Madeleine Kristin Wieser

Circular Design Guide for the Use of Plastic in Furniture

Master's thesis in Industrial Design Engineering
Supervisor: Jon Herman Rismoen
July 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
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I think it needs to be said from the start that furniture is one of the more positive industries for the use of plastic [...] but I haven't seen a guide that might advise me on the subject. If you know of one please tell me about it?

Jasper Morrison in an interview for this master's thesis

written by Madeleine Kristin Wieser
Industrial Design, NTNU
Summer 2021

Acknowledgment

First and foremost, I want to thank my mentor, Stefan Diez for giving me the opportunity to work on this interesting task. Thank you for all the contacts you trusted me with, this thesis would not have been the same without them. And most of all thank you for all the inspiring talks and guidance throughout this thesis, you always seem to know what to say.

I also want to thank my supervisor Jon Herman Rismoen for guidance, constructive feedback, and for supporting me in my decisions along the way. I also want to thank Johannes Blöndal Sigurjónsson for helping me get to die Angewandte and for letting me stay in Vienna. Right before I went on the exchange you said I might not come back to Trondheim, at the time I doubted it, but turns out you were right.

Thank you so much to all who participated in the interviews. Your input is the foundation of my work, it would not have been possible without you.

And thank you Armin Muhamedagić for helping me with the layout for this thesis.

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Abstract

This master's thesis focuses on the circularity of plastics in the furniture industry, or what through this thesis was discovered to be a more accurate description, the seemingly non-existing circularity of plastics in the furniture industry. The thesis was conducted in collaboration with internationally renowned designer Stefan Diez, and the aim of it has been to investigate and evaluate the circularity of plastics in the furniture industry.

The main method used for this thesis has been interviews. This thesis contains 19 interviews with designers, experts on plastic recycling and representatives of different companies, mostly furniture manufacturing companies. Theoretical research was also conducted along the way, as well as a case study.

The thesis can be divided into three phases, the first phase is the industry insight phase, where interviews were conducted with furniture manufacturer representatives to identify the challenges facing the industry in regard to the circularity of plastics. The second phase was the case study where different chairs that the manufacturers claimed contained recycled and/or recyclable plastic were analyzed as a means to assess the current state of circularity in the industry. These two phases revealed that there currently does not seem to be a circular economy for plastic in the furniture industry, at least not amongst what has been examined for this thesis. Circular systems seem to be missing, and plastic furniture seems to at best be circular-ish. Furthermore, phase one and two served to identify the changes needed to transition from linearity to circularity in the furniture industry, especially for the use of plastic.

The last phase of the thesis was to develop a circular design guide for the use of plastic in furniture, which is the result of this thesis. The circular design guide, based on the findings from phase one and two, sums up all findings of this thesis into a set of twelve guidelines. This guide is meant to advance the transition to a circular economy for plastics in the furniture industry by helping designers design circular plastic furniture, that will be ready to circulate once circular systems have been established.

Sammendrag

Denne masteroppgaven fokuserer på sirkulæriteten til plast i møbelindustrien, eller som gjennom denne oppgaven ble oppdaget at kan sies å være en bedre beskrivelse, den tilsynelatende ikke-eksisterende sirkulæriteten til plast i møbelindustrien. Masteroppgaven ble utført i samarbeid med den internasjonalt anerkjente designeren Stefan Diez, og målet har vært å undersøke og evaluere sirkulæriteten til plast i møbelindustrien.

Hovedmetoden brukt for denne masteroppgaven har vært intervjuer. Masteroppgaven omfatter 19 intervjuer med designere, eksperter på plastresirkulering og ressurspersoner i forskjellige bedrifter, hvorav de fleste bedriftene var møbelprodusenter. Teoretisk research ble også gjennomført underveis, samt en casestudie.

Masteroppgaven kan deles inn i tre faser, den første er industriinnsiktsfasen, der intervjuer med representanter for møbelprodusenter ble gjennomført for å identifisere utfordringene industrien står ovenfor med hensyn til sirkulæriteten til plast. Den andre fasen var casestudien der forskjellige stoler som produsentene hevdet at inneholder resirkulert og/eller resirkulerbar plast ble analysert for å evaluere den nåværende sirkulæriteten i bransjen. Disse to fasene avslørte at det for tiden ikke ser ut til å eksistere en sirkulær økonomi for plast i møbelindustrien, i det minste ikke blant det som er undersøkt for denne oppgaven. Sirkulære systemer ser ut til å mangle og plastmøbler ser i beste fall ut til å være «circular-ish». Videre har fase en og to tjent til å identifisere de nødvendige endringene som må til for å gå fra linearitet til sirkulæritet i møbelindustrien, spesielt for bruk av plast.

Den siste fasen av masteroppgaven var å utvikle en sirkulær designguide for bruk av plast i møbler, som er resultatet av denne oppgaven. Den sirkulære designguiden, som er basert på funnene fra fase en og to, oppsummerer alle funn fra denne masteroppgaven i et sett med tolv retningslinjer. Guiden er ment å fremme overgangen til en sirkulær økonomi for plast i møbelindustrien ved å hjelpe designere designe sirkulære plastmøbler, som vil være klare til å sirkulere når sirkulære systemer har blitt etablert.

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List of abbreviations

ABS: Acrylonitrile butadiene styrene
CSR: Corporate social responsibility
HDPE: High-Density Polyethylene
PCR: Post-consumer recycled
PE: Polyethylene
PET: Polyethylene terephthalate
PIR: Post-industrial recycled
PP: Polypropylene
PU: Polyurethane
R&D: Research and development

Chapter 1

Introduction

How it all began

The journey that led me to this master's thesis started almost two years ago when I went on an exchange to the University of Applied Arts in Vienna (die Angewandte). I had dreamt of going to die Angewandte for a long time and the stay exceeded my expectations, much thanks to the talented professor, Stefan Diez. So, I extended my stay for another semester, but after 1,5 years of exchange I felt that I still had much left to learn from Diez. I therefore asked him if he would be interested in a collaboration for my master's thesis and that is how this adventure began.

Collaboration with Diez Office

Stefan Diez is an industrial designer and the head of Industrial design 1 at the university of applied arts in Vienna. He also runs his own design studio, Diez Office, in Munich. Diez has created award-winning furniture, luminaires and accessories and works with internationally renowned manufacturers. His design studio develops everyday objects focusing particularly on the potential of the circular economy.

Diez Office has been working on creating products for a circular economy since around 2008 and based on the experience the team has gained over the years, Diez has defined 10 circular design guidelines which for a long time have worked as a checklist on how to design products for a future circular economy within the studio. These guidelines were recently published and have gotten quite a lot of attention in the media.

Due to the collaboration with Diez, I decided to stay and write my master's thesis in Vienna. The initial idea was for me to go to Munich a couple of times during this semester, unfortunately that was not possible due to covid restrictions. I did however meet with Diez every time he was in Vienna, which was either monthly or every other week.

About the task

The topic for the thesis was given by Diez. Given his interest and belief in a circular economy, he suggested the circular economy as the overall topic for my thesis. As a subtopic to narrow it down, he suggested that I should focus on the material cycle of plastics, and since Diez and his studio mostly work with furniture, it was natural to further narrow the topic to the circularity of plastics in the furniture industry, especially because Diez Office had recently started working on a new project that involves designing a chair from recycled plastic.

For the content of the thesis, Diez suggested that I should do interviews with representatives of furniture manufacturing companies and that I should conduct a case study comparing different chairs containing recycled material, the rest was up to me to decide. Furthermore, he overall wanted me to have an investigative and explorative approach to the task, like that of a journalist.

Purpose

Diez assigned me with this task of evaluating the circular economy in the furniture industry, especially focusing on plastics, in order to gain a better understanding of the practical problems of implementing a circular economy. He wanted me to do this project to, amongst others, make discoveries that could improve his 10 circular design guidelines as well as to aid as initial research for the recycled plastic chair project and eventually also for another project the studio took on while I was working on this thesis.

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Master's Thesis for Madeleine Kristin Wieser

Circular Design Guide for the Use of Plastic in the Furniture Industry
Sirkulær design guide for bruk av plast i møbelindustrien

Plastic is an important material in the modern economy and everyday life, but the way the material is currently produced, used and discarded results in most of it ending up as waste. This master thesis will focus on the circularity of plastic in the field of the furniture industry. The reason for choosing to focus on the furniture industry is that per now it does not have a functioning recycling system for plastics. The project will be conducted in collaboration with Diez Office, a design studio led by designer Stefan Diez, who has created award-winning furniture and is currently designing products created to exist within the framework of a circular economy.
This project will investigate the furniture industry to see what type of plastic is used, how and where it is used. It will explore how furniture companies respond to the themes of sustainability and circular economy and assess whether what they are doing is a serious attempt or greenwashing. Furthermore, it will use the chair, an archetypical piece of furniture that is easy to compare, to conduct a case study comparing different ways of using recycled plastics or of using plastic in such a way that it is recyclable. Based on the findings, the thesis will result in a circular design guide for the use of plastic in the furniture industry.

This master's thesis will mainly include:
- Interviews with furniture companies that work on projects involving recycled plastics/plastics for a circular economy, examination and assessment of the findings
- Comparison, analysis and evaluation of some relevant examples of chairs from the last 6 years that are made for recycling or from recycled plastics
- Development of a circular design guide for the use of plastic in the furniture industry

The thesis is conducted in accordance with "Retningslinjer for masteroppgaver i Industriell design".

Responsible tutor: Jon Herman Rismoen
Business contact: Stefan Diez, Diez Office

Start date: 08.01.21
Due date: 16.07.21

Trondheim, NTNU, dato 08.01.2021

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Changes

Interviews have not only been conducted with representatives of furniture manufacturing companies, like the task says, but also with representatives of other relevant companies, as well as with designers and experts on plastic recycling. Furthermore, other seating furniture, not only chairs, were used for the case study and some of the products used in the case study were older than 6 years old. At last, the formulation has been changed from a "circular design guide for the use of plastic in the furniture industry" to a "circular design guide for the use of plastic in furniture", as a means to avoid confusion about who the guide is meant for.

Guidance

Diez has acted as my external supervisor and employer. He suggested the task and has guided me along the way, contributing with knowledge and contacts. Diez has also designed one of the chairs used in the case study in chapter 4. Jon Herman Rismoen has been my supervisor from NTNU, he has given me continuous professional guidance on how to work on and write a master's thesis.

Motivation

When Diez presented me with this assignment, it seemed perfect. I love to work on new challenges, attaining new knowledge and I did not know much about the concept of a circular economy, plastics or how things work in the furniture industry. So, this seemed like the perfect opportunity to use my last semester as a student to soak up as much knowledge as I could. I therefore wanted to do this as a theoretical thesis to really be able to delve into the issues, understand and reflect on them. The goal for me was to take on an investigative role in order to get a unique look inside the furniture industry and use my skills and position as a designer to offer guidance on how to navigate the complexity of the issue. I therefore decided to make a circular design guide as the final result to sum up all my research and findings into a concrete and understandable guide for designers on how to ease the transition to a future circular economy, especially focused on how to create circular plastic furniture. I believe that designers have a unique role that make them a key player when it comes to driving the circular economy forward because they are in contact with practically everyone involved in the making of a product. I also found it intriguing to design something specifically for designers, which I had never done before.

Process & methods

Overall, the time spent working on this thesis can be said to be divided into three phases: industry insight, case study and development of the circular design guide. The first phase consisted of doing interviews with furniture manufacturers to gain insight into the industry. After gathering all information needed, I proceeded to phase two, the case study. The goal of the case study was to compare, analyze and evaluate already existing solutions to get an overview of the current state of circularity in the furniture industry. At last, all the knowledge and experience gathered from the two first phases were used to develop the circular design guide for the use of plastic in furniture.

Multiple methods have been used in this thesis, but given the investigative approach to the topic, interviews have been used as the main method of gaining insight. Overall, 19 interviews have been conducted, just under half of which were conducted with furniture manufacturers to gain insight into the industry. A case study was also conducted, for which experts on plastic recycling were interviewed. At last, for the development of the design guide, some designers have also been interviewed.

Literary research has been conducted along the way to supplement with knowledge where needed. For the first phase, literary research was conducted to understand the concept of a circular economy and plastic recycling. For both the first and second phase, literary research was done regarding circularity in the furniture industry. For the last phase of developing a circular design guide, different circular design methods and guides were reviewed. A more detailed description of the different methods used will follow in their respective chapters.

Defining plastic furniture and plastic chair

In this master's thesis, furniture that contains plastic, but is not necessarily made of 100% plastics, will be referred to as plastic furniture. The same applies to the chairs in the case study. Not all of the chairs are made entirely out of plastics, but all will from now on be referred to as plastic chairs.

Chapter 2

Circular Economy, Plastics & the Furniture Industry

This chapter is a general introduction to the topic of this thesis, explaining concepts such as the circular economy, plastics, recycling and how they relate to each other and fit into the context of the furniture industry. This was important work to begin with in order to get insight into the current situation and its challenges to have an understanding of the topic before conducting interviews with representatives of the furniture industry.

The chapter is divided into three parts. Firstly, it generally discusses the concept of a circular economy. Secondly, it takes a look at the current state of circularity in regard to plastics as a material, explaining relevant terms and issues. At last, it places circular economy and plastics into the context of the furniture industry to get an overview of the current situation. The role of design in regard to the topic is also briefly discussed.

The circular economy

Although Diez and Diez Office believe in the concept of a circular economy, I found it important to critically review the concept and make up my own mind about it before proceeding with this project. The concept of a circular economy was therefore critically reviewed to understand both the opportunities and challenges of a circular economy.

Circular Economy: The concept

According to the Ellen MacArthur Foundation (2012, p. 26), a charity organization that aims to accelerate the transition to a circular economy, "The circular economy concept has deep-rooted origins and cannot be traced back to one single date or author", but "its practical applications to modern economic systems and industrial processes [...] have gained momentum since the late 1970s as a result of the efforts of a small number of academics, thought-leaders, and businesses", one of them being architect, industry analyst and circular economy proponent Walter R. Stahel. According to Stahel (2016)

> *A 'circular economy' would turn goods that are at the end of their service life into resources for others, closing loops in industrial ecosystems and minimizing waste. It would change economic logic because it replaces production with sufficiency: reuse what you can, recycle what cannot be reused, repair what is broken, remanufacture what cannot be repaired".*

In other words, a circular economy aims to decouple economic growth from resource use (European Comission, 2020).

The theoretical construct of a circular economy has been described as an economic model, a strategy, or as a system: "A circular economy is an industrial system that is restorative or regenerative by intention and design." (The Ellen MacArthur Foundation, 2012, p. 7). At the core of a circular economy is the idea that one can design out waste. In the ideal circular economy, waste does not exist and "products are designed and optimized for a cycle of disassembly and reuse." (The Ellen MacArthur Foundation, 2012, p. 7). This idea is "grounded in the study of non-linear systems, particularly living ones." (The Ellen MacArthur Foundation, 2012, p. 22). In nature there is no waste, because discards become resources for others (Stahel, 2016). Consequently, the concept of a circular economy aims to optimize systems to run in circular closed loops, focusing on the careful management of two types of material flows as described by McDonough and Braungart: “biological nutrients, designed to re-enter the biosphere safely and build natural capital, and technical nutrients, which are designed to circulate at high quality without entering the biosphere.” (The Ellen MacArthur Foundation, 2012, p. 22). As a result, the circularity of the circular economy does not only imply that it operates in cycles, but also that it is constructed to achieve climate neutrality (The Ellen MacArthur Foundation, 2012, p. 2).

The Circular Economy: Why it is gaining momentum - or is it just a trend?

The current linear model of consumption displays an unsustainable overuse of resources (The Ellen MacArthur Foundation, 2012, p. 2). According to the European Commission (2020, p. 2), “Global consumption of materials such as biomass, fossil fuels, metals and minerals is expected to double in the next forty years, while annual waste generation is projected to increase by 70% by 2050.“. The linear model follows a take-make-dispose pattern in which materials are extracted and applied energy to, to manufacture products that are then sold to consumers who dispose of the products when they no longer fulfil the consumers’ purpose (The Ellen MacArthur Foundation, 2012, p. 15). The linear economy is a system based on the consumption of resources, rather than on the reuse of resources, which consequently, according to the Ellen MacArthur Foundations report (2012, p.14-16), leads to significant resource losses. The report states that these resource losses already incur during production, where it is common that “significant volumes of materials are commonly lost in the chain between mining and final manufacturing” (The Ellen MacArthur Foundation, 2012, p. 15). Furthermore, there is the issue of end-of-life waste. In comparison to primary manufacturing rates, the recovery rates for most materials after the end of their functional life are quite low, resulting in a significant loss of materials that are valuable for the system (The Ellen MacArthur Foundation, 2012, pp. 15-16).

A leaking lake

While the linear economy flows like a river, the circular economy is like a lake, in which resource consumption and waste is reduced (Stahel, 2016). In a circular economy, products circulate in tighter cycles, products and materials are kept in use longer and materials are brought back into a repurposed use, as described by the Ellen MacArthur Foundation (2012, pp. 30-31). All of which results in a substantially decreased need for virgin material distraction and a decrease in the growth of landfill and total material stock (The Ellen MacArthur Foundation, 2012, p. 32). This will in turn have a positive effect on the environment because "half of total greenhouse gas emissions and more than 90% of biodiversity loss and water stress come from resource extraction and processing [...]" (European Comission, 2020, p. 2) and because landfills generate methane, which is a key greenhouse gas (Gregson, et al., 2015, p. 14). However, one could argue that the circular economy is just, like discard studies researcher Giles suggests, a "kind of romantic thought that we'll just recover materials and then everything will be fine" (Hawkins, et al., 2019).

