomplished, but have a high importance to make a sustainable plastic packaging design, and this therefore results in a relatively low plastic recycling compared to the possibilities. A reason for the lower importance of the plastic packaging design for better recycling, is because packaging once was only seen as an necessary cost, and therefore it was seen as a low priority, but this is changing. Consumers seem to want more plastic recycling in Denmark, which means better plastic designs, because of their concern of plastic waste, and therefore some of the companies in this research are using their sustainable designs in their CSR report and with branding.

3.) How is the packaging fillers ability to design plastic packaging affected by other actors?

The actors in the network have been categorized by the network we have appointed them, as described in the theory of *Network analysis* in Søndergård et al. (1997).

In the regulatory network the EPR and non-streamlined waste fractions place a role. The EPR have not yet been planned by the government, which makes it problematic for the filler companies to make a decision on their plastic packaging designs. This goes hand-in-hand with the non-streamlined waste fractions, which makes it difficult to make plastic designs which is going to fit all the different municipalities in Denmark.

In the business network power imbalance was a repeated barrier/opportunity, where the power begins at the consumer to the retailer, and then goes from actor to actor up-stream throughout the production chain to the packaging manufacturer (see figure 2.5).
The design of plastic packaging often happens in collaboration between the filler company and the plastic manufacturer, which provides the filler companies with opportunities in design, because the solution to a sustainable plastic packaging design differs from manufacturer to manufacturer. This however can also create chaos for the filler company, because it can be hard to know which design is best. For filler companies it could prove beneficial to make a collaboration, between them selves, to demand a common solution from the plastic manufacturers.
The power imbalance between the retailer from the filler companies are even stronger, because the large amount of filler companies, in comparison to the amount of retailers, makes it easier for a retailer to replace products, if he pleases. Retailers commonly have their own private labels, which transfers the packaging design to the retailer. Some retailers have created their own design manuals, which makes it harder for the filler companies to create packaging which comply with the specific retailers demands. Because of the possibly demanding of product design from retailers, they also have the opportunity to push the filler companies to produce a more recyclable design.
Consumers are concerned with sustainability, but because of their lack of scientific knowledge, their preferences is not necessary sustainable or in alignment, and therefore their

effect on the plastic packaging design depend on what have been communicated to them. This concerns the filler companies, also because there have been experiences with consumers not understanding innovative product designs or switches in materials.

The development network can help the value chain with a center of information on sustainable plastic. This center could consist of a national design manual, the latest knowledge on sustainable packaging and consultants who can help companies design their packaging for recycling in a danish context. With this center, the different design concepts for better recycling developed by the different danish companies, could be collected. This could create a powerful and resourceful center, which would lead the way for better sustainable plastic packaging in a infrastructure which supports it. This would also help politicians make decisions on the EPR and the streamlining of the waste management.

In the end the analysis identified the problems and the discussion answered how the companies could overcome the challenges of designing recyclable plastic packaging by constructing three recommendation, which should be taken into account for the creation of a circular economy for plastic packaging. The recommendations will be presented here:

1. If possible, use PET (virgin/recycled) for food products, if PE or PP is needed, then only use virgin material. Use recycled PE and PP only for non-food products. If not possible to comply with mono-material design, use other resins than PE, PP and PET, to keep waste fractions clean, see Figure 7.3.
2. Create a collaboration in Danish plastic industry to streamline design, utilize resources and create national state-of-the-art.
3. Include reuse as a possible system for better sustainable packaging, and elaborate on what companies would have to do in order to implement such a system. Provide examples of how systems like this would function.

Bibliography

, **2018**. *RECUP*, 2018. URL: https://recup.de/.

Affaldsbekendtgørelsen, **2019**. Affaldsbekendtgørelsen. *Affaldsbekendtgørelsen*, 2019. URL: https://www.retsinformation.dk/Forms/R0710.aspx?id=207367#id2c99286f-49c9-4723-a84f-ec2acd210753. /eli/lta/2019/224.

Andrady, **2015**. A. L. Andrady. *Plastics and environmental sustainability*. Wiley, 2015.

Andrady and Neal, **2009**. Anthony L. Andrady and Mike A. Neal. *Applications and societal benefits of plastics*. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1526), 1977–1984, 2009. doi: 10.1098/rstb.2008.0304.