An issue with the circular economy is that "the recycling process of modern products is far from 100% efficient", according to low-tech proponent De Decker (2018). Of course, it is commonly agreed upon by experts that recycling is important to recover valuable materials and to reduce waste, while at the same time "reducing greenhouse gas emissions and conserving significant amounts of energy and water" (Schaart, 2020). However, according to De Decker (2018), today's products are complex, and therefore in need of multiple steps and processes to be recycled. There is a loss of resources and energy in every step of this process. In other words, the loss of resources generated throughout the recycling process will always “have to be compensated with more over-extraction of the planet’s resources” (De Decker, 2018). Recycling processes will improve, but in its current state “The low efficiency of the recycling process is, on its own, enough to take the ground from under the concept of the circular economy” according to De Decker (2018).

Saving Energy

Although the circular economy has some shortcomings, it still stands as a more environmentally friendly alternative to the current model of linear consumption, for instance in regard to energy use. In the linear economy, as described by the Ellen MacArthur Foundation (2012), products are disposed of in landfills, where all their residual energy is lost. Furthermore, incinerating or recycling discarded products in a linear economy only recoups a small share of the energy invested in the production process The Ellen MacArthur Foundation, 2012, p. 16). Substantial amounts of energy are invested in extraction of materials from earth and the conversion of them into a form that can be used commercially (The Ellen MacArthur Foundation, 2012, p. 16). The circular economy, on the other hand, claims to save energy through tight component and product cycles (The Ellen MacArthur Foundation, 2012, p. 7). Furthermore, in a circular economy, systems run on renewable sources of energy, and not fossil fuel (The Ellen MacArthur Foundation, 2012, p. 22).

Nevertheless, even if the circular economy were to switch to 100% renewable energy, the circle will not be made round. Resources are needed “to build and maintain renewable energy plants and accompanied infrastructures" (De Decker, 2018). Furthermore, the technology that is used "to harvest and store renewable energy relies on difficult-to-recycle materials", such as solar panels or wind turbines, which are landfilled or incinerated (De Decker, 2018). Not to forget that currently, fossil fuels make up 20% of the total resources used in the world, and "98% of that is burnt as a source of energy", so it cannot be reused or recycled (De Decker, 2018). The second law of thermodynamics also poses a challenge, because when energy is transformed, its quality will diminish (De Decker, 2018). As a result, new fossil fuels will always need to be mined (De Decker, 2018). At last, energy is also needed to recycle materials, not only in the recycling process, but also for transporting materials, both recycled material and material that is to be recycled (De Decker, 2018). To use resources responsibly, as the circular economy suggests, is a good idea. However, it cannot be achieved only through recycling and reuse, and it would demand the use of less fossil fuel, "which isn't the same as using more renewable energy". (De Decker, 2018)

The Numbers

The circular economy is an economic model, and thus makes arguments based on how it would be economically favorable in comparison to the linear economy. According to the Ellen MacArthur Foundation (2012, p. 9), the circular economy poses "an economic opportunity worth billions", in fact, the foundation "estimates that the circular economy represents a net material cost saving opportunity of USD 340 to 380 billion p.a. at EU level for a 'transition scenario' and USD 520 to 630 billion p.a. for an 'advanced scenario'". Another perceived economic advantage of the circular economy is "the mitigation of price volatility and supply risks", as the net material savings would result "in a shift down the cost curve for various raw materials" (The Ellen MacArthur

Foundation, 2012, p. 10). Furthermore, applying a circular economy could result in possible employment benefits, as shown by a recent study which estimates that applying the principles of a circular economy across the economy of the EU has the potential to create around 700 000 new jobs by 2030 (European Comission, 2020, p. 2). All in all, the circular economy claims ”lasting benefits for a more resilient economy” (The Ellen MacArthur Foundation, 2012, p. 10).

Regardless of how promising the economic opportunity might seem, the numbers do not seem to add up. The circular economy concept is “intended to align sustainability with economic growth”, but “Growth makes a circular economy impossible, even if all raw materials were recycled and all recycling was 100% efficient. The amount of used material that can be recycled will always be smaller than the material needed for growth.” (De Decker, 2018). Consequently, there are not enough recyclable raw materials to stop the constantly expanding extracting economy: “71% of all resources cannot be recycled or re-used (44% of which are energy sources and 27% of which are added to existing stocks)” (De Decker, 2018). Furthermore, according to De Decker (2018), proponents for a circular economy misunderstand how the system operates because they tend to “only focus on a very small part of the whole system”, the resources that are “put in landfill, incinerated or dumped” (De Decker, 2018). One could therefore say that the circular economy operates with a limited goal of “total recycling of a fraction of resources”, and even if everything that is put into landfill, incinerated or dumped was recycled and the recycling process would be “100% efficient, the circle would still not be closed” (De Decker, 2018). The only way to get better numbers would be to reduce total use, that includes making less stuff, which “would result in a double profit: we would need less resources”, and a growing “supply of discarded materials available for re-use and recycling” (De Decker, 2018).

From consumption to use

Reducing consumption is a cornerstone of the circular economy concept. The circular economy draws a sharp distinction between consumption and use of materials: "The circular economy advocates the need for a 'functional service' model in which manufacturers or retailers increasingly retain the ownership of their products and, where possible, act as service providers - selling the use of products, not their one-way consumption." (The Ellen MacArthur Foundation, 2012, p. 22). Shifting to the use of products would benefit consumers and users because it would give them "more choice at a lower cost and higher convenience" (The Ellen MacArthur Foundation, 2012, p. 75). Products would no longer be built for planned obsolescence, which would in return "bring down total ownership costs and deliver higher convenience" because one would avoid struggles associated with repair and return (The Ellen MacArthur Foundation, 2012, pp. 75-76). According to the European Commission (2020, p. 2), product-as-service models could even "bring about a better quality of life". To sum up, services would free users of "the burden of ownership and maintenance", and in return offer them flexibility (Stahel, 2016).

However, shifting from consumers to users is not a small change. It involves a radical re-categorization of things in general, as stated by Tonkinwise (2017), design researcher within the field of sustainable design and transition design. Product service systems entail that service providers would have to enter homes on a regular basis to tweak or even replace equipment, which according to research could end up changing the nature of being home (Tonkinwise, 2017, p. 352). According to Tonkinwise (2017, p.350), research focused on technical assessments of sustainability performance, even arrived at questioning notions of property in radically sociopolitical ways. Moreover, since a shift to usership also plays out in the space of employment, it would consequently "challenges the very nature of ownness – our 'proper identity'." (Tonkinwise, 2017, p. 357). The idea of shifting to usership is inherently good as it is less material intensive, but lifestyles structured around usership instead of ownership could be less autonomous (Tonkinwise, 2017, p. 349). It seems that "the sense that technical solutions will fix it all, which relates to the idea that circular economies will fix it all", as discard studies researcher Phillips put it, can be said to be a myth (Hawkins, et al., 2019). Shifting to usership does not only affect economy and environment, but also the social aspect of sustainability, which the circular economy has been criticized for overlooking. For a circular economy to be sustainable, it needs to take consumer behavior and mindset into account. In other words, as stated by social business researcher Lazell et al. (2018) the social dimension is crucial.

The moral & political economy

Regardless of all the challenges and critique, there is currently a big movement in the EU around the circular economy (Hawkins, et al., 2019). The EU "will continue to lead the way to a circular economy at the global level" (European Comission, 2020, p. 3), and will "take action with the aim to ensure that the EU does not export its waste challenges to third countries." (European Comission, 2020, p. 15). According to the European Commission (2020, p. 14), exporting waste results not only in "negative environmental and health impacts in the countries of destination", but also in the "loss of resources and economic opportunities for the recycling industry in the EU". Therefore, EU circular economies try to "transform wastes to resources within the boundaries of the EU", claiming that the way waste is recovered as resources in non-EU countries is "a dirty and illegal trade", as described by human geographer Gregson et al. (2015, p. 2). However, the recovery via global recycling networks is partly the result of the Global North's inability to transform wastes to resources (Gregson, et al., 2015). At the moment, the EU struggles to meet standards for high quality recycling demanded by markets for recycled products (Gregson, et al., 2015). The global recycling networks, on the other hand, do close loops and keep materials circulating around the planet, achieving circular economies (Gregson, et al., 2015). Consequently, Gregson et al. (2015, p. 6) states that the circular economy in the EU takes on the form of a moral economy, defining "right and wrong ways of keeping materials circulating". In addition, by continuing to insist that resources can only be recovered in the right way in the EU, the EU figures "itself as the model and/or leader for the rest of the world", also making the circular economy in the EU a political economy (Gregson, et al., 2015, p. 26). In other words, forging circular economies entails challenges.

Reflections

All in all, the idea of the circular economy to bring together sustainability and economic growth seems contradictory. Furthermore, the goal of eradicating waste altogether, seems close to impossible. However, the notion that changes need to be made to the current way of take-make-dispose is true, and the idea that design can be part of that solution is intriguing. Although it is incredibly challenging to create a truly circular system, the circular economy can serve as an ideal to strive towards for more sustainable production, consumption and waste management. The fact that waste might not be eradicated, does not mean that the idea of closing loops should be given up on. On the contrary, there is clearly room for improvement. That goes, in particular, for one material: plastic.

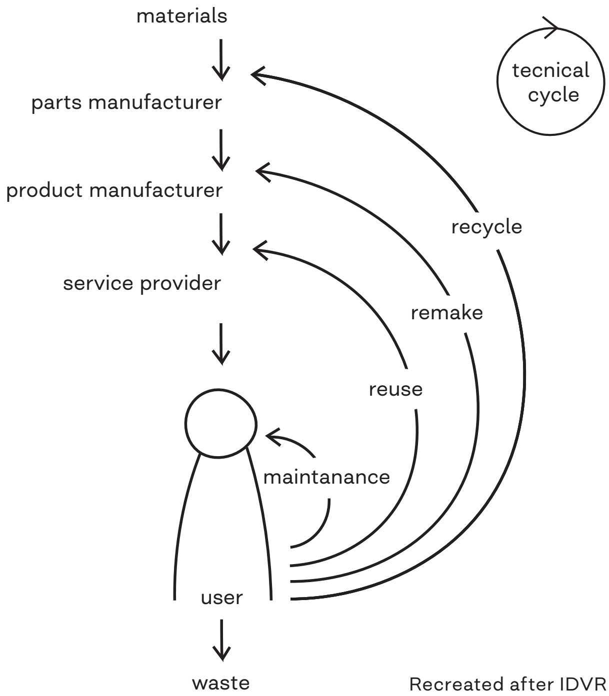
Plastics

A circular economy for plastics

Plastic is an important material in the modern economy and everyday life. However, the way the material is currently produced, used and discarded results in most of it ending up as waste (European Commission, 2018) and plastic waste is harming the environment, which is made evident, amongst others, through the million tonnes of plastic waste that yearly ends up in the ocean (European Commission, 2018, p. 1). This has in recent years given rise to concerns and led organizations and policymakers to begin taking measures to make plastic more sustainable by moving towards a circular economy for plastics (Fortum, 2019). In 2016, the Ellen MacArthur foundation launched the New Plastics Economy Initiative, promoting a circular economy for plastics (The Ellen MacArthur Foundation, 2017). Following in 2018, the European Commission proposed a strategy for Plastics in a Circular Economy (European Commission, 2018), recognizing plastics as a priority in the EUs work towards a circular economy (Fortum, 2019). However, the transition to a circular economy for plastics is still in its early stages.

One of the key principles of the circular economy is to design out waste and keep materials circulating at their highest value (The Ellen MacArthur Foundation, 2016, p. 47). Since plastic is a synthetic material, it should not enter the biosphere, but should instead be kept in a technical cycle. If possible, plastics should first be reused, to keep the plastic product circulating as long as possible, and then recycled to keep the plastic material circulating (The Ellen MacArthur Foundation, 2016, p. 47). Consequently, plastic recycling is essential to create a closed loop circular economy for plastics (EuRIC, 2020).

Since the large-scale production and use of plastics, which only dates back to the 1950s, plastic has "become one of the most ubiquitous materials used in production" (ECOS, 2019, p. 4). According to the European commission (2018, p. 2): "Over the past 50 years, the role and importance of plastics in our economy has consistently grown.



Recreated after IDVR

Global production of plastics has increased twentyfold since the 1960s", and in the next 20 years, it is expected to double again. To put that into perspective, as of 2015 only 9% of all plastics ever made has been recycled, whereas "12% was incinerated, and 79% was accumulated in landfills or the natural environment" (Geyer, et al., 2017, p. 1). The production of plastic has exploded in recent years, but waste management and recycling systems is nowhere near developing at the same speed (Fortum, 2019). In other words, there is still a long way to go to make plastics circular as most plastics still follow a linear economy model that entails disposal and incineration (EuRIC, 2020, p. 3).

Plastic fantastic – the unsustainable material

One might question why plastics is needed in the first place, or if it would be better to eradicate plastics altogether. Although that might seem like a solution, plastics have a lot of important qualities that actually help tackle challenges facing modern society. According to the Ellen MacArthur Foundation (2017, p. 5), it is the «workhorse materials of the modern economy" and has "unrivalled functionality". It is cheap to produce, lightweight, versatile and durable, in many ways it is a superior material (Fortum, 2019). For example, plastics is used to make lightweight cars and planes to save fuel and cut CO_2 emissions, and it is used in packaging to reduce food waste (European Commission, 2018, p. 1). So, plastic can sometimes even be considered as an environmentally friendly alternative to other materials.

It is not the plastic material itself that is inherently bad, but the way it is produced, used and treated at end of life. Most plastics originate from petroleum production, known as "an industry with considerable environmental impacts" (ECOS, 2019, p. 8). With the growing production and use of plastic, emissions that arise in exploitation, production, transport and refining of oil and gas are also increasing (Heinrich Böll Stiftung, 2019, p. 26). So, the current way of producing virgin plastic from fossil raw materials is not sustainable and neither is the way the material is handled when it becomes waste.

It is no secret that plastic waste harms the environment. Plastic production and incineration is estimated to generate “approximately 400 million tonnes of CO_2 a year globally” (European Commission, 2018, p. 3). Degradation of natural systems due to leakage of plastic waste, is another important issue. Globally, every year, “at least 8 million tonnes of plastics leak into the ocean - which is equivalent to dumping the contents of one garbage truck into the ocean every minute” (The Ellen MacArthur Foundation, 2017, p. 12). Plastic is estimated to account for 80% of marine litter, most of which is single use plastics (European Commission, 2018, p. 3). By 2050 there is likely to be “more plastic than fish in the ocean, by weight” (The Ellen MacArthur Foundation, 2017, p. 22). A new source of plastic leakage called microplastics, that does not only pose a threat to the environment, but also to human health, is also on the rise. Microplastics do not only accumulate in the sea, but also enter food chains and can be found in the air. In the EU alone, “between 75 000 and 300 000 tonnes of microplastics are released into the environment every year” (European Commission, 2018, p. 4). Altogether, the negative externalities of traditional plastic production and plastic waste serve as an incentive to look for alternative sources of raw material to produce plastics.

Bioplastics – an alternative?

Plastics can also be made from renewable raw materials; these plastics are known as biobased plastics. There are three different types of feedstocks that can be used to produce biobased plastics, these are known as first, second and third generation.

1st generation

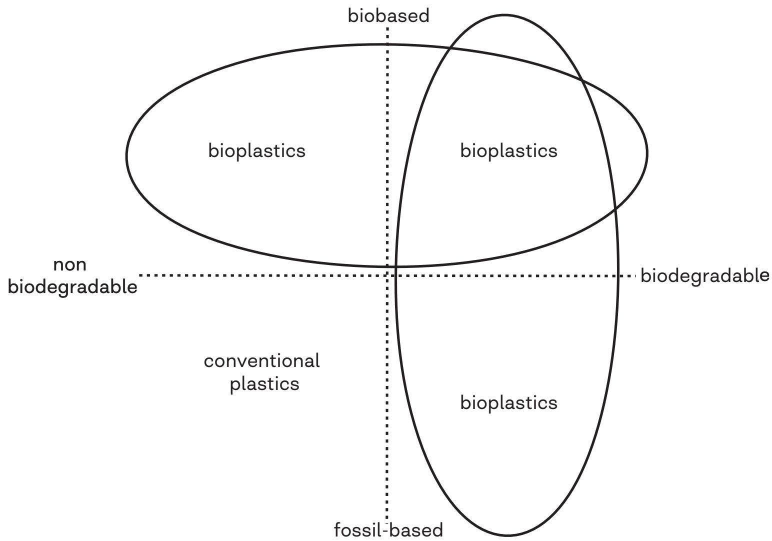
First generation feedstocks are made from plants that are rich in carbohydrates and can be used as food for humans or animals, such as corn and sugar canes (The Ellen MacArthur Foundation, 2016). First generation feedstocks can be problematic because they can potentially be in competition with food production, meaning that they essentially take away food meant to be consumed by humans or animals (Barrett, 2018).

2nd generation

Second generation feedstock is made from plants that are not suitable for food for humans and animals and can either be non-food crops such as cellulose or it can be waste materials from first generation feedstock such as waste vegetable oil (The Ellen MacArthur Foundation, 2016, p. 92). This type of feedstock can be problematic if grown on land meant for food production (Barrett, 2018).

3rd generation

The last type of feedstock, third generation is biomass derived from algae (The Ellen MacArthur Foundation, 2016). This type of feedstock does not compete with food production like the first- and second-generation feedstocks and it has a higher efficiency as well (Barrett, 2018). The issue with this type of biobased plastic is the price, it is more expensive than traditional fossil-based plastics (Barrett, 2018).



In theory, biobased plastics can help move of the reliance on fossil fuel to produce plastics and reduce the greenhouse gas footprint of plastic products (The Ellen MacArthur Foundation, 2016, p. 92). However, “the need for fossil raw materials in production can cancel this advantage out, and the carbon footprint of biobased plastics may, as a result, be larger than that of fossil-based ones” (Fortum, 2019, p. 15). Biobased plastics are currently not “the most sustainable solution” (EuRIC, 2020, p. 11). If one considers the full manufacturing chain and lifecycle, “current biobased plastic products may have a larger carbon footprint compared to fossil ones” (Fortum, 2019, p. 14). Furthermore, there is the issue that some types of biobased plastics are not recyclable with existing methods (Fortum, 2019, p. 14).

Biobased & biodegradable

Biobased plastic is one of the two groups of plastics known as bioplastics, the other group is called biodegradable plastics (EuRIC, 2020, p. 11). Not all biobased plastics are biodegradable and not all biodegradable plastics are biobased, so biodegradable plastics can also be made from fossil raw materials.

Biodegradable means that the plastic material can break down into natural elements such as water, biomass and CO_2 with the help of micro-organisms (The Ellen MacArthur Foundation, 2016, p. 69). However, the conditions required to break down biodegradable plastics are rarely found in nature as biodegradable plastics require long term exposure to high temperatures to break down (Breyer, 2020). Therefore, biodegradable plastics are typically only industrially compostable, meaning that they only degrade under industrially controlled conditions (The Ellen MacArthur Foundation, 2016, p. 19). They are usually not home compostable and generally do not degrade quickly on land, resulting in plastic pollution (Heinrich Böll Stiftung, 2019, p. 35). The same goes for degradation in water, the ocean is in fact too cold, which at worst causes the material to not break down at all (Martinko, 2021). Another huge issue is that biodegradable plastics also contaminate recycling streams as they are usually non-recyclable (EuRIC, 2020). In Europe, most biodegradable plastics currently end up being incinerated (Heinrich Böll Stiftung, 2019, p. 35). All in all, biodegradable plastics do not contribute to a circular economy as it is commonly agreed upon that "they do not prevent littering and pollution" (Fortum, 2019, p. 17).

Currently, bioplastics only makes up about 1% of all plastics produced annually, but that number is estimated to grow in the future (EuRIC, 2020, p. 11). Bioplastics might be a viable solution in the future, but as of today bioplastics are not the solution and only seem to distract from the actual solution: recycling (Fortum, 2019, p. 17). Therefore, going forward, this thesis will mainly focus on the use of recycled plastics.

Mechanical recycling - best, but still not good enough

Currently, "the biggest environmental benefits can be achieved by the recycling of existing materials in use over and over again" (Fortum, 2019, p. 14). Producing recycled plastic has a lower environmental impact than producing new plastic from oil (Grønt Punkt Norge, n.d. -a). Savings can be made in extraction, refining, processing and plastic manufacturing processes (Grønt Punkt Norge, n.d. -a)). For plastics initially made from virgin material, "recycling one tonne of plastics can avoid the emissions of 2.5 tonnes of CO_2" (EuRIC, 2020, p. 15). Producing recycled plastics also uses less energy than producing virgin plastics (Fortum, 2019, p. 18). So, recycling is "the best way to save resources and reduce a product's environmental footprint" (Fortum, 2019, p. 15).

Furthermore, plastics recycling is not only good for the environment, but also an integral part of closing loops in a circular economy.

The concept of plastic recycling is a good idea; however, the current system fails to prove the concept. Before 1980, plastic recycling was negligible, and it is still far from being closed loop (Geyer, et al., 2017, p. 3). In the EU, "the potential for recycling plastic waste remains largely unexploited." (European Commission, 2018, p. 2). Out of the around 25.8 million tonnes of plastic waste generated in Europe every year, less than 30% is collected for recycling (European Commission, 2018, p. 3). The reuse and recycling of end-of-life plastic is very low, and the current demand for recycled plastics only accounts for "around 6% of plastics demand in Europe" (European Commission, 2018, p. 3). Whereas the rates of plastic waste going to landfill (31%) and incineration (39%), remain high (European Commission, 2018, p. 2). Globally, out of the 9 percent of all plastics ever made that had been recycled by 2015, only 10% has been recycled multiple times (Geyer, et al., 2017, p. 3). Currently, recycling does only delay and not prevent plastic from becoming waste (Geyer, et al., 2017, p. 2)

Plastic is not just plastic

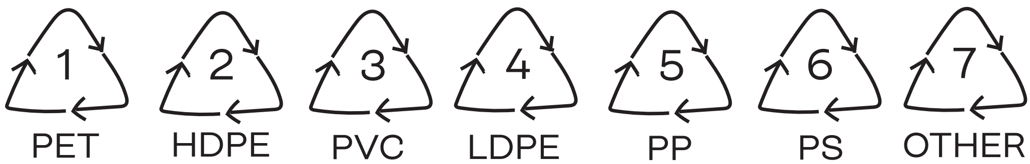
There are so many different types of plastics and generally they cannot be recycled together (Delva, et al., 2019, p. 9). To add to that, some plastics are not even recyclable. Plastics are

> *synthetic chemicals extracted mainly from petroleum and made of hydrocarbons (chains of hydrogen and carbon atoms). Most plastics are polymers, long molecules made up of many repetitions of a basic molecule called a*

monomer and this structure makes plastic particularly durable and long lasting. (Precious Plastic, 2020)

They arise from a sequence of chemical reactions known as polymerization (Heinrich Böll Stiftung, 2019, p. 10). Various forms of polymerization can be used to produce plastics with different properties (Heinrich Böll Stiftung, 2019, p. 10). However, to simplify, plastics can be divided into two main groups: thermosetting plastics and thermoplastics. Thermoset plastics cannot be remelted and are not recyclable (Precious Plastic, 2020). Thermoplastics, on the other hand, become soft when heated and hard when cooled down and can be cooled and heated multiple times, making them suitable for recycling (Precious Plastic, 2020). 80% of all plastics are thermoplastics (Precious Plastic, 2020). Therefore, going forward, this thesis will focus on thermoplastics, which will be referred to as plastics.

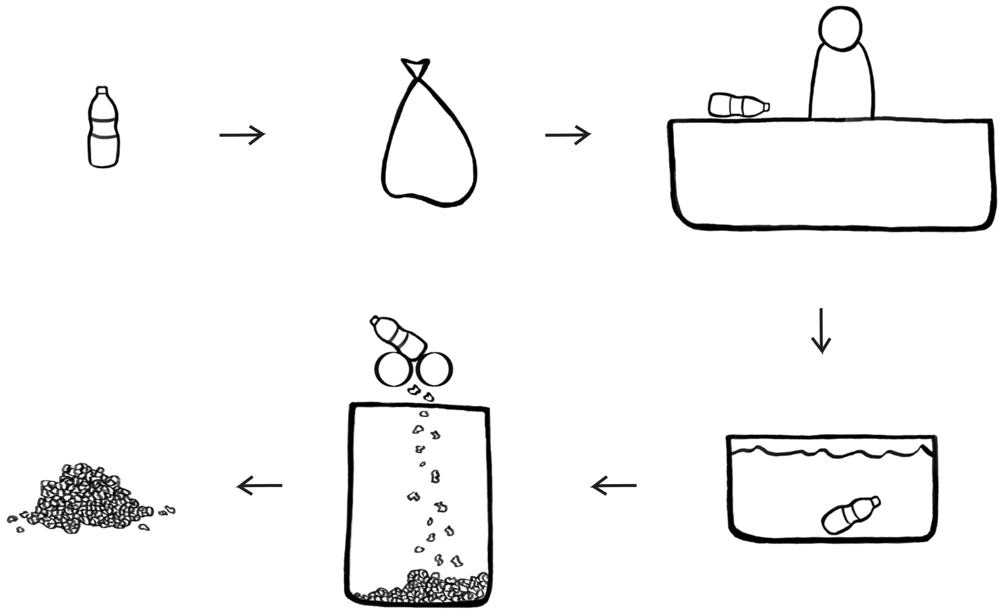
There are seven main types of plastics: Polyethylene terephthalate (PET), High-Density polyethylene (HDPE), Polyvinyl chloride (PVC), Low-density polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and other plastic - a group that consists of other types of plastics such as Acrylonitrile butadiene styrene (ABS) (Heinrich Böll Stiftung, 2019, p. 11). HDPE and LDPE are two types of polyethylene plastics, also known as PE. PE is the most used type of plastic today, followed by PP (Geyer, et al., 2017, p. 1). Together PE (36%) and PP (21%) make up about half of plastic demand, and they belong to the same family of plastics known as polyolefins (Geyer, et al., 2017, p. 1). On the way to a circular economy, working material cycles are of the essence, and to get a circular economy for plastics up and running, one would go for the big volumes first, namely the polyolefins. However, as of today, the recycling of polyolefins is only partially closed looped.



Although in theory recyclable, the different types of plastics are not necessarily recycled in the real world. Out of the seven most commonly used types of plastics, only PET and HDPE can be said to have closed loop recycling. Closed loop recycling is defined as "recycling of plastics into the same or similar-quality applications" (The Ellen MacArthur Foundation, 2016, p. 27). PET to PET bottle recycling is a commonly used example of actual closed loop recycling (The Ellen MacArthur Foundation, 2016, p. 27). HDPE is the only polyolefin that is currently recycled in closed loops. As a recycled plastic, HDPE is increasingly establishing itself as a real alternative to traditional fossil-based plastics (Initiative Frosch, n.d.). Recycling HDPE is common, recycling systems are widespread and the material also has a good market price (Grønt Punkt Norge, 2017, p. 33). PP, on the other hand, although fully recyclable, is usually downcycled. This type of recycling, also referred to as cascading, works in open loops and can be defined as "recycling of plastics into other, lower value applications" (The Ellen MacArthur Foundation, 2016, p. 27). With this type of recycling, new plastics still needs to be made from fossil raw materials (Initiative Frosch, n.d.). As of today, recycled PP typically is of poorer quality than virgin plastics and it costs more(Grønt Punkt Norge, 2017, p. 30). However, PP is a newer plastic than PE. Recycled PP has only been available on a significant scale for a few years and is therefore still developing (Arbeitsgemeinschaft Verpackung + Umwelt, n.d.).

The technology & its limits

The type of recycling talked about so far is defined as mechanical recycling, which is a commonly used method for recycling plastics such as PP, PE and PET (Delva, et al., 2019, p. 5). Mechanical recycling, as the name implies, only entails mechanical processes (Delva, et al., 2019, p. 5). In short, the mechanical recycling process consists of collection, sorting, washing and grinding (Delva, et al., 2019, p. 5). First, the plastic is collected.



Secondly, it is sorted, other materials that contaminate the waste stream are sorted out and the different types of plastics are separated (Delva, et al., 2019). At last, the plastic material is reprocessed. The plastics is washed to remove any residues and grinded to reduce the size of the plastic into flakes (Delva, et al., 2019). The material can then be melted and extruded into pellets, which is a secondary raw material that can be used to produce new plastic products (Grønt Punkt Norge, n.d. -a). However, even after all those steps, it is possible that "impurities from both within the plastic structure and from external sources remain" (Rollinson & Oladejo, 2020, p. 13).

Although mechanical recycling is the most ubiquitous in the industry today, it has some issues in regard to closing loops. To recycle polyolefins mechanically is relatively straightforward, but they degrade under normal processing temperatures, meaning that they degrade every time they are recycled (Netværk for cirkulær plastemballage, 2019, p. 48). What happens in mechanical recycling is that the length of the polymer is shortened and that results in plastics of poorer quality than the original (Rollinson & Oladejo, 2020, p. 13). As the Ellen MacArthur foundation states "given the inherent quality loss during mechanical recycling, closed loop mechanical recycling cannot continue indefinitely" (The Ellen MacArthur Foundation, 2016, p. 47). Eventually, after a certain number of times being mechanically recycled, the plastic material is so degraded that it can no longer be recycled mechanically. Furthermore, most plastics materials are not pure polymers, but they also contain some additives that can make them more difficult to recycle mechanically (Delva, et al., 2019). Such additives are for instance glass or wood fibers. Glass or wood fiber reinforced plastics are a type of composite material. To recycle these types of plastics, another solution is needed.

Chemical recycling – a foreseeable future or just a dream?

Chemical recycling is an alternative to mechanical recycling. While mechanical recycling tries to preserve polymers, chemical recycling breaks them down to monomers that can be used to produce new plastics (Zero Waste Europe, 2020). There are many different chemical technologies that can be referred to as chemical recycling, but what they have in common is that they “subject plastic waste to a combination of heat, pressure, and/or other chemicals inside some form of reaction vessel.” (Rollinson & Oladejo, 2020, p. 4). Chemical recycling can be divided into two groups: depolymerization and solvent-based processes (Rollinson & Oladejo, 2020, p. 7). One method of depolymerization is pyrolysis, and it can be used to recycle plastics that are not possible to recycle mechanically, such as fiber reinforced plastic, and can even recycle it into virgin quality plastics (Fraunhofer CCPE, 2020). To recycle a material in such a way that it creates a material of higher quality is known as upcycling. So, chemical recycling takes plastics that are difficult to recycle and “turn them back into chemicals” that can be used to produce new plastics, which seems to create a circle that would fit into the concept of a circular plastics economy (Rollinson & Oladejo, 2020, p. 2).

However, chemical recycling is far from perfect. First of all, pyrolysis does not directly result in recycled plastics, the output is an oil that needs to be upgraded for repolymerization (Rollinson & Oladejo, 2020). Repolymerization “also involves additional chemical processing and energy input” (Rollinson & Oladejo, 2020, p. 11). It is also important to point out that depolymerization only can contribute to a circular economy if the plastic is used to produce new plastic, burning the pyrolysis oil as fuel is not recycling (Rollinson & Oladejo, 2020). Furthermore, like mechanical recycling, chemical recycling also struggles with impurities (Rollinson & Oladejo, 2020).

Chemical recycling is not only promoted as a way of closing the loop of plastic waste, but also as an environmentally friendly technology. However, the contrary seems to be the case as chemical recycling is both energy and carbon intensive. Around half of carbon in the plastic material would be lost in upgrading for repolymerization (Rollinson & Oladejo, 2020, p. 29). Furthermore, as of today, there is no chemical recycling technology that is able to “offer a net-positive energy balance” (Rollinson & Oladejo, 2020, p. 34). Chemical recycling is actually so energy intensive that it cannot be rendered as a sustainable technology (Rollinson & Oladejo, 2020, p. 34). According to Rollins and Oladejo (2020, p. 30), chemical recycling can be “characterized by high energy inputs, process losses, and greenhouse gas emissions; very little of the original material can return to the economy as new plastic”.

Furthermore, although all plastics theoretically can be recycled chemically, that does not imply that it is working in the real world, “there is currently no large scale industrial chemical recycling plastic-to-plastic plant in operation” (Zero Waste Europe, 2020, p. 3). In fact, chemical recycling in general “is not at present, and is unlikely to be in the next ten years, an effective form of plastic waste management” (Rollinson & Oladejo, 2020). To sum up, so far, chemical recycling has more cons than pros.

Chemical VS mechanical recycling

All in all, out of the different recycling technologies, mechanical recycling is still, despite its limitations, the proffered one as it has the lowest carbon and environmental footprint (Fortum, 2019, p. 17). Mechanical recycling demands less energy and therefore has a smaller carbon footprint (Rollinson & Oladejo, 2020, p. 14). Furthermore, mechanical recycling also produces fewer toxic byproducts (Rollinson & Oladejo, 2020, p. 14). So, although not all types of plastic waste can be recycled mechanically, mechanical recycling is far less energy intensive and therefore the preferred technology. According to the Ellen Macarthur foundation (2016, p.47), the order of preference in regard to recycling is first mechanical recycling in closed loops followed by mechanical recycling in open loops, at last followed by chemical recycling. So, chemical recycling can be used when the plastic material is so degraded that it can no longer be mechanically recycled and the plastic could be upcycled into virgin quality plastics again (The Ellen MacArthur Foundation, 2016, p. 47).

All in all, as of today no recycling technology is working perfectly and there is little closed looped recycling. In other words, to create a closed loop circular economy for plastics seems in general to be quite a complex issue.

The furniture industry

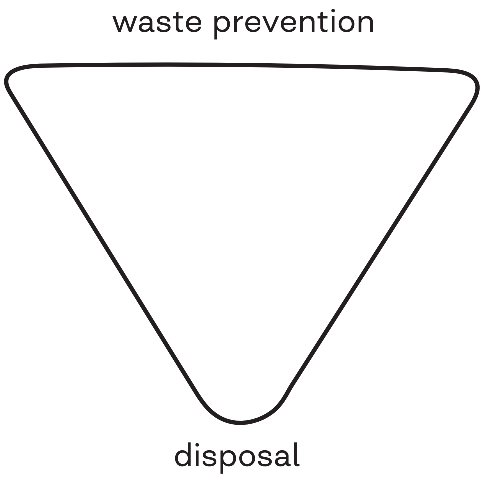
Circularity in the furniture industry

The furniture industry cannot be said to be one of the industries that have been given the most attention in regard to circular economy, at least not yet. Nevertheless, the notion of a circular furniture industry is slowly gaining interest. For instance, the European furniture industry has acknowledged the European Commission's Circular Economy Action Plan and is committed to creating a circular economy for furniture (EFIC, 2020, p. 3). However, as the European Furniture Industries Confederation (EFIC) states: "from a circularity point of view, the wide range of products that are considered 'furniture' and the diverse use of materials in their production makes this a complex area to address" (EFIC, 2020, p. 3).