Arla, **Apr. 2019**. Arla. *Interview with Arla*, 2019. Interview with two packaging innovation managers.

Arla Foods, **2019**. Arla Foods. *Sustainable packaging*, 2019. URL: https://www.arla.com/sustainability/sustainable-packaging/. Accessed 24.05.2019.

Arvanitoyannis and Bosnea, **2001**. I. S. Arvanitoyannis and L. A. Bosnea. *Recycling Of Polymeric Materials Used For Food Packaging: Current Status And Perspectives*. Food Reviews International, 17(3), 291–346, 2001. doi: 10.1081/fri-100104703.

Atria, **Apr. 2019**. Atria. *Interview with Atria*, 2019. Interview with a procurement officer on packaging and the quality and laboratory manager in Denmark.

Atria Plc, **2019**. Atria Plc. *Atria – Finnish with international presence*, 2019. URL: https://www.atria.fi/en/group/. Accessed 24.05.2019.

Bocken et al., **2016**. Nancy M. P. Bocken, Ingrid De Pauw, Conny Bakker and Bram Van Der Grinten. *Product design and business model strategies for a circular economy*. Journal of Industrial and Production Engineering, 33(5), 308–320, 2016. doi: 10.1080/21681015.2016.1172124.

Braungart and Donough, **2002**. Michael Braungart and William Donough. *Cradle to cradle: remaking the way we make things*. North Point Press, New York, NY, 40(02), 2002.

Brinkmann and Tanggaard, **2015**. Svend Brinkmann and Lene Tanggaard. *Kvantitative metoder en Grundbog*, volume 2 of *1*. Hans Reitzels Forlag, 2015.

COOP, **Apr. 2019a**. COOP. *Interview with COOP Danmark A/S*, 2019. Interview with the project manager in CSR development.

COOP, **2019b**. COOP. *Emballagestrategi*, 2019. URL: https://ansvarlighed.coop.dk/vores-fodaftryk/emballage/emballagestrategi/.

Creswell, **2017**. John W. Creswell. *Qualitative Inquiry and Research Design: Choosing Among Five Approaches.* SAGE publications, 2017.

Danish Crown, **2018**. Danish Crown. *CSR Report - For a more sustainable future.*, 2018. URL: https://www.danishcrown.com/media/5780/csr-17-18.pdf. Accessed 24.05.2019.

Ellen MacArthur Foundation, **2015a**. Ellen MacArthur Foundation. *Potential for Denmark as a Circular Economy*, 2015.

Ellen MacArthur Foundation, **2013**. Ellen MacArthur Foundation. *Towards the circular economy: Business rationale for an accelerated transistion*, 2013.

Ellen MacArthur Foundation, **2015b**. Ellen MacArthur Foundation. *The New Plastics Economy: Rethinking the future of plastics*, 2015. URL: https://www.ellenmacarthurfoundation.org/publications/the-new-plastics-economy-rethinking-the-future-of-plastics. Accessed 13.02.2019.

Eriksen and Astrup, **2019**. M.k. Eriksen and T.f. Astrup. *Characterisation of source-separated, rigid plastic waste and evaluation of recycling initiatives: Effects of product design and source-separation system.* Waste Management, 87, 161–172, 2019. doi: 10.1016/j.wasman.2019.02.006.

European Commission, **2018**. European Commission. *A European Strategy for Plastics in a Circular Economy*, 2018.

European Commission, **2016**. European Commission. *Directive 2008/98/EC on waste (Waste Framework Directive)*, 2016. URL: http://ec.europa.eu/environment/waste/framework/. Accessed 26.02.2019.

European Commission, **2015**. European Commission. *Closing the loop - An Eu action plan for the Circular Economy*, 2015. URL: https://ec.europa.eu/transparency/regdoc/rep/1/2015/EN/1-2015-614-EN-F1-1.PDF. COM(2015) 614.

European Commission, **Feb 2019**. European Commission. *Food Contact Materials*, 2019. URL: https://ec.europa.eu/food/safety/chemical_safety/food_contact_materials_en. Accessed 01.05.2019.

European Parliament and Council of the European Union, **2018a**. European Parliament and Council of the European Union. *Directive 2008/98/EC on waste (Waste Framework Directive amendment of 30 May 2018)*, 2018.

European Parliament and Council of the European Union, **1994**. European Parliament and Council of the European Union. *Directive 94/62/EC on packaging and packaging waste*, 1994.

European Parliament and Council of the European Union, **2018b**. European Parliament and Council of the European Union. *Amending directive 94/62/EC on packaging and packaging waste*, 2018.

Eurostat, **2019**. Eurostat. *Packaging and packaging waste*, 2019. URL: https://ec.europa.eu/eurostat/web/waste/key-waste-streams/packaging. Accessed 10.04.2019.

Flyvbjerg, **2006**. Bent Flyvbjerg. *Five Misunderstandings About Case-Study Research.* Qualitative Inquiry, 12(2), 219–245, 2006. doi: 10.1177/1077800405284363.

Forum for Circular Plastic Packaging, **2018a**. Forum for Circular Plastic Packaging. *Forum for Circular Plastic Packaging - recommendations and actions*, 2018. URL: https://plast.dk/wp-content/uploads/2018/11/Recommendations-and-actions-ENG-Forum-for-Circular-Plastic-Packaging-NOVEMBER-2018.pdf. Accessed 20.02.2019.

Forum for Circular Plastic Packaging, **2018b**. Forum for Circular Plastic Packaging. *Reuse and recycling of plastic packaging for private use*, 2018. URL: https://plast.dk/wp-content/uploads/2018/11/Design-manual-ENG-Forum-for-Circular-Plastic-Packaging-NOVEMBER-2018.pdf. Accessed 20.02.2019.

Færch Plast, **Apr. 2019**. Færch Plast. *Interview with Færch Plast A/S*, 2019. Interview with the head of group technology at Færch.

Geissdoerfer et al., **2017**. Martin Geissdoerfer, Paulo Savaget, Nancy M.p. Bocken and Erik Jan Hultink. *The Circular Economy – A new sustainability paradigm?* Journal of Cleaner Production, 143, 757–768, 2017. doi: 10.1016/j.jclepro.2016.12.048.

Geyer et al., **2017**. Roland Geyer, Jenna R. Jambeck and Kara Lavender Law. *Production, use, and fate of all plastics ever made.* Science Advances, 3(7), 2017. doi: 10.1126/sciadv.1700782.

Ghisellini et al., **Sep 2015**. Patrizia Ghisellini, Catia Cialani and Sergio Ulgiati. *A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems.* Journal of Cleaner Production, 2015.

Grabher, **1993**. Gernot Grabher. *Rediscovering the social in the economics of interfirm relations.* The Embedded Firm: On the Socioeconomics of Industrial Networks, 1993.

Hahladakis and Iacovidou, **2018**. John N. Hahladakis and Eleni Iacovidou. *Closing the loop on plastic packaging materials: What is quality and how does it affect their*

circularity? Science of The Total Environment, 630, 1394–1400, 2018. doi: 10.1016/j.scitotenv.2018.02.330.

Hanegal, **Apr. 2019**. Hanegal. *Interview with Hanegal A/S*, 2019. Interview with the co-founder and chief ideologist at Hanegal.

Harvey and Watts, **Oct 2018**. Fiona Harvey and Jonathan Watts. *Microplastics found in human stools for the first time*, 2018. URL: https://www.theguardian.com/environment/2018/oct/22/microplastics-found-in-human-stools-for-the-first-time. Accesssed 28.03.2019.

Hatch & Bloom and VE2, **2018**. Hatch & Bloom and VE2. *Rethink Plastic - Dogmeregler for øget genanvendelse af plast fra fødevareemballager*, 2018. URL: http://www.rethinkplastic.dk/. Accessed 20.02.2019 - The report can be downloaded and is send by E-mail.

Håkansson and Ford, **2002**. Håkan Håkansson and David Ford. *How should companies interact in business networks?* Journal of Business Research, 55(2), 133 – 139, 2002. doi: https://doi.org/10.1016/S0148-2963(00)00148-X. Marketing Theory in the Next Millennium.

Ignatyev et al., **2014**. Igor A. Ignatyev, Wim Thielemans and Bob Vander Beke. *Recycling of Polymers: A Review.* ChemSusChem, 7(6), 1579–1593, 2014. doi: 10.1002/cssc.201300898.