A case of bulky waste

The furniture industry produces various products made with a variety of materials, plastics being only one of them. To establish a circular economy for furniture, the materials used in furniture products should flow in circular closed loops. As of today, that is not the case. There is not much information about what happens to furniture at end of life, but the European Federation of Furniture Manufacturers statistics estimates that "80% to 90% of the EU furniture waste in municipal solid waste is incinerated or sent to landfill, with ~10% recycled" (EEB, 2017, p. 12). To put this in perspective, it is estimated that around 10 million tonnes of furniture become waste annually (EEB, 2017, p. 12).

When disposed of, furniture becomes what is described as bulky waste, which is a challenging waste stream. As the name indicates, bulky waste is of perceived low value, and its size also makes it expensive and difficult to move around and transport (RSA, 2015, p. 9) Bulky waste mainly consists of furniture (RSA, 2015, p. 9), and although there is not a lot of information available on how furniture is recycled, bulky waste is generally a waste stream with little opportunity for recovery of materials and is therefore either landfilled or inciner-



ated (URBANREC, 2020, p. 6). However, by weight, about 32% of all bulky waste is actually reusable in its current state. That figure even rises to 51% if one also considers products that need a little repair (RSA, 2015, p. 9). So, it seems that reuse is failing to be prioritized in the furniture industry (EEB, 2017).

The missing dimensions of circularity

In a circular economy, reuse is preferred over recycling to keep products circulating at the highest value for as long as possible. Reuse is, however, not the only circular strategy that should be prioritized over recycling, and according to the European Environmental Bureau (EEB) “there is minimal activity in higher-value circular resource flows” in the furniture industry (EEB, 2017, p. 3). This prioritized order of strategies is called the waste hierarchy. There are multiple versions of it, ranging from between four to ten different strategies with preventing waste at the top and disposal at the bottom (Bjørnbet, et al., 2021, p. 3). Other circular strategies in the waste hierarchy that are preferred over recycling and mentioned as relevant to the furniture industry are repair, refurbishment and remanufacturing. The issue, however, is that furniture normally is “not managed in accordance with the waste hierarchy” (EEB, 2017).

Currently in the furniture industry, there is an underinvestment in circular strategies such as reuse, repair and remanufacturing, which restrains the furniture industry from becoming circular (EEB, 2017). Remanufacturing, for instance, “accounts for less than 2% of the EU manufacturing turnover” and costs for repair and refurbishment remain high (EEB, 2017, pp. 3-4). Furthermore, the demand for reused furniture is poor and it does not help that “initiatives which provide consumers and repair and reuse organization with information to maximize the likelihood that products are repaired and reused, is significantly underdeveloped in the furniture sector" (EEB, 2017, pp. 24-25). In fact, it is not required to include information about proper use, disposal or recovery when selling a piece of furniture (RSA, 2015, p. 18). To sum up, so far, circular systems seem to be absent in the furniture industry.

According to the EEB (2017, p.25) "A lack of information from manufacturers on the durability, disassembly, reassembly, reconfiguration, reparability and reuse of furniture products, coupled with the availability and affordability of spare parts and short product warranties, inhibits repair and reuse activity.". However, the issue is not just information related. Many furniture pieces are designed to live short lives and are given short warranties that do not encourage repair, reuse or longevity in general. To design "for long life and fixability", also known as design for longevity is an important circular design strategy (RSA, 2015, p. 11). As the RSA acknowledges "The ideal scenario for bulkier products in a circular economy is that these items are designed for longevity." (RSA, 2015, p. 20). However, currently with no mandatory requirement for longer warranties, longevity is not encouraged.

The Incentives (or lack thereof)

All in all, the infrastructure for a circular furniture industry is not yet developed. As EFIC states "collection and reversed logistics infrastructure is limited" (EFIC, 2020, p. 12). Furthermore, the incentives for improving are absent. There exist no producer responsibility legislations for furniture, at least not on EU level, as it for instance does for packaging and electronics (RSA, 2015, p. 18). So, there is no legal incentive for furniture manufacturers to consider what happens to their products at end of life (RSA, 2015, p. 18). That is possibly also the reason why poor design is identified by the EEB as one of the barriers to a circular furniture sector (EEB, 2017). There are weak drivers for making product design more circular so that products for instance can be repaired, remanufactured or recycled. In general, there is little reason for the furniture industry to change ‘business as usual’.

Although there might not be any legal incentives to create a circular furniture industry, that does not mean that the there are no benefits associated with the transition to a circular economy. For instance, “re-using (as opposed to recycling or incinerating) 1 tonne of sofas would save almost 1.5 tonnes of CO_2 emissions and would also create net employment benefits” (RSA, 2015, p. 9). So, a circular furniture industry would also create jobs. According to the EEB, the opportunities for a circular economy sector is 160 000 extra jobs and 3.3-5.7 mt additional reused or recycled furniture products, which would avoid 3.3-5.7 mt of CO_2 equivalent (EEB, 2017, p. 5). So, there are economic and environmental benefits to a circular furniture industry.

Furthermore, measures are being taken to improve the reuse of furniture and recovery of materials found in furniture. URBANREC is a project that aims to enhance “prevention and re-use, improving logistics and allowing new waste treatments to obtain high added value recycled products” (URBANREC, 2020, p. 6). The URBANREC project focuses on three categories of bulky waste, furniture being one of them (URBANREC, 2020). Within the furniture category, the project, amongst others, focuses on plastic materials (URBANREC, 2020). The lack of circular systems and infrastructure in the furniture industry also applies to plastics. As of today, the furniture industry does not seem to have a functioning recycling system for plastics.

Currently, there is no clear plan for how to move the furniture industry towards circularity, let alone for the circularity of plastics in the furniture industry. However, what is obvious, is that there are huge challenges that need to be overcome if the furniture industry is to become circular. Only some of these challenges have been mentioned here, more will be identified and discussed later on in the thesis, especially regarding plastics.

A brief history of plastics in the furniture industry

Plastic transformed the last century and also set its mark on the furniture industry. In fact, the most commonly used piece of furniture across the entire world today is a plastic chair, known as the monobloc (Vitra Design Museum, 2017). Plastics was originally not intended to be used in furniture, but the material intrigued the interest of many designers and eventually established itself as a material used to mass-produce furniture. This brief history of plastic in the furniture industry tells the story through looking at the development of the plastic chair, a piece of furniture that has become an everyday item (Vitra Design Museum, 2017).

Plastics was initially invented to imitate natural materials that were rare or expensive, such as ivory (Heinrich Böll Stiftung, 2019, p. 10). The supply of these natural materials was becoming scarce in the late 1800, largely due to industrialization (Fritz, 2012). At that time, plastics were made from natural materials, but over the course of two world wars, plastic became a synthetic material that could be mass produced (Heinrich Böll Stiftung, 2019). When the plastic boom started after the second world war, the material had an image of being clean, modern and glamourous (Heinrich Böll Stiftung, 2019). Plastics did no longer serve as a substitute material, instead it became a material that inspired a wide range of new products, also in the furniture industry (Fritz, 2012).

The golden era of the plastic chair

Entirely new products were designed using plastics. Plastics opened up new possibilities for furniture design, amongst others making furniture pieces lighter and more compact (Fritz, 2012). Plastics introduced a whole new formal language characterized by exploring the opportunities of the material. No other material could be used to produce chairs with seamless organic shapes in a singular form (Rashid, 2017).


Eames' plastic chairs


Joe Colombo's Universale


Panton chair

The post war period can be said to be the "golden era of design objects made of plastic" (Fritz, 2012). Many chairs that are design classics today, were made during that time period. Charles and Ray Eames' famous molded plastic seat shells is one example (Fritz, 2012). For these seat shells, fiber reinforced polyester was used (Fritz, 2012). Up until today, reinforcing plastic with fibers is common for plastic chairs. Another infamous example is the Panton chair, designed by Verner Panton in 1959 (Fritz, 2012). This chair was one of the first mass produced models. Whereas Joe Colombo's chair Universale, designed in 1965, was the first injection molded chair (Rashid, 2017). Today, injection molding is a widespread and commonly used production method for plastic chairs. It is amongst others used for the monobloc, the very symbol of a mass consumer product (Vitra Design Museum, 2017).

The monobloc & mass consumption

The golden era did not last long, and plastic furniture eventually became products of mass production and consumption. The image of plastic furniture became negative as environmental awareness grew, eventually resulting in plastics furniture being perceived as cheap, bad for the environment and tacky (Fritz, 2012). This change in perception of plastic furniture can to a large extent be credited to the monobloc. The name monobloc is used for a plastic chair that is "fabricated from a single piece of plastic in just one work step" (Thiel, 2010, p. 6). That is what makes the monobloc so cheap, it only takes about one minute to produce a typical polypropylene monobloc chair, making it perfect for mass production (Thiel, 2010).

Actually, the first plastic chair, made in 1946, was a monobloc (Rashid, 2017). However, it was first in 1972 that the archetypical inexpensive plastic chair came to be,

Fauteuil 300

Grosfillex Resin Garden Chair

with the Fauteuil 300 designed by Henry Massonnet (Vitra Design Museum, 2017). From the 1980s, increasingly more companies produced similar chairs (Vitra Design Museum, 2017). In 1983 Grosfillex produced the Grosfillex Resin Garden Chair, the first high-volume mass-produced chair (Rashid, 2017). This is the typical plastic garden chair that everyone is familiar with. Since then, the monobloc chair has become to the furniture industry, what a white T-shirt is to the fashion industry, a basic (Schreiner, 2017). As of today, it is estimated that there exists as much as over a billion monobloc chairs (Schreiner, 2017). To put that into perspective, there has only been sold 100 million of the famous Thonet 14 chair (Schreiner, 2017). However, with the plastic crisis becoming increasingly more evident, the monobloc is becoming “a relic of bygone times” (Schreiner, 2017).

Current plastic furniture

Given the current plastic crisis, one might start to think that plastic furniture is bad for the environment. It is however a bit more nuanced than that, as furniture is far from the worst application for plastic. In fact, plastic furniture can in some cases have a better carbon footprint than furniture made of other materials (Miniwiz, 2021). Plastic is lighter than for instance wood and metal, which gives it a lower carbon footprint from transportation and delivery (Miniwiz, 2021). Furthermore, furniture is a product category that is made to last, and plastic is a long-lasting material. So, in difference to single-use disposable products, plastic furniture is not the type of plastic product that poses the biggest waste problem. On the contrary, plastic furniture is long-lasting, making it well-suited for circular activities such as reuse and repurposing (Miniwiz, 2021).

Today, plastics is used by designers to make furniture that is accessible to a wider audience. In the golden age of experimental plastic chair design, a wide range of production methods were used as well as different plastic materials such as glass fiber-reinforced plastics, polyester, polyamide (PA) and ABS. (Fritz, 2012) These days, chairs are often injection molded or rotationally molded and more non fiber hard plastics are used, such as PP, PE and polycarbonate (PC). As in the beginning when plastics was introduced, designers are still experimenting with new materials. However, today the experiments focus on finding ways to make the production, use and disposal of plastics more sustainable. The materials that are experimented with today are bioplastics and recycled plastics. It is becoming increasingly more common for designers to experiment with recycled plastics, so many chairs are currently made with recycled plastics (Isaac, 2020).

At last, to circle back to the circularity of plastics in the furniture industry: "most plastic chairs currently on the market [...] are destined to end their days buried in landfill sites. While some chairs proudly claim they are made from materials that are fully recyclable – it is highly unlikely that they will actually be recycled." (Isaac, 2020, p. 21). So, there does not seem to be any simple solution to the issue of the circularity of plastics in the furniture industry.

The promising role of design

One might ask how design first into all of this. The Ellen Macarthur Foundation has the answer to that question: "Design sits prominently at the heart of the circular economy" (The Ellen MacArthur Foundation, n.d.). So, design must play a role in creating a circular economy for plastics in the furniture industry. Out of the three main principles of the circular economy, which are to design out waste and pollution, to keep products and materials in use and to regenerate natural systems, the two first are the most relevant for this thesis (The Ellen MacArthur Foundation, n.d.). To design out waste and pollution is important to close the material loop of plastic. The second one, to keep products and materials in use, is important to keep both the furniture products, and plastic materials used in them, circulating at the highest value for as long as possible.

Design alone cannot solve the plastics crisis, but according to the European Commission, "it is one of the keys to improve recycling levels." (European Commission, 2018, p. 7). In fact, "up to 80% of products' environmental impacts are determined at the design phase" (European Comission, 2020, p. 3). Designers can therefore be said to have a crucial role in getting plastics to circulate in closed loops. Change is needed along the entire plastics value chain and design can be part of the solution, both at the very beginning and at the very end.

Design for & from recycling

There are two main approaches to design in relation to recycling, design for recycling and design from recycling. Design for recycling is a well-known strategy focusing "during the design process, on the recyclability of products at their end of life" (Veelaert, et al., 2017, p. 130). The goal is to ensure that the materials used in the product can be "recycled as efficiently and effectively as possible and can be looped back into the economic system" (den Hollander, et al., 2017, p. 520). Design from recycling, on the other hand, "is a new approach within the concept of circular economy, which examines to what extent a new product can be produced from an existing flow of recycled polymers, and the design specifications this entails" (Veelaert, et al., 2017, p. 130). The design process attempts to figure out how to design specifically with recycled plastics to create sustainable high-quality products (Veelaert, et al., 2017, pp. 130-131). It can be challenging to implement these new materials, so design from recycling aims to take advantage of the unique identity and use it as an opportunity to differentiate these new materials on the market (Veelaert, et al., 2017, p. 130). However, as the Ellen MacArthur foundation states "Recycling is, without doubt, a key component of a circular economy, but it is nothing more than that." (The Ellen MacArthur Foundation, n.d.).

So, there is more to circular economy than just recycling, and so there are more design strategies for products in a circular economy as well. Design from recycling could contribute to designing out plastic waste. Whereas design for recycling can be said to prevent and reverse obsolescence at a material level and could therefore keep plastic materials in use (den Hollander, et al., 2017). Another strategy is however needed to keep the furniture products in use, and that strategy is called design for product integrity.

Design for product integrity

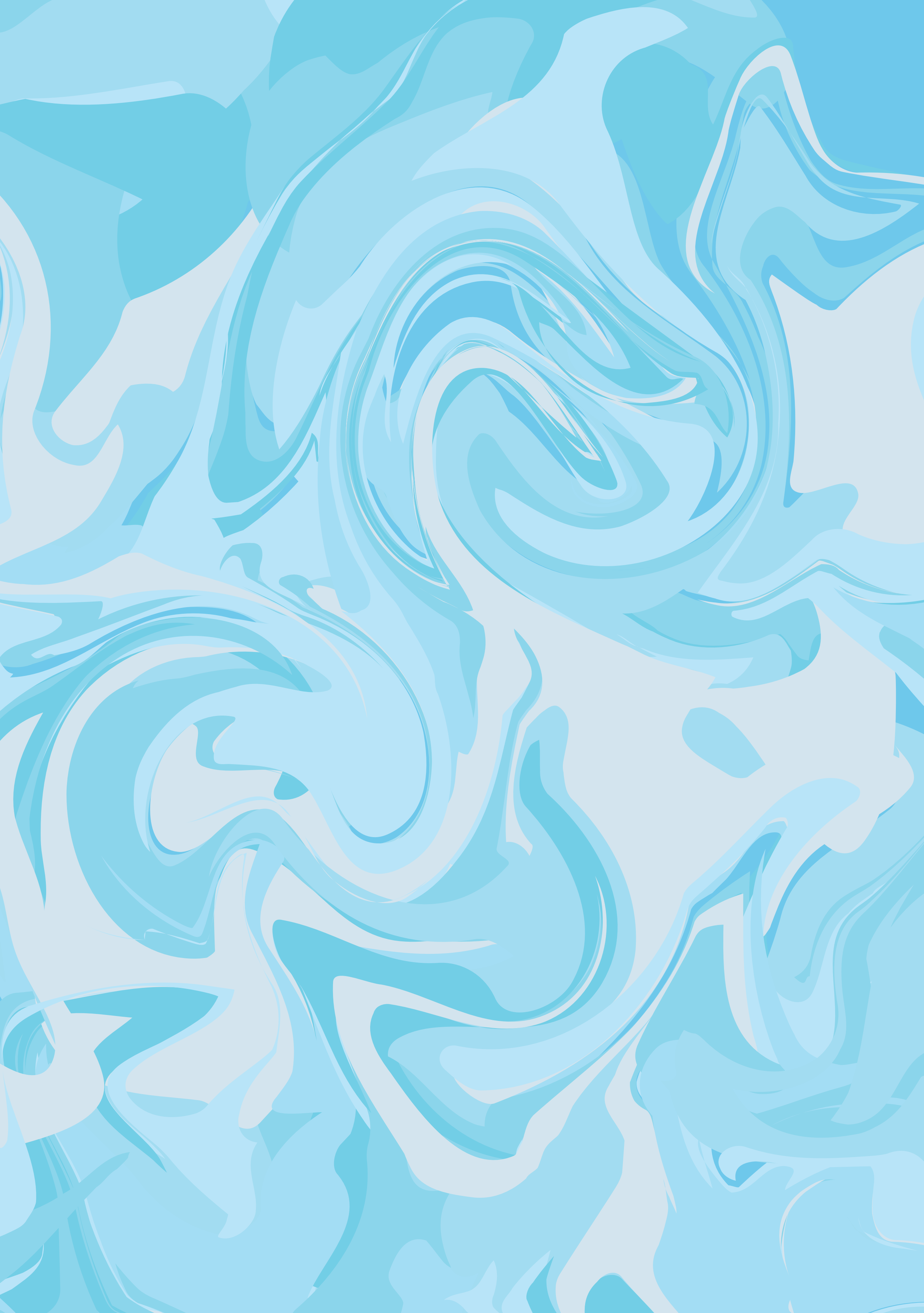
Design for product integrity aims, according to den Hollander et. al. (2017), to prevent and reverse obsolescence at a product and component level. Den Hollander et. al. (2017) states that to keep products in use, designers can create products that resist, postpone or reverse obsolescence. Products can be designed to resist obsolescence by being both physically and emotionally durable (den Hollander, et al., 2017, p. 520). Furthermore, designing products to be easy to maintain and/or upgrade would postpone obsolescence (den Hollander, et al., 2017, p. 520). At last, if products are designed for easy repair, refurbishment or remanufacturing, obsolescence can be reversed according to den Hollander et. al. (2017, p 520). So, preventing, postponing and reversing obsolescence would enable long and extended use of products (den Hollander, et al., 2017, p. 520). In other words, design for product integrity is a strategy that could theoretically contribute to keep plastic furniture products in use. Design for a circular economy, also known as circular design, will be further investigated later in this thesis.

Sum up of chapter 2

This chapter has looked at the three main keywords of this thesis: “circular economy”, “plastics” and “furniture industry” both separately and in relation to each other. Terms relevant to all three topics and to their use in this thesis have been explained. All in all, the chapter has given an overview of the current situation of circularity, both in regard to plastics as a material and in regard to the furniture industry. It also took a brief look at the historic use of plastics in the furniture industry and on some circular design strategies that could be relevant for plastic products.

What this chapter has shown is that neither plastics as a material nor the furniture industry in general are fully circular. Plastics is in its early stages of circularity and there is definitely room for improvement in increasing recycling of the different types of plastics. The same goes for the furniture industry, which so far has not been a prioritized industry for implementing circularity and is therefore, amongst others, lacking legal incentives and infrastructure to become circular. Furthermore, plastics is no stranger to the furniture industry, the material has been widely used since the plastic boom last mid-century. At last, this chapter showed that design has an important role to play in regard to the topic of this thesis.

To sum up, plastics, as a material, does not flow in closed loops and the furniture industry is lacking circularity systems and infrastructure. So, the circularity of plastics in the furniture industry seems to be quite a complex issue in definite need of further investigation. On that note, it is time to delve deeper into the issue of the circularity of plastics in the furniture industry.



Chapter 3

Industry Insight

This chapter presents the interviews conducted with representatives of the furniture industry as well as a few representatives of other companies of interest and relevance to the topic of this thesis. These interviews were done to get insight into the furniture industry, to form a picture of the current state and challenges facing the industry in regard to plastics and circularity.

The chapter describes, analyses and assesses the findings of the interviews. Firstly, the scope of and method for the interviews is described, secondly the interviewees and the companies they represent are briefly presented, followed by a comparison, analysis and assessment of the topics discussed in the interviews. At last, an interview with an expert on corporate social responsibility (CSR) is presented. This interview briefly discusses the topic of greenwashing in the furniture industry.

Scope & method

The interviews for the industry insight phase have been conducted with the case study in mind. The interviewees all work for companies that are or have been working on seating furniture projects involving recycled and/ or recyclable plastics that will, with a few exceptions, be used in the case study. So, most interviews were conducted with representatives of furniture manufacturing companies. A few representatives of other companies that are or have been working on relevant projects were also interviewed. In total, the industry insight phase consists of 11 interviews, with interviewees from 7 furniture manufacturing companies, one architecture and design office, one bioplastic production company, one fashion brand and one CSR expert.

The interviews were semi structured in order to allow for exploration of the themes discussed in the interviews, and qualitative in order to do a deep dive into how the industry thinks, works and operates. An interview guide was developed and used for all furniture manufacturing companies. The guide was divided into four main themes. The first part was about circular economy and sustainability in the companies. The second part was about the use of plastics, what types of plastics were used, where and how they were used. The third part was about design of future products, mainly focusing on circular design. The last part was about the plastic chairs used in the case study. The questions in the last part therefore differ with the different chairs from the different manufacturers. Some extra questions were also added to the interviews where it was useful to ask about something that only applied to a specific company.

These interviews were conducted to explore what the furniture industry is doing to design sustainable plastic furniture that could function within a circular economy, and to uncover what challenges the industry is facing regarding the circularity of plastics. The goal was to gain an understanding of the industry's approach to both plastics and circular design as well as the industry's strategies for the future in regard to the circularity of plastics. This chapter presents the answers to the categories: circular economy & sustainability, use of plastics and design of future products. Answers to the questions regarding the specific chairs used in the case study will be discussed in the next chapter.

The interview guides for the remaining interviews with the three representatives of other companies, that are not furniture manufacturers, were all different and adapted to what information was wanted from the specific company. Furthermore, the interview with the CSR expert was conducted after all the other interviews were done and analyzed, so the interview guide for that interview contained questions based on the findings of the other interviews. All interview guides can be found in the appendix.

The majority of interviews were conducted via a video meeting on Teams, some via a phone call and some via email. In collaboration with the supervisor of this thesis it was deemed as inexpedient to anonymize the interviewees of these interviews. All interviewees have given their consent to use their full name, job title and answers to the interview questions in this thesis.

The interviewees

This is a short description of the different interviewees and the companies they represent as well as a brief explanation of why they were interviewed. The contact to the interviewees was mostly established by Diez and sometimes on own initiative if he did not have any contacts in the respective companies.

HAY

The first interview was conducted with Gustav Lindholm, senior product developer for furniture for danish design company HAY. The interview was conducted via Teams and lasted about an hour. A representative of HAY was interviewed because the company produces two chairs used in the case study.

HAY, founded in 2002, is the youngest of the design companies represented in the interviews. The company started as a furniture company but has expanded into other categories such as lighting and accessories over the years. The company has recently started to implement the use of recycled plastic in some furniture pieces as it aims to make the majority of all plastic components with recycled content by 2025 (HAY, n.d.).

Fritz Hansen

The second interview was conducted with Jesper Thimes Langballe, product development manager for danish design company Fritz Hansen. The interview lasted about an hour and was conducted via Teams. A representative of Fritz Hansen was interviewed because the company produces a chair that is used in the case study.

Fritz Hansen was founded in 1872 and is the oldest furniture manufacturing company represented in the interviews, so it is a company with a big heritage (Fritz Hansen, n.d.). Fritz Hansen is both a design and production company and the company produces both design classics, such as Arne Jacobsen chairs, and designs new furniture. The company therefore has an interesting viewpoint, as it is balancing between trying to make design classics fit into a circular economy and designing new circular furniture.

HAY

FRITZ HANSEN

MAGIS

Snøhetta

An interview was also conducted with architect Stian Alessandro Ekkernes Rossi, Snøhetta's unofficial "plastics oracle". The interview was conducted via Teams and lasted about an hour. This interview was conducted both to get information about a chair used in the case study that Rossi helped design and generally to learn about a plastic research project he had done for Snøhetta.

It was a conscious choice to not do this interview with the manufacturer of the chair, but with Rossi, an architect, to get another point of view on the furniture industry from someone who knows the industry and how it works but is not in the middle of it. Furthermore, Rossi was interviewed to learn more about the plastics research project he did for Snøhetta that aimed to "understand plastic as a material, its journey and footprint in the value chain, as well as its inherent qualities" which seemed very relevant for this thesis (Snøhetta, n.d.).

Magis

The next interview was conducted with designer Enrico Perin from Magis, an Italian design company. This interview was conducted via email. A representative of Magis was interviewed because the company produces two of the seating solutions used in the case study.

Magis has a long tradition of creating plastics furniture and has produced many famous plastic furniture pieces over the years. So, ever since the company was founded in 1976, plastics has been a material of great reference to Magis and the company therefore has a rich experience with making plastics furniture. Furthermore, the company has also, for quite some time, been looking into alternatives to virgin plastics (Magis, n.d.).

emeco

FLUIDSOLIDS®
BIOCOMPOSITES

Emeco

The fifth interview was conducted with Jaye Buchbinder who works in product development and heads up sustainability for Emeco, an American furniture design company. The interview was conducted via Teams and lasted about an hour. A representative of Emeco was interviewed because the company produces two of the chairs used in the case study.

Emeco is the only non-European company represented in the interviews. The company was founded in 1944 and has a long tradition of using waste materials, starting with the famous 1006 Navy chair made with recycled aluminum (Emeco, n.d.). Since 2010 the company has been producing chairs from recycled plastic materials developed by the company itself.

Fluidsolids

The sixth interview was conducted with Beat Karrer, founder and CEO of FluidSolids, a swiss company that has created a biocomposite material. The interview was conducted over the phone and lasted about 30 minutes. Karrer was interviewed because he, using the FluidSolids material, has designed one of the seating solutions used as an alternative example in the case study.

FluidSolids is not a furniture manufacturer, it's a company founded by an industrial designer who has developed a biodegradable biobased plastic that is home compostable and not in competition with food production, and the material can be used for furniture. This interview was conducted to get another point of view, from someone who does not use recycled plastic that would circulate in a technical loop, but a plastic material that would fit into a biological system. It was also interesting to hear why an industrial designer would prioritize to focus on bioplastics over recycled plastics.

Ecoalf

The seventh interview was conducted with PR & Collaborations manager Mónica Oliart from Spanish fashion brand Ecoalf. This interview was in part conducted over phone and in part via email. A representative of Ecoalf was interviewed because of a collaboration between the company and furniture manufacturer Viccarbe.

Ecoalf is a sustainable fashion brand that makes clothes from recycled materials, amongst others from ocean plastic. The company is therefore experienced with turning waste into value. Ecoalf is currently collaborating with Viccarbe on developing new furniture pieces from recycled materials. The interview with a representative of Ecoalf was conducted to learn from a company that has managed to build a business that is designing products while cleaning the planet of plastic waste. Furthermore, it was interesting to get the fashion industry's point of view on the issue.

Viccarbe

The eight interview was conducted with Ruben Mateos Brea, product manager for Spanish design company Viccarbe. This interview was conducted via email. Viccarbe has not produced any chairs used in the case study, but a representative of the company was interviewed because of a collaboration with Ecoalf and Diez Office.

The interview with a representative of Viccarbe was conducted because the company is doing a collaboration with Diez Office and Ecoalf to create a chair made from recycled ocean plastic. In addition to the chair that Diez Office is designing, the Viccarbe and Ecoalf collaboration will also result in a sofa made from recycled and recyclable materials. In difference to the furniture from the other companies represented, both the chair and sofa of this collaboration are still in the early stages of development, so it was interesting to gain insight into an ongoing project as well, to see what challenges they are facing.

Flokk

The ninth interview was conducted with Christian Lodgaard, Senior Vice President, Products and Brands for Flokk. Flokk is the owner of leading office furniture brands, amongst others Norwegian brand HÅG. The interview lasted about an hour and was conducted via Teams. A representative of Flokk was interviewed because the company produces a HÅG chair that is used in the case study.

Flokk is the market leader in creating workplace furniture in Europe and it is a company that has been working with sustainability and circular design for quite some time (Flokk, n.d.). HÅG, one of the company's brands, produced a chair from recycled plastics as early as in 1997. The company also introduced circular design guidelines for its products in the nineties, and they are still in use today. In 2019, Flokk managed to use 649 tonnes recycled plastics in its products (Flokk, n.d.). So, the company is experienced with using recycled plastics in furniture.

Vestre

The last interview with a furniture manufacturer representative was conducted with Jan Christian Vestre, CEO of Vestre, a Norwegian company that produces urban furniture. The interview lasted about an hour and was conducted via Teams. Vestre was interviewed because his company produces a bench that is used in the case study as well as to learn about the company's other recent circularity initiatives.

Vestre has a long tradition with circularity. When the company was founded, it started using scrap materials. In recent years the company has started to look into other circular economy initiatives, one of them being to build what Vestre says is probably the world's first circular furniture factory (Vestre, n.d. -a). Another project aims to create a value chain that can clean the ocean of plastic waste, the bench used in the case study is part of this project.

Analysis

After conducting all the interviews, answers to all the questions that were the same for all representatives of furniture manufacturers were placed side by side in a spreadsheet and compared. First, the answers from each interviewee were summarized, after which similarities and differences between the different interviewees were found, and main topics and trends were identified. Furthermore, questions that were not identical for all interviewees but identified as similar were grouped together, the answers summarized and compared as well. For each question or group of similar questions, observations were made, and conclusions drawn based on the comparison of the answers. This was done for every category of the interviews.

Circular economy & sustainability in the furniture industry

The first part of the interview with the furniture manufacturer representatives was generally about circular economy, sustainability and general thoughts about the industry to warm up to the topic and get a sense of the general work the manufacturers are doing in regard to circularity and sustainability. It is not a given that circularity is synonymous with sustainability in manufacturing companies (Bjørnbet, et al., 2021). Therefore, it was important to ask about both topics and not only about circularity.

Circular Economy Efforts

The first topic discussed was circular economy. The interviewees were asked about their company's take on a circular economy and if the company is working towards a circular economy, what specifically is being done. The length of the answers varied greatly, but what all furniture manufacturers had in common was that they all believe in a circular economy, and they are all working towards it. Some have been working with circularity for a longer time and had more specific stories to tell about their initiatives, whereas others have started more recently and are still working to convert the concept into practice. In regard to what is being done specifically, all manufacturers answered that they create durable and long-lasting products and that design for recycling, in terms of being able to disassemble products and recycle the parts, is an important part of circular economy. Nevertheless, there were also some differences between the answers given by the interviewees.

Interestingly, the companies' understanding of circularity differed. Some companies had a greater focus on design for longevity as an important part of circular economy, whereas others perceived circular economy more as simply design for recycling. Although important because all products eventually become waste, recycling is a last resort. Focusing on extending the life of products is equally, or even more important in order to keep the product circulating at the highest value for as long as possible. As Vestre (2021) explained, "the point isn't to reuse things or recycle them too early". To create durable products is part of design for product integrity and it is important, but only making a product durable can be said to be business as usual, it is comfortable for the manufacturers, but it does not actively contribute to keeping products circulating for as long as possible. Efforts mentioned by the interviewees to extend life or postpone death of products were largely to offer spare parts or repair. The minority of the manufacturers also offers long warranties and refurbishment or other circular strategies. The companies that have come the furthest in implementing circularity, and that have somewhat established circular systems, services or business models seem to be the ones who have been working towards circularity the longest, such as Flokk and Vestre, who are worth mentioning because they both have services for extending life of their products, such as for instance buy back and refurbishment.

Some of the companies also focus on the use of waste materials and on turning waste into value, which is also important to close the loop. However, it is not circularity unless those materials are also recyclable at the tail end, and that seems to be what many of the companies are working on improving now in regard to the circularity of their products. The reason for using waste materials mentioned by the interviewees was that one can clean the planet of waste while at the same time producing new products.

So, the companies seem to have different views on circularity and different levels of implementation, also according to their understanding of the concept. There seems to be three aspects to a circular economy that furniture manufacturers focus on, as described by Buchbinder (2021) from Emeco, those are "Design from materials that would be scrap, make them last as long as possible and then make them so they are able to be recycled on the tail end.". The minority of the companies have managed to implement all three. Some companies for instance use waste material and make long-lasting products, but struggle to recycle them, whereas others make recyclable products, but without using waste materials. It seems that the industry needs help to turn circular economy from a theoretical concept into real practice, especially in terms of establishing circular services, systems and business models, which with a few exceptions were absent.

Although few, there are however some examples of circular economy in practice, one of them being Vestre's new circular factory the Plus, which "will have a dedicated line to take in old products and upgrade and refurbish them" (Vestre, 2021). With this factory Vestre is putting circular strategies into system so that the company can take products back in an industrial way (Vestre, 2021). The factory is set up in such a way that it can produce new furniture side by side with refurbishing old ones without ruing the pace of mass production (Vestre, 2021). Another example is FluidSolids, a business based on circular economy. When asked how difficult it was to implement circular economy into a business, Karrer (2021) from Fluidsolids answered that it was quite easy because

> *turning biomass that has low or very little value into a material is obviously an economic advantage, an added value, and therefore it's actually been quite easy to turn that into a business. There are hundreds of companies that are interested in turning their waste into value.*

Both these companies prove that circularity in practice is both possible and profitable, although it might be easier said than done.

Sustainability Efforts

The second topic discussed was sustainability. The interviewees were asked about their company's sustainability goals and how they are working to reach them. The companies all have different approaches, but general efforts that were mentioned by many were responsible production, lowering carbon footprint and energy use. Furthermore, about half of the furniture manufacturers use the UN sustainable development goals. Goals nr 12 – responsible consumption and production, 13 – climate action, 15 – life on land and 7 – affordable and clean energy were used the most. The minority of manufacturers focused on sustainability efforts beyond those that affect or are affected by their own production.

Same as with the circular economy efforts of the companies, some have been working with sustainability for a long time, whereas others have started more recently. Naturally, the companies that have been working with sustainability longer, have put it more into system with clear goals and results to show to. There is also a great difference in what information can be found online on the different companies' websites in regard to sustainability. Those that have very little information online also had vaguer goals and did not have any specific actions to show to in the interviews, whereas those that had informative publicly accessible sustainability reports online were more specific about what they do in terms of sustainability in the interviews as well.

Communicating what one is doing was another topic mentioned by multiple interviewees as important in regard to sustainability. Many of the companies have only recently started to put words on their sustainability efforts. This was identified as a tendency in the industry, that manufacturers are trying to be more open and communicate what is being done, but that they find it difficult to do. Those that have been working with sustainability longer also seem to be better at communicating their efforts and they, on the other hand, advocate for transparency and real action in the industry as they argue that sustainability is more than a communication concept.

There can also be said to be a correlation between the companies that have been working with sustainability for a long time and circularity. In other words, those who have worked with sustainably for a long time, may also seem to have progressed further in regard to circularity. Furthermore, the companies with extensive sustainability efforts also seem to have a more comprehensive understanding of circularity. These companies for instance focus on extending life of products because recycling and production requires energy, which again is related to environmental impact and sustainability.

At last, in relation to sustainability, certification was something some of the manufacturers focused on, and it was also a recurring topic in the interviews.

Certification

This was a recurring topic in the interviews with the furniture manufacturer representatives and an interesting one as well, as the opinions about and priorities in regard to certification differ greatly. When asked why certification was important, there were two identified trends. One group said that certification was essentially important for their own benefit as it allowed them to sell products or reach the company's sustainability goals. The other group answered that certification was important for consumers when buying products in order for consumers to make informed choices.

Furthermore, what type of certification should be prioritized also provided divided opinions. Some manufacturers preferred ecolabels, whereas others favored Environmental Product Declarations, also known as EPDs, and one manufacturer preferred both side by side. Ecolabels are environmental labels of type 1, meaning that they are voluntarily and based on multiple criteria with third party verification, "indicating overall environmental preferability of a product within a particular category based on life cycle considerations" (The International Organization for Standardization, 2018, p. 1). Whereas EPDs are environmental labels of type 3, meaning that they provide "quantified environmental data using predetermined parameters and, where relevant, additional environmental information" (The International Organization for Standardization, 2010, p. 2). The manufacturers that preferred EPDs did so because they show documented numbers such as the product's carbon footprint and energy use. Interestingly, the Norwegian companies seem to generally advocate for EPDs, whereas for instance the danish companies focus on ecolabels. However, it is worth noting that the Norwegian companies also do use ecolabels on their products. Snøhetta architect Rossi also preferred EPDs over ecolabels.

The different types of certifications, and the issues related to them, will be discussed further in the next chapter, following the case study.

Change in the industry

Following the questions about circularity and sustainability, the interviewees were also asked what change they wish to see in the furniture industry in general, and they all wanted different things. An explanation for the different answers might be that the interviewees are biased by their own personal opinion or by what would benefit their company. Nevertheless, some trends were identified.

Around half of the interviewees said that they want the industry to, as Perin (2021) from Magis said, “produce LESS, but BETTER” products. Furthermore, around half also wished for the industry to use more recycled materials as that would create a demand for the material, consequently improving the quality and cost of it. Additionally, the companies that measure the carbon footprint of their products want the rest of the industry to do so too.

One of the things that some companies feel is missing and needed in the industry are some guidelines. Langballe (2021) from Fritz Hansen described this issue quite well:

> *I think it’s hard at the moment to navigate in because there are so many opinions about what is right. How do you calculate the carbon footprint on a chair’s life cycle? How do you make that calculation? I think you find three or four different ways to do that, but which one is right? I think it will help us a lot if we somehow have a benchmark that we can talk from in the industry.*

There are currently no such guidelines in the furniture industry. What would however help to get there, is as some companies also wished for in the industry: more transparency. Architect Rossi (2021) had also noticed the lack of transparency in the furniture industry, or as he said “I do think that the furniture industry has been an industry with a lid on it. Very few have gained insight or have pushed the industry because it has been lucrative.”. That appears to change and according to some of the interviewees, designers can help drive this change.

The role of the designer in regard to changing the furniture industry was also something a couple of the interviewees mentioned. They believed that designers have a huge potential to implement change in the furniture industry, as Lindholm (2021) from HAY said: “I also believe designers can make a huge difference by designing in a responsible manner, they have more power than they think.”. Architect Rossi (2021) also shared this belief and said that he thinks “a lot of the responsibility lies with you as industrial and product designers in the future, to make demands and be careful of what you design and for what clients you want to design something.”. Interestingly, designer was the only profession that was specifically mentioned as one that could implement change.

By acknowledging that they want the industry to change, the interviewees also confirmed that the current state of things is not optimal. Lodgard (2021) from Flokk, said that

> *I think that the industry in general hasn’t done enough at all, it’s far too characterized by symbolic actions, that you do something simple, like creating a series and then there’s one green product there, but usually that is so expensive and exotic that no one can afford it and so you buy the usual products that are made in a normal way and that’s not just neutral or no change, that’s negative, its counterproductive because it creates an illusion that you’ve done something when you haven’t done anything.*

Vestre (2021) also shared this belief and said that the change he wants, to sum it up briefly was “less talk, more action”. Interestingly, the companies that themselves have implemented refurbishment and reuse into their business wish for other manufacturers do so as well. They want the industry to follow and implement return systems or ways of making reuse possible. These companies also had much more concrete wishes for specific things they wanted, ranging from longer warranties to purchasing criteria, which is quite contrasting to the companies that first and foremost wish for guidance. It indicates that different companies in the furniture industry are at different stages of implementing circularity and sustainability into their businesses. Some are frontrunners and others have recently started to follow. However, what was commonly agreed upon was that change indeed is needed.

Responsibility

As the last question of the first part of the interviews, the interviewees were asked what they consider to be the responsibility of the industry and what the consumers responsibility is. This was an interesting question to ask as a means to gain insight into what the companies see as their role in relation to the user. The majority said that both industry and users hold responsibility, whereas a minority answered that the industry should take the lead.

The minority who believes it is the industry's responsibility, said that the industry needs to guide the consumer to make environmentally friendly choices because consumers are not experts on how the industry works. The industry needs to lead and advice the customer, because if the industry does not take the first step, if it is left up to the consumer, nothing will happen. As Brea (2021) from Viccarbe said "The industry has the power to change consumer habits.".

The majority, on the other hand believes that manufacturers and consumers share the responsibility. It is the industry's responsibility to demonstrate what is possible and be more value driven, meaning that the industry should not just make things, but make good products, as Vestre (2021) explained

The manufacturers themselves, even though they don't have strict regulations today or too many legal requirements, and the customers may not be demanding enough, it's not like you have to not do the right thing just because you're allowed to do wrong things.

That also touches upon what the industry sees as the consumers responsibility, to make more demands and be more interested in the environment. However, it is, as Buchbinder (2021) explains, a complex issue: "it's kind of like the chicken and the egg, the more consumers demand, the more manufacturers will build that way, however sometimes consumers don't know what to demand until they've seen it".

It seems clear that all furniture manufacturers want consumers to make the right choices, but that the manufacturers need to get better at displaying the reason why. They need to get better at communicating, because as Buchbinder (2021) said "no one cares if you're using recycled material if you can't figure out how to transparently and accurately show that information.".

Concluding observations

The intention of this thesis is not to put anyone in a bad light or expose any companies, therefore quotes are used with caution in some parts and left out in others. That is also why words such as majority, minority, some and others are used some places instead of the number or names of companies. The same applies to the next two sections of this chapter.

All in all, the companies all seem to be committed to becoming circular. It is the how that is missing, how they can implement that change. What makes it even more challenging is that the companies seem to have somewhat different understandings of circular economy, there seems to be no official definition within the industry. Furthermore, given this lack of a unified definition, surprisingly few expressed the need for a common ground to talk from or a need to collaborate in the industry. It seems that all manufacturers have their own strategies and do their own thing.

There also seems to be a connection between how long a company has been working towards circularity and the degree of implementation. The frontrunners seem to start to profit from the work they have invested over the years, and the rest are trying to follow. It would, however, be better if the industry was more transparent and cooperative, that knowledge was shared within the industry to bring everyone to the same understanding and level of implementation of circularity in order to build circular business models, services and systems that the entire industry, and of course the users of their products, can benefit from.

A promising finding for this thesis was the acknowledgment of the designer as a key person to implement change in the industry. That motivates to identify challenges the industry is facing in order to develop a tool for designers to assist the industry in its journey towards circularity, especially for plastics.

Use of plastics in the furniture industry

The second part of the interviews addressed how the furniture industry uses plastic, where or for what purposed plastics is used and what types of plastics are used. The questions were mostly about "plastics" in general without defining any specific types, purposely as a means to keep it open and see what types are being used by the industry. This part of the interview served to form a picture of the circularity of the material in the industry. Furthermore, it served to gain an understanding of what challenges the industry experiences with plastics. Some main topics were identified and will be discussed in this section of the thesis.

Change in approach to plastic

The first thing the furniture manufacturer representatives were asked was if they had noticed any change in the company's approach to plastic over the last years, which the majority had. Some said that they try to avoid plastics as much as possible and use other materials instead because of the environmental challenges caused by the plastics crisis. Whereas others said that is precisely why they have increased the use of plastic, to take plastic waste and turn it into a resource because currently it is more important to use that waste stream than to try to move off plastic reliance. However, what all agreed upon, was that if they had to use plastics, they would try to use more recycled plastics. Even architect Rossi had noticed a change in the furniture industry's approach to plastics that he dated back to 2016. From then onward, a bigger change happened, especially due to increased media coverage (Rossi, 2021).

Why use plastics?

When asked why the furniture manufacturers use plastics, the interviewees all agreed that it was because plastic is a fantastic material given its properties and the cost of the material. The properties mentioned were that it is light, strong, durable and easy to mold and manufacture, it simply has unique properties that no other material can provide. However, just under half of the manufacturers use plastics first and foremost because of the available waste stream. In fact, Vestre, for instance, only recently started using plastics and the reason for that was to create change by creating a value chain that can help clean the ocean of plastics (Vestre, 2021). Vestre also said that using plastics is probably not something the company will be doing for all future as it is not their core business (Vestre, 2021). Emeco also only got into using plastics because of the available waste stream, and seems to share Vestre's view, as Buchbinder (2021) said that "if we got to the point where we're running out of material to use, which unfortunately or fortunately we're very far from, then we would completely rethink using plastic.". So, it seems that the reason for using plastics also goes beyond its material properties, and is more value driven. Furthermore, as explained by Lodgaard (2021),

> *a lot is connected to efficiency in production, meaning time spent in production, which is linked to emissions from the materials and to the possibility of sorting into pure material fractions again and ease of repair afterwards, and all of that results in, if you calculate the climate footprint of a seat shell in wood and one in plastic, even made with virgin plastic, you'll find that a virgin PP seat shell has a lower climate footprint than a wood shell with press-in nuts.*

So, it can sometimes even be more environmentally friendly to use plastics than other materials.

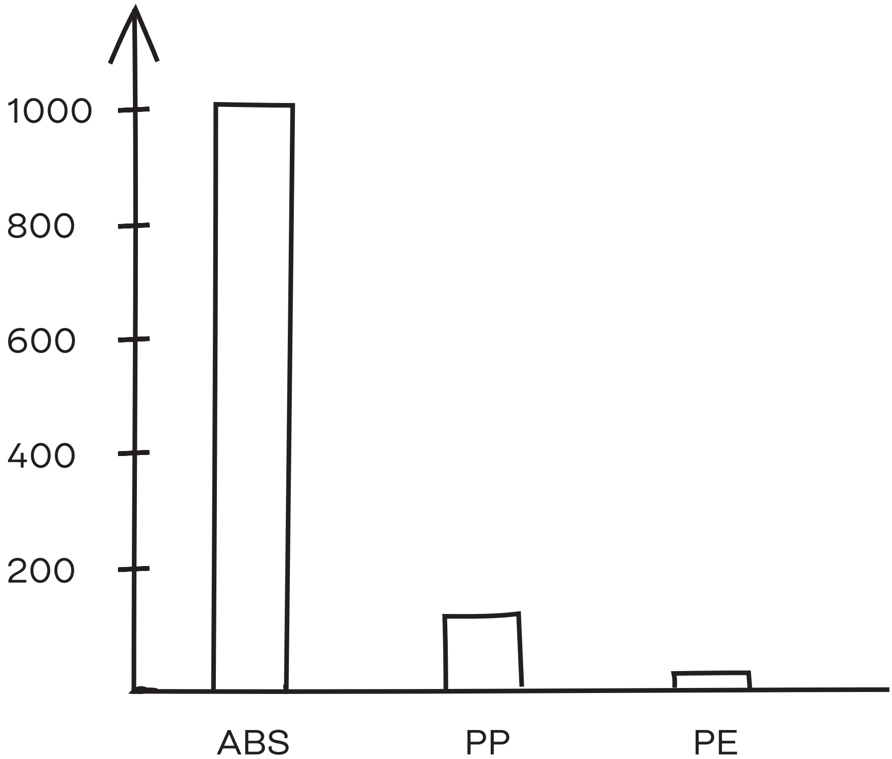
The different types of plastics

The furniture manufacturer representatives were also asked what type of plastics were used in the company's products. Here the answers differed quite a lot, but some plastics were used by most manufacturers, these were PP and PE. PP was used by all, and just over half use PE. PP was used for injection molded products, such as seat shells, whereas PE was used for rotationally molded products. Other plastics mentioned were polyoxymethylene (POM), polyamide, polycarbonate, nylon, PET and ABS.

ABS was a material the interviewees had divided opinions about. Some companies avoid using ABS because of chemicals compounds that may not be safe for human use.

Others, on the other hand, do use it, mostly for older products that were made with ABS before one became aware of the health risks, but some also use ABS for newly released products. According to Precious Plastic, ABS contains “styrene, benzene and ethylbenzene […] which create a lot of fumes and may cause cancer. Benzene is a human carcinogen, and styrene and ethyl benzene are probable carcinogens (probable carcinogen means that the compounds have not yet proven to cause cancer)” (Precious Plastic, 2020). In fact, ABS creates 5 to 7 times more fumes than other plastics when melted (Precious Plastic, 2020). Avoiding ABS therefore seems to make sense, given that there also are other more common types of plastics that are less toxic as well as more widely recycled, such as PE and PP which are the safest plastics to melt (Precious Plastic, 2020).

Another plastics material the different interviewees disagreed on whether to use or not, was composite materials. Some companies, such as Flokk do not use composites, in fact, Lodgaard (2021) said that “we avoid that like the plague”. Rossi (2021) also shares the same opinion, calling composite materials “a living nightmare”. The reason for the strong opinions against composite materials is that they cannot be, or are at least difficult to, recycle mechanically. Composites cannot be separated into pure fractions, at best a product made of composite materials can only be recycled into itself again, that is if there is a recycling system for it. It is worth noting that only the Norwegians had strong opinions about composite materials, which might be connected to the fact that those materials currently are not recyclable in Norway. About a third of the companies do use composite materials, either glass fiber reinforced or wood fiber reinforced plastics. These companies use glass fibers to give the plastic product needed strength. Wood fibers were also used for strength, as well as for the aesthetics of the product. Composite materials will be further discussed in the next chapter regarding the case study as some of the chairs consist of fiber reinforced plastics.



Recreated after Precious Plastic

Where is plastics used?

Naturally, since these companies are furniture manufacturers, they use plastics for furniture. However, what was interesting when asked where or for what products plastic was used, most interviewees answers that they use it for almost all products. Plastic is even used for non-plastic products, because the glides they use are made of plastics, as explained by Lindholm (2021): “We use plastics for almost all our furniture pieces, because we normally use plastic for glides. Even a steel chair has plastic glides”. So, the amount of plastic used for a product varies a lot, from glides on a steel product to a product made completely out of plastic. In regard to what furniture products are largely made of plastic, the majority answered chairs. So, plastics is either used for technical purposed, such as in glides, or for entire product designs, mostly chairs.

Virgin VS recycled

All in all, it was agreed upon that the different types of plastics were used for different purposes or application because they have distinct properties. The shape or design of the product often determined what material to use. However, sometimes, the material also determined how the design needed to be, which was the case for multiple manufacturers when using recycled plastics.

The furniture manufacturer representatives were asked about the difference between their virgin and recycled plastic products. The majority said that there was no difference in the life span of recycled plastic products in difference to virgin plastic products. Furthermore, the majority also said that there was no difference in quality, strength or other physical properties between recycled and virgin plastics products, that is if you design for it. However, all agreed that there inherently are differences between recycled and virgin plastic material that makes producing a product from recycled plastics different than making it from virgin plastics.

The differences mentioned between virgin and recycled plastics, were mainly challenges connected to recycled plastics, the most prominent ones being quality, color and sourcing. According to the majority of interviewees, recycled plastics has different mechanical properties than virgin plastics and usually poorer quality in terms of for instance strength or durability, meaning that recycled plastics is more structurally fragile. Another issue is color. According to the majority, the choice of color is more restricted. There can also be some color irregularities when using recycled plastics, meaning that there for instance can be a mismatch in color between different parts of the product or that there can be a mismatch in color between different batches of recycled plastics. Some also mentioned that other aesthetic qualities such as the surface could also be different for recycled plastics. Consequently, the development time when using recycled plastics is longer than for virgin plastics according to the majority of the interviewees. The cost of the material is also higher according to some. Furthermore, according to the majority, it is difficult to find a reliable good quality source of recycled plastics.

The majority of the furniture manufacturers therefore still use virgin plastics, to say it in the words of Perin (2021), because "the mechanical performances are superior". So, virgin plastic is used because of its superior quality. Manufacturers know what they get out of the material, it is perceived as more predictable than recycled plastics. Other reasons for using virgin plastics mentioned by the interviewees was for specific colors, such as white and bright colors, and for some types of plastics that simply are not possible to find recycled because they are not recyclable. The reasons for using recycled plastics, on the other hand, are not because of mechanical or aesthetical properties. The reasons for using recycled plastics are more value driven. The most prominent reason for using recycled plastics is because of the available waste stream, with the aim of creating a value chain that can clean the planet while at the same time producing new products, which in return is meant to reduce the footprint of the product produced.

When asked about the distribution between the use of virgin and recycled plastics, the answers again differed greatly. Some could give a specific percentage of the proportion of recycled plastics, whereas others simply answered that they do not know or could not say. Some said that they still use higher quantities of virgin plastic, and a minority uses more recycled than virgin plastics. Furthermore, an interesting observation was made. The ones that were the most transparent and detailed in their answers regarding sustainability were also able to answer this question.

Post-industrial VS Post-consumer

As already explained, using recycled plastics for furniture is, according to the interviewees, not without challenges. However, the challenges differ based on the source of waste the plastics material is derived from. There are two sources of waste that recycled plastics can be made from, these are known as post-industrial and post-consumer waste, and both are commonly used in the furniture industry.

Post-industrial material, also known as pre-consumer material, is defined by ISO Standard 14021 as "Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it." (International Organization for Standardization, 2016, p. 15). Whereas post-consumer material is defined as "Material generated by households or by commercial, industrial and institutional facilities in their role as end-users of the product which can no longer be used for its intended purpose. This includes returns of material from the distribution chain." (International Organization for Standardization, 2016, p. 15)

The interviewees from companies that use both post-industrial recycled (PIR) and post-consumer recycled (PCR) plastics were asked about the difference between the two materials and for what applications they use them, whereas the interviewees from companies that only use one of the two, were asked why they only use that type of recycled plastic.

The value driven reason for using recycled plastics is connected to the use of PCR plastics. As described by Lodgaard (2021): "there's a huge difference in what change you impact between sourcing post-industrial and post-consumer because post-industrial doesn't really change any behavior [...] but if you put a price tag on the garbage dump [...] then change happens.". Post-consumer waste is the closest to being actual trash and that is what makes the biggest environmental impact, according to the proponents of PCR plastics.

However, PCR plastics, being closer to actual trash, is according to some interviewees often polluted. This pollution is what they see as a challenge with PCR plastics because it can affect the mechanical properties of the material. According to some interviewees, PCR plastic does not have a spec sheet with set parameters in the same way as virgin plastics does, there is a bigger span, and it is much more difficult to get the specs right. They cannot control what they get in the same way as if they were to use PIR plastic or virgin plastic. Around half of the interviewees experience it as difficult to find a source of post-consumer waste that has the quality and durability they need and that can be delivered reliably. They say that PCR plastic sometimes simply is not consistent enough. So, according to them, sometimes the only option to use recycled plastics, is to use PIR plastic.

Furthermore, aesthetic qualities, especially color, was mentioned by around half of the interviewees as a challenge with PCR plastics. A quite contradictory finding was that two of the interviewees said that finding white PCR plastics is impossible, whereas others do not perceive color to be an issue as they produce white chairs made with PCR plastics. So, there were divided opinions about the possibilities of colors in regard to the use of PCR plastics. What is actually possible and not regarding colors for PCR plastics will be further investigated in the next chapter through interviews with experts on plastic recycling.

The reason for using PIR plastic in difference to PCR, is somewhat the same as the reason for using virgin instead of recycled plastics. The quality of post-industrial waste can be controlled as it is a more stable source where one knows the origin of the plastic material, and it has not been used in the same way as PCR plastics. PIR plastic therefore has a more consistent quality than PCR plastics and is simply easier to use in production, it is more cost and time efficient. However, to quote Lodgaard (2021) again: "post-industrial recycling is as old as the industrial revolution [...] and it simply has to do with good housekeeping and good economy". What is commonly agreed upon by all the furniture manufacturers is that they would like to use more PCR plastics, but that it, for different reasons, is not always feasible.

To illustrate the difference between PIR and PCR plastics and how they might be applied to products in the industry, Fritz Hansen serves as a good example, as Langballe (2021) explained:

> *I could easily see some of the things that we are struggling with now, where we have to change a product that was designed with virgin material and translate it into a recycled material, that here post-industrial waste will*

probably be a way to go because we have a design, product, tool and production that is set up for something with no possibility to change the parameters because then things do not fit together. So, here if you can find a source of post-industrial waste that is very stable, that will be a way to go, in difference to when you take a brand-new product where you say we will use this post-consumer recycled material and these are the limitations, so we take it into consideration in our design process, then you create a different product.

So, it seems that for already existing products, applying PCR recycled plastics is more challenging than to design a new product with PCR plastic as a prerequisite for the design of the product.

What happens at end of life?

In order to look at the bigger picture and get a sense of the circularity of plastics in the furniture industry, the furniture manufacturer representatives were asked what happens to the plastic products their company produces at end of life. The majority do not have any system or service to control what happens to their products at end of life. These manufacturers do however make their products for disassembly and recycling. So, once the product has left their factory, the responsibility to dispose of their plastic products properly lies with the end user of the product.

The minority of the manufacturers do have some sort of system or service to account for what happens to their products at end of life, but they do not account for all products. Even those that do have some type of system or service do recognize reversed logistics as an issue. Tracking all products is close to impossible, as Buchbinder (2021) describes that “the logistics aren’t there for any given chair end of life”. There were, however, presented some promising new strategies. Flokk is amongst others looking into deposit refund schemes (Lodgaard, 2021). Whereas Emeco is looking into ways of reusing products that are disposed of not because of a quality issue in the sense that the product is broken, but are disposed of because of a change in taste, that the customer is simply tired of the product (Buchbinder, 2021). The company is therefore looking at ways to help customers sell their products to someone nearby, as that will have a lower carbon footprint than shipping the products back for recycling, especially if the product is still in a good working condition (Buchbinder, 2021). One of Vestre’s new business models is also worth mentioning as it seems like a good strategy for tackling the problem upfront. The company’s only plastic product, a bench made from plastic collected from the ocean, is only available for rent, as Vestre (2021) explained “You can’t buy this bench, it’s only for rent, and that is because we don’t want to give up the ownership rights to the plastic because then, in the worst case, you could risk that the customers throw it back into the ocean and then we’re right back where we started.”.

Take back systems

The interviewees were also asked if their companies have a take back system for their plastics products. The minority does have a system, and only a minority of those systems are systemized on a large scale. Usually, the customer reaches out to the manufacturers and the manufacturer then takes the products back. Vestre is currently working on putting it into system with the new circular factory the Plus (Vestre, 2021). Vestre (2021) explained the importance of manufacturers being organized in such a way that they can take products back, he said that manufacturers need to

> *be there in such a way that we don't push new things all the time, we have to push less new things, but when people want something new, we should be able to take the product back and make it as a new product for someone else.*

Vestre (2021) also illustrated this with an example:

> *if you have a bench from Vestre that is orange and after 5 years you're tired of that color and you want a blue one and a different model, and that bench is still fine, then Vestre takes it back and repaints it and sells or rents it to another customer who then gets a new design and a new color, and you can get the same. Then I've solved your problem and the other customers problem and the energy use in that transaction was only 20% of you buying a new one because we only reuse it and change the color of it and refurbish it*

This is a promising initiative, both for environment, manufacturers and users. However, as Flokk has experienced, customers are reluctant to buy used furniture. Flokk already collaborates with secondhand dealers in several countries to buy back, refurbish and resell their furniture, but consumer behavior is not changing as fast as the company had hoped for (Lodgaard, 2021). In addition, it is worth noting that a few of the other companies are at least playing with the thought of establishing take back systems. Nevertheless, it seems that even though the industry might be ready for circular business models, the consumers might not be, and that can pose a challenge.

The majority does however not have any take back system. When asked why they do not have a system the reasons were because of the cost it would entail and because of how complex it is to implement logistically, given that there currently is no generalized system for it. When asked if they are planning to create one, the majority answered no. Brea (2021) had an interesting respond to these questions: "No, because as we produce with pure materials, and all of them are correctly marked, any recycling plant could easily detect how to recycle our plastic components.". If that works, it is an interesting approach to rely on existing recycling infrastructure.

Bioplastics – yes and no

The majority of these companies focus on increasing their use of recycled plastics in the future. However, a topic that also recurred as a strategy for the circular future of plastics was bioplastics. Magis will for instance introduce biopolymers in the future, in the sense of recyclable biobased plastics. The reason for focusing on bioplastics in addition to recycled plastics was that "it is more practicable than pre/post-consumer plastic, which is not always easy to find, and sometimes the mechanical properties are too degraded to be used on any type of product." (Perin, 2021). Interestingly, a couple of years ago, Flokk had the same idea, but in contrast to Magis did not follow through on it (Lodgaard, 2021). According to Lodgaard (2021), Flokk asked the Swedish equivalent of SINTEF to do a study of bioplastics to figure out what type of bioplastics Flokk should focus on in the future. Surprisingly, the answer they got was to not do it because after researching all that existed at that time or was in development in laboratories, Flokk was told that "nothing can compare to what you already do, post-consumer recycled goods, so just forget about that other direction and focus all your energy on getting even better at using plastic that has been waste once" (Lodgaard, 2021). Flokk was told to scale up the use of PCR plastic, use it in more products and to get better at controlling the quality, to even upcycle the material because out of the bioplastics, "none of these technologies have the potential to become better than 4 times as bad as what you already know how to do today" (Lodgaard, 2021).

Magis is, however, not the only company that is introducing bioplastics. Fluidsolids was founded by an industrial designer who has created his own bioplastic material, and when asked why he chose to focus on bioplastics given his design background Karrer (2021) answered that designers have three main skills, one of which is to be curious and

> *if you're curious and you're dealing with materials and you're in the very beginning of the value chain then it's pretty obvious that you should think about new materials and mainly sustainable materials, so that's what led me to look into bioplastics and create a new bioplastic.*

Karrer (2021) also said that the reason for choosing bioplastics over recycled plastics was because recycling, in its current state, simply does not work and that he does not see the point in why one should focus on "existing plastics or oil-based plastics given that there are endless amounts of biomass available that can also be transformed into plastic."

Furthermore, when asked about whether the material is suited for furniture, Karrer (2021) answered yes, but only for indoor use as the material is not only a biobased plastic, but also biodegradable and home compostable. It can be used just like normal plastics in production used for injection molded parts. The company currently has two furniture projects under development (Karrer, 2021). The details were confidential, but what Karrer could say was that the projects were targeted more towards jointing elements. So, bioplastic also seems to be an alternative that the furniture industry is looking into. However, whether it is better than or as good as recycled plastics, especially PCR plastics, remains to be seen. In the next chapter, this will be investigated further in relation to the case study, where bioplastics is discussed with some plastic recycling experts.

Ecoalf - A case of fashionable recycling

The furniture industry is not the only industry that uses recycled plastics. There are other companies in other industries that have managed to extensively implement the use of recycled plastics, for instance in the fashion industry. In the interview with Brea (2021), when asked about why Viccarbe chose to collaborate with Ecoalf, he said that Viccarbe “thinks that fashion and furniture are well connected and share a similar language. So why not apply solutions from fashion in furniture and backwards?”. It therefore seemed useful to also interview fashion brand Ecoalf to learn more about a success story of how to turn PCR plastics into valuable items.

According to Viccarbe, Ecoalf is “a reference in the industry for integrating sustainability in the core business plan” (Brea, 2021). When Oliart (2021) from Ecoalf was asked about the company’s circular economy efforts, she was refreshingly honest saying that “We cannot talk about circular economy at the moment, because we do not close the loop, but we are working on a system to take back all garments to make new garments with them and then we will truly be closing the loop.”. Despite not closing the loop yet, the company has managed to collect more than 700 tonnes of waste from the bottom of the ocean (Oliart, 2021). However, only 5-10% of the collected trash is PET, which is the only material that can be turned into a high-quality yarn (Oliart, 2021). The perhaps biggest difference, according to Viccarbe, between Ecoalf fabrics and other recycled fabrics is that Ecoalf’s fabric is made from PCR plastics recollected from the ocean, creating synergies in different fishing ports. All waste collected by the fishing boats at sea is recycled, so the company does not just recycle plastic, but is at the same time cleaning the planet of waste (Brea, 2021). Turning ocean plastic into high quality yarn is however no easy task and has required years of R&D, and the ocean plastic still needs to be mixed with plastics from land to get the needed quality. So, what Ecoalf is bringing to the collaboration with furniture manufacturer Viccarbe is their knowledge about and experience with recycled plastics, that the company has made over 10 years of investing in research and development (R&D) (Oliart, 2021).

When asked about differences between the furniture and fashion industry, Oliart responded that she thinks sustainability is currently more present in the fashion industry. That it is because fashion is the second most polluting industry in the world and is therefore more visible than furniture (Oliart, 2021). Oliart does however think that the only future for the furniture industry is to become sustainable so that customers can also buy sustainable products for their homes. When asked what the furniture industry can learn from Ecoalf, Oliart (2021) responded that "Everything can be done if you want to do it the right way" and that the industry needs to understand that the way to do it is to maybe spend a bit more in the process of making a product in order to do it the right way, to make high quality products that last. So, according to Ecoalf, the aim of the collaboration with Viccarbe is to "highlight the responsibility of manufacturers and agents involved in the furniture industry, and to impact the environment in the most positive way possible." (Oliart, 2021).

It will be interesting to see what the joined venture between Ecoalf and Viccarbe will result in. The first step of the collaboration is to apply Ecoalf fabrics to Viccarbe's furniture, which seems like a decent first step in regard to using recycled plastics, but without a recycling system for the fabric it is not yet circular. The second part of the collaboration, which is still in development, is where it gets interesting because the goal is to create two new circular products. One is a sofa, made of recycled materials that is to be fully recyclable, which no sofa is as of today. The other product will be a chair with a seat shell made out of recycled PP collected from the ocean and designed by Diez Office. So far, Ecoalf is only recycling nylon and PET into fabrics, so in order to recycle PP collected at sea into furniture, the value chain first needs to be established and the material needs to be tested and developed. Per now, there are still many open questions, mostly regarding the strength and color of the material, that need to be investigated to see if it is even feasible.

Snøhetta's Plast

Another collaboration story, that has already been realized in the shape of a chair, is the collaboration between furniture manufacturer Norwegian Comfort Products (NCP) and Snøhetta. The chair will be further discussed in the case study in the next chapter. For now, the research project that led to the collaboration will be explored. Snøhetta's research project Plast was actually never intended to result in a chair.

> *It was totally random that this project resulted in a chair. The intention or scope of this project was never to design a chair, but to see who wanted to collaborate to transfer the curiosity to something physical that could then again be used as a catalyst for further work. (Rossi, 2021)*

What initiated this project was, as Rossi (2021) described, "just a big curiosity about plastic as a material". He thinks that plastic in general is a great material but finds it "very frustrating that something as high tech as plastic does not have an equivalent value." (Rossi, 2021). So, what Snøhetta works with and focus on is that they believe that "plastic is a resource that should regain its value" (Rossi, 2021)

Furthermore, Rossi found it strange that no one at Snøhetta seemed to know anything about the material, not even the basics of where plastics came from, where it was produced or where it ended up. So, Snøhetta applied for public funding to do a rough examination of the material and that is what resulted in the research project Plast. The project facilitated for a material investigation, in which many different types of plastics were tested, melted and processed with machines, much inspired by Precious Plastic. Technical examinations and tests were also done by professional institutes or labs. The project got quite a lot of media coverage, and eventually caught the attention of NCP, resulting in the collaboration where theory was turned into practice. (Rossi, 2021)

When asked what this project had taught him about plastics, Rossi (2021) replied that

> *There were a lot of established truths before you tested them. Meaning, you were told that a lot of things were not possible, that absolutely were possible. Those with a bigger interest in not changing their well-functioning rhythm, had these established truths about how you couldn't use recycled plastic and so on because you would lose quality and so on, but we quickly got that disconfirmed and proven possible.*

That is very interesting in comparison to answers from the furniture industry regarding the use of recycled plastics. The most common answer to why the furniture manufacturers would use virgin over recycled plastics was because of the inferior quality of recycled plastic. Furthermore, Rossi (2021) said that he thinks "the furniture industry should flip everything upside down and start from scratch again." when asked what the furniture industry can learn from this project. There probably are some established truths in the furniture industry regarding the use of recycled plastics, but as the saying goes old habits die hard, so to start from scratch might be easier said than done.

Concluding Observations

As with the general part about circularity and sustainability, the manufacturers also have different strategies for the use of plastic. They also seem to have different perceptions of, or opinions about, different types of plastics, and especially about recycled plastics. Some manufacturers have a more value driven approach to the use of recycled plastics, whereas others are more occupied with the quality of the material. It is of course important to make long-lasting products, but there also needs to be systems or services to keep those products circulating for a long time. To only create products that are long-lasting is simply not enough if closing loops is the goal.

Furthermore, there seems to be a trend in the industry to clean the planet of waste while at the same time producing products. For instance, ocean plastic seems to be of interest to the furniture industry, with Vestre starting to use plastics only because of it and with Viccarbe's newest joint venture. It seems that manufacturers generally focus their circularity efforts regarding plastics on production by using recycled plastics, and less on the end-of-life phase of their products, which generally seems to be largely underdeveloped or simply dismissed as being too difficult to do anything about. The lacking infrastructure is a problem. Without it, loops will not be closed, and the quality of recycled material is not likely to improve either, which was one of the main challenges mentioned by the interviewees. The two other biggest challenges were color and sourcing.

Most of the challenges mentioned with recycled plastics seem to be connected to the use of PCR plastics. Interestingly, it also seems that those furniture manufacturers that use more recycled plastics, and especially more PCR plastics, identify less challenges with using recycled plastics. Furthermore, there is Rossi's statement about established truths which is very interesting and contrasting to the industry's answers. The recycled plastic challenges were therefore discussed with experts, presented in the next chapter, in an attempt to verify or falsify them and see if they are indeed real problems or just established truths in the furniture industry.

Another interesting finding was that in order to successfully implement the use of recycled plastics, especially PCR plastics, some interviewees mentioned that one has to design for it. So, maybe design could be used to overcome the challenges facing the industry regarding the circularity of plastics.

Design of future products

The third part of the interviews focuses more specifically on design of plastic products, especially on circular design. This part of the interview served to gain an understanding of the furniture industry's understanding of what circular design entails, especially for designing plastic products. One question was also about sustainable design, in order to see if the manufactures differentiate between circular and sustainable design. All the furniture manufacturer representatives and Rossi were asked the same questions. Some main topics were identified and will be discussed in this section of the thesis.

Designing new products: virgin VS recycled

The first question was an extension of the use of plastic questions, while at the same time an entry into the topic of design. The furniture manufacturer representatives were asked if the new products they design, mostly consist of virgin or recycled plastics, and the answers differed greatly. Two interviewees did not really answer the questions, two others say that their company uses virgin for small technical components or for specific colors whereas three manufacturers make all new products using recycled plastics. So, just under half of the manufacturers do no longer use virgin plastics in new designs.

Designing sustainable plastics furniture

When asked what was important in order to design sustainable plastics furniture, making the product long-lasting and durable was mentioned. To use recycled plastics and not mix different materials was also mentioned, and, as Brea (2021) said, to "use plastics that can be easily recycled". To consider the entire cycle of the product and its energy consumption was also mentioned.

The most interesting answer, given by two of the interviewees, was that one has to take the plastic material into account when designing. One has to work with the material, understand its limitations and benefits and design for what the material can and cannot do. As Lodgaard (2021) said:

> *You have to start with it as a prerequisite from the very beginning, that is why we say that so much of our environmental efforts rotate around and centers on these design criteria because that is where you decide, you have to design for it, otherwise you won't be able to implement it afterwards.*

Fritz Hansen is one of the companies that has experienced firsthand how difficult it is to try to do it the other way around. Taking a product designed for virgin plastic and then applying recycled plastic to make it more sustainable is not easy, as described by Langballe (2021)

> *When you look at one of the chairs, all of the things we have to do, it actually might be easier, to do a new product based on the material instead of trying to fit a new material into an old product because the way that the bases are mounted needs to be changed, thickness of the material needs to be changed. Of course, there is some seating comfort and some design that is still valid, but from a technical perspective, all the things you need to go through again, changing from virgin to recycled, actually requires you to redesign or reengineer the whole product again.*

At last, about half mentioned that one simply genuinely has to want to design sustainable plastics furniture, as described by Buchbinder (2021) "making sure that it's a genuine approach to sequestering waste material and using waste material, not just saying something is recyclable at end of life and making a plastic product out of virgin material". It seems that one first needs to genuinely want to do it and then one needs to design for it.

Design for recyclability

The interviewees were asked what their company is doing in order to design for recyclability. It was a conscious choice to ask this question and not what the company is doing in regard to circular strategies higher up the waste hierarchy, such as reuse, as a means to see if the interviewees would bring it up themselves. The question did not exclude other circular strategies, it gave the interviewees a chance to point out that other strategies are more important than recycling. Interestingly, some did, whereas others did not.

Everyone said that they make their products for easy disassembly, meaning for instance that they do not use glue. In regard to disassembly, it was also mentioned that the simpler the product is, the better. Few and large components are preferrable. Flokk, for instance, tries to

> *strive for as large and few parts as possible based on the ambition that when the product finally reaches end of life, every part of the product has to be large enough to represent a value that makes it worth going to the right container with so that it can be recycled. (Lodgaard, 2021)*

Furthermore, some interviewees answered that they focus on the full life cycle of the product, for instance also considering logistics. Using recycled or renewable materials was also mentioned as a strategy, and multiple companies mark parts with type of material. Some only use pure materials, not composites, as well as materials that can be recycled and for which there is a system. Others, on the other hand, said that most materials are recyclable, and that the bigger issue rather is the infrastructure or lack thereof, as described by Buchbinder (2021): "So, it might not even be how do you make something recyclable, but how do you actually recycle it at end of life.", the company is therefore working on that infrastructure.

However, what was the most interesting was that some of the interviewees said that they focus on design for longevity first and foremost. These interviewees said that design for longevity or product integrity should be prioritized over design for recycling. The product should be designed so that it does not need to go to the grave. They also mentioned that circular systems and services such as refurbishment and repair were important to extend the life of a product, so their products are made to be easily taken apart for ease of reuse and repairability. Vestre was one of the interviewees that mentioned longevity as the most important. The company has a Vision Zero, meaning that Vestre will not make products that cannot last forever. Vestre (2021) also explained how that works for the company's products.

> *First of all, the product should live extremely long and be able to be maintained and repaired so that we can postpone death to the maximum and then once the product is so worn out that it is going back, then we'll either restore it so that it can live another 50 years or when that is no longer possible, everything should be taken apart and sorted for recycling.*

Interestingly, most of the interviewees did at some point mention that design for longevity should be prioritized before recycling. However, only a minority mentioned it when asked this question, and that minority consists of the companies that seem to have come the furthest in systemizing circularity and for instance have implemented refurbishment in their business.

Furthermore, in regard to design for longevity, some of the interviewees stressed the importance of having services and systems in place that can help the products circulate. To design long-lasting products is a step in the right direction, but it does not help that a product can live forever if the user is tired of it after a short time. So, that is why some manufacturers focus on timeless design. However, as Vestre (2021) explained: "if you've had a product for 20 years you might be tired of the design and color, even though the design itself is timeless". That is why manufacturers need to have return programs, to allow for products to be used for as long as they are made to last. As Vestre (2021) said, the industry cannot teach people to not desire anything new, from time-to-time people want to change their products, but then the manufacturers should help facilitate that change in an environmentally friendly way by helping users reuse or refurbish products.

All in all, answers to this question ranged from only "disassembly" to more extensive and elaboratively explained circular strategies, not only for recycling. So, there seems to be quite a big contrast between the level of understanding of circular design between the different companies or at least between what they prioritize and see as most important in regard to design for circularity.

Challenges with design for recyclability

The interviewees were also asked what they experience as challenges connected to designing for recyclability. Interestingly, some said that there are no challenges. The majority, however, said that the biggest challenge was infrastructure, as explained by Lindholm (2021): "the biggest challenges today is that there are lacking effective system for managing used materials and looping them into production.". One could say that this might be a geographic issue depending on the given country's recycling infrastructure, but the issue was not restricted to one country, as Perin (2021) also said that "The main challenge is to create a system; what at the moment seems to be the most difficult part to cover is what happens at the end of its life, what happens to the product". The problem is not only restricted to Europe, also Buchbinder (2021) described the issue

You have furniture going all over the world to different places that have different levels of recycling programs and just making sure you can consolidate and recycle and remake something in a consistent way is going to be so tough. I think we're at the point where it's not really cost or quality anymore, it's just like the how, like how do you get those products back, and in a responsible way, where the carbon footprint of the transport isn't ridiculous also.

This lack of infrastructure or systems for recycling seems to be a recurring issue.

However, as described by Lodgaard (2021), it seems to also be a knowledge issue.

You have to know how to do it, it's very difficult to start from scratch because you have to know what material you can get a hold of what that material is capable of and how you can design to get the function and longevity that you need for it to become a safe, good and beloved product for those who will buy it. You need to control all those things and then you need the competence to manage such knowledge and to use it.

Flokk has managed to systemize it by establishing a value chain where they only have one source of PCR plastic so that they can control the material spec. They have three different material specs that they buy, so they have become good at making products with those three specs. Flokk has even created cookbooks on how to construct a plastic component for the use of those materials. So, the company has structured the knowledge and make it available for their designers. Something that is also worth mentioning is that, in difference to the majority of the interviewed furniture manufacturers, Flokk does not outsource design, and they do not do it for this very reason, because without the knowledge it is difficult to design for recyclability.

Furthermore, Rossi mentioned two other challenges. There are not always short-term financial gains and that there are no governmental incentives either, at least not in Norway (Rossi, 2021). This lack of governmental incentives was also criticized by Vestre, who advocated for a ban on selling products with a short lifespan. So, the lack of regulations in the furniture industry is also identified as a challenge, at least in Norway.

Designing with recycled plastics

The interviewees were also asked what the challenges are when designing a product made from recycled plastics. The quality of the material was mentioned as a challenge, especially in terms of strength or structural fragility. There are pollutants in the recycled plastics that affect the quality. So, achieving the wanted durability for a product could be challenging.

Another challenge was in regard to aesthetics. Recycled plastics often is black or grey or some dark color that does not look very appealing. Furthermore, it is difficult to color the recycled plastics and achieve the wanted colors, especially if one wants light or bright colors. However, whether this truly is an issue or something the industry perceives as an issue because of how they are used to tackling aesthetics when designing with virgin plastics is debatable. To quote Lodgaard (2021),

> *if you need color matching to be 100%, then that means using virgin material. So, you have to tackle that aesthetic ideal of control and precision a little differently and say that here there is actually some variation and signs of having lived life and [...] you have to celebrate that instead.*

So, in regard to using recycled plastics, it seems that the industry should reconsider how it approaches aesthetics.

However, other interviewees say that today there is no visual difference between virgin and recycled plastics and that the requirements for recycled plastics are also higher than before, as Langballe (2021) says.

> *If you go five years back and people said recycled plastic then maybe users could live with, so to speak, that it was a little bit different visually [...] but now there are expectations to quality. Recycling of plastic is starting to become a norm where it does not have to differ that much from virgin plastic.*

Buchbinder (2021) also addresses the issue by saying that

> *I think a lot of time it's just getting everyone out of the mindset that it's going to look different, people think because it's a recycled plastic it needs to have some kind of blemish which just is not the case anymore.*

According to Buchbinder (2021) recycled plastics can even be stronger and better than virgin plastics, and they look just the same. This difference in opinions could be explained by differences in the plastic that is sourced by the different companies. It is also worth noting that neither Fritz Hansen nor Emeco mentioned color as a challenge with recycled plastics. Nevertheless, it is positive that there does not necessarily need to be a visual difference between recycled and virgin plastics.

A challenge that, on the other hand, seems to be quite real for all manufacturers is sourcing. This was also mentioned by Rossi (2021) as the main challenge in the industry, besides the established truths.

> *I just think it's those established truths that you have to overcome. Once that is done, it's more about the sourcing, that the fractions are pure. I think you have to have control of the sourcing, that's the number one thing I would put on the to do list.*

This was the main issue mentioned by most interviewees. The companies would like to use more recycled plastics, but it is difficult to find a good supply chain that can deliver recycled plastics of high quality consistently. The manufacturers rely on a steady source so that they can continue to deliver products of the same quality over and over again.

Because of all of these challenges, the development time is often longer than if the manufacturers were to just use virgin plastic where they would get a spec sheet and know exactly what material they are getting. Furthermore, not just time needs to be invested in R&D, but also capital, so the cost is often higher than for virgin plastics as well. These challenges seem to make using recycled plastics appear as more cumbersome to some of the manufacturers. It is challenging to efficiently produce with recycled plastics, at least in the initial phase, as Rossi (2021) explained, "it might be a bit more expensive and takes a little longer and it's a little more tiring now, but once you've started, it's just as efficient". Flokk is a good example of how it could work. Although the company is also facing challenges in regard to designing with recycled plastics, cost and time were not mentioned, and the company uses a majority of PCR plastics in its products.

Upcoming sustainable plastics projects

The interviewees were also asked if their companies have any upcoming sustainable plastics projects to form a picture of what the future of plastic furniture might bring. Vestre was the only company that answered no, giving the reason that they use very little plastics in general. Flokk will launch two new projects, one by the end of this year and one next year. For these projects the company will have increased the proportion of weight of recycled material even further and they will introduce different colors for recycled plastics. These new products will also be circular designs. The last Norwegian company, Snøhetta is also embarking on a new assignment, Rossi could, however, not give any details about it.

The danish companies have a different focus. Fritz Hansen is not producing any new products but is looking into how the company can change the existing portfolio into recycled plastics. Hay is also looking at some of the present collections to see how to recreate products the company already offers in a more sustainable way, but is also working on some new projects.

Magis also has some projects under development, focusing on implementing bioplastics. Viccarbe has, as already mentioned, some projects under development, but focused on ocean plastic. At last, Emeco also has a few projects in R&D, but they are not close to launching them yet. These projects focus on getting closer to the waste stream source, as Buchbinder (2021) explained that they are “looking closer and closer to actual trash, how do we recycle actual trash and not just things that are already deemed recyclable”.

All in all, the different companies are all working on new solutions, but with different strategies and approaches. It remains to see what will become of these projects, but it is definitely intriguing.

Concluding Observations

It seems that recycled plastics might have gotten an undeserving bad reputation. At this point in time, it is possible to create products with recycled plastics that are just as good as virgin plastic products and one does not necessarily see any difference either, but one has to of course design for it. That seems to be key, to design for it. It seems that those companies that start with recycled plastics as a prerequisite for their design manage to implement it with less challenges and more success. However, although it is possible to make recycled plastics look like virgin, finding recycled plastics of good enough quality remains an issue.

At the beginning, finding good quality recycled plastic material is a challenge, and at the end, the lacking infrastructure is challenging recycling. The industry finds it difficult to design for end of life of plastic furniture, besides designing for disassembly, because there seemingly exist no systems. However, those systems are not going to design themselves, so the industry should consider designing systems for end of life before, or at least alongside with, designing new products for which no systems exist.

However, circular design is more than designing from recycled plastics and designing for recycling. To sum it up in the words of Vestre (2021): “we must not let circular economy become that we get so occupied with recycling things that we don’t care about the quality because ‘it doesn’t matter because it will be recycled anyways’, then we haven’t solved a problem either.”. Between producing products with recycled plastics and recycling them at end of life, it is important to design for product integrity or longevity. It is, however, not enough to only design long-lasting durable products, which is usually the claim of the industry in regard to sustainability. The products need not only to last long, but to be used long, and in order to assure that, the industry needs to implement new business models, services and systems, which so far, with a few exceptions, are lacking in the furniture industry.

A case of greenwashing?

In the task description it said that this thesis will, amongst others, “explore how furniture companies respond to the themes of sustainability and circular economy and assess whether what they are doing is a serious attempt or greenwashing.”. The analysis of the interviews identified some trends that possibly could be greenwashing and needed to be further explored. The term greenwashing was therefore researched especially in relation to plastic and furniture, followed up by an interview with Fritz Lietsch, expert on sustainability and CSR, to discuss topics from the furniture manufacturers interviews.

What is greenwashing?

Sustainability is not a communication concept, it is about what you actually do. Greenwashing is defined as “spending more time and money claiming to be “green” through advertising and marketing rather than actually implementing business practices that minimize environmental impact” (Acaroglu, 2019). The problem is that most companies are not intentionally greenwashing. They do it by accident because they are either ill-informed or do not have the needed expertise about what is actually environmentally beneficial (Acaroglu, 2019). The problem with greenwashing is that it is “not only misleading, but it’s also really not helping to further sustainable design or circular economy initiatives.” (Acaroglu, 2019).

A problem contributing to greenwashing, according to Dezeen’s founder and editor-in-chief Marcus Fairs (2019) is that terms like “sustainable” and “circular” are “not well understood, and in some cases have never been precisely defined. They are therefore open to abuse, both accidental and deliberate.”. That results in manufacturers using the terms in meaningless ways and making irrelevant claims, like Fairs (2019) describes: “How can a bedside table be sustainable? What is it sustaining, beyond the consumer’s illusion that they are making a difference?”. So, usually when companies say that their products are sustainable, they often mean that they are a bit more sustainable than other products in the same product category. However, the products in that category do not necessarily need to be good for the environment, meaning that the products that claim to be more sustainable actually rather might just be “a bit less destructive” (Fairs, 2019).

Other typical signs of greenwashing are to not show any proof to substantiate environmental claims and generally to use vague language (TerraChoice Environmental Marketing, 2007). The language misuse is, as Fairs (2019) points out, “most acute when it comes to dealing with plastic: as anxiety over plastic pollution rises, the