Ingenøren, **2019**. Ingenøren. *Danske kommuner sorterer affald vidt forskelligt*, 2019. URL: https://ing.dk/artikel/danske-kommuner-sorterer-affald-vidt-forskelligt-224597.

Kalmykova et al., **2018**. Yuliya Kalmykova, Madumita Sadagopan and Leonardo Rosado. *Circular economy – From review of theories and practices to development of implementation tools.* Resources, Conservation and Recycling, 135, 190–201, 2018. doi: 10.1016/j.resconrec.2017.10.034.

Kirchher et al., **2017**. Julian Kirchher, Denise Reike and Marko Hekkert. *Conceptualizing the circular economy: An analysis of 114 definitions.* Resources, Conservation & Recycling, 127, 221–232, 2017. doi: https://doi.org/10.1016/j.resconrec.2017.09.005.

Kirkegaard, **Apr. 2019**. Henrik Kirkegaard. *Interview with I/S Reno Nord*, 2019. Interview with the head of innovation at Reno-Nord.

Kumar et al., **2011**. Sachin Kumar, Achyut K. Panda and R.k. Singh. *A review on tertiary recycling of high-density polyethylene to fuel.* Resources, Conservation and Recycling, 55(11), 893–910, 2011. doi: 10.1016/j.resconrec.2011.05.005.

Kvale and Brinkmann, **2009**. Steinar Kvale and Svend Brinkmann. *Interview -Introduktion til et hånd-værk.* Hans Reitzels Forlag, 2 edition, 2009.

Lithner et al., **2011**. Delilah Lithner, Åke Larsson and Göran Dave. *Environmental and health hazard ranking and assessment of plastic polymers based on chemical composition*. Science of The Total Environment, 409(18), 3309–3324, 2011. doi: 10.1016/j.scitotenv.2011.04.038.

Lyngsted, **March 2019**. Lotte Lyngsted. *Interview with Rethink Plastic*, 2019. Project Manager of the Rethink Plastic project.

Miljø- og Fødevareministeriet, **2018**. Miljø- og Fødevareministeriet. *Plastik uden spild – Regeringens plastikhandlingsplan*, 2018. URL: https://mfvm.dk/fileadmin/user_upload/MFVM/Miljoe/Plastikhandlingsplan/Regeringens_plastikhandlingsplan_web_FINAL.pdf. Accessed 25.02.2019.

Miljø- og Fødevareministeriet og Erhvervsministeriet, **2018**. Miljø- og Fødevareministeriet og Erhvervsministeriet. *Strategi for cirkulær økonomi - Mere værdi og bedre miljø gennemdesign, forbrug og genanvendelse*, 2018. URL: https://mfvm.dk/fileadmin/user_upload/MFVM/Miljoe/Cirkulaer_oekonomi/Strategi_for_cirkulaer_oekonomi.pdf. Accessed 25.02.2019.

miljø og fødevareministeriet, **2018**. miljø og fødevareministeriet. *Vejledning om mærkning af fødevarer*, 2018. URL: https://www.foedevarestyrelsen.dk/SiteCollectionDocuments/Kemi%20og%20foedevarekvalitet/M%C3%A6rkning/Maerkningsvejledningen%20maj%202018.pdf?fbclid=IwAR1wRSTa2jukoMDe0oLG3_Mc5yzy_hVLGF-IeqY_Heg3D_CI23b_cix1Coo.

Miljøbeskyttelsesloven, **2019**. Miljøbeskyttelsesloven. *Miljøbeskyttelsesloven*, 2019. URL: https://www.retsinformation.dk/Forms/R0710.aspx?id=207970#id22db9019-b651-4085-ae6a-8f015cd5896f. /eli/lta/2019/241.

Moustakas, **1994**. Clark Moustakas. *Phenomenological research methods*. SAGE publications, 53, 1994. doi: 10.4135/9781412995658.

og Griesemer, **1989**. Star og Griesemer. *Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology*. Social Studies of Science, 39(19), 1989.

PlasticsEurope, **2018**. PlasticsEurope. *Plastics – the Facts 2018: An analysis of European plastics production, demand and waste data*, 2018. URL: https://www.plasticseurope.org/en/resources/publications/619-plastics-facts-2018. Accessed 13.02.2019.

PlasticsEurope, **2019**. PlasticsEurope. *What are Plastics?*, 2019. URL: https://www.plasticseurope.org/en/about-plastics/what-are-plastics. Accessed 15.02.2019.

Ragaert et al., **2017**. Kim Ragaert, Laurens Delva and Kevin Van Geem. *Mechanical and chemical recycling of solid plastic waste*. Waste Management, 69, 24–58, 2017. doi: 10.1016/j.wasman.2017.07.044.

Rahimi and García, **2017**. Alireza Rahimi and Jeannette M. García. *Chemical recycling of waste plastics for new materials production*. Nature Reviews Chemistry, 1 (6), 2017. doi: 10.1038/s41570-017-0046.

Rethink Plastic, **2018**. Rethink Plastic. *Dogmeregler og designprincipper - Et redskab til at øge genanvendelsen af fødevareemballager i plast.*, 2018. URL: http://www.rethinkplastic.dk/. Accessed 20.02.2019 - The design principles are visible on the website but can also be requested as a booklet via E-mail.

Singh et al., **2017**. Narinder Singh, David Hui, Rupinder Singh, I.p.s. Ahuja, Luciano Feo and Fernando Fraternali. *Recycling of plastic solid waste: A state of art review and future applications*. Composites Part B: Engineering, 115, 409–422, 2017. doi: 10.1016/j.compositesb.2016.09.013.

Sky-light, **May 2019**. Sky-light. *Interview with Sky-light*, 2019. Interview with factory manager and director assistance working with communication and marketing.

Søndergård et al., **1997**. Bent Søndergård, Ole Erik Hansen and Søren Kerndrup. *Miljøregulering - tværfaglige studier*. Roskilde Universitetsforlag, 1 edition, 1997.

The Danish Government, **2013**. The Danish Government. *Denmark without waste I - "Recycle more-Incinerate less"*, 2013. URL: https://eng.mst.dk/media/mst/Attachments/Ressourcestrategi_UK_web.pdf.

Tine Brødegaard Hansen, **2019**. Tine Brødegaard Hansen. *Lidl vil være bæredygtigt fyrtårn*, 2019. URL: https://sustainreport.dk/nyheder/sustainability-er-vigtigt-ben-i-lidls-nye-strategi/. Production: SustainReport.

Tulip, **May 2019**. Tulip. *Interview with Tulip*, 2019. Interview with the category director for fresh meat in Denmark.

UNEP, **2018)**. UNEP. *SINGLE-USE PLASTICS: A Roadmap for Sustainability*, 2018).

Valentin, **2001**. E. K. Valentin. *Swot Analysis from a Resource-Based View*. Journal of Marketing Theory and Practice, 9(2), 54–69, 2001. doi: 10.1080/10696679.2001.11501891.

Vingwe, **Apr. 2019**. Edward Vingwe. *Interview with Edward Vingwe*, 2019. Interview with a Phd. student at Aalborg University working with plastic recycling.

Appendices

Interview Guide Example A

Research Question	Interview Question
Initial understanding	Who are you? What is you position in —COMPANY—
Interpretation of design manuals and how they would be able to be implemented?	What do you think about the manuals? How much can you implement them? If not, why? What do you think is the biggest barrier trying to implement them? Can you do something about those barriers? If so, does it change the company's or design manual's requirements?
Reason for design of product	What kind of requirements do you follow when you design your product packaging? Is there anything special, design wise, that you do with your packaging, not because of legal requirements but because you think it helps your consumers or your marketing? Do you think it affects the sustainability of the packaging that companies want to differentiate from each other?
Questions about Extended Producer Responsibility	Have you heard about extended producer responsibility? What do you think will happen? We think bad recyclability=higher fees, do you think that would help Would you change your products if it come like that?
Additional Questions	Who do you think will benefit from this change in or around your business? Have you ever been working on presenting yourself as sustainable? What are your core values in the company? Do you think you are ready for the change these design manuals are calling for? Do you have the resources to make these changes and do you think there is support in the company to do this? Do you think this is something your customers would like and understand? Do you have employees who can take care of this implementation, or does it become a side project on someone else's table? What resources do you think are needed to make these changes on your packaging, internally within the company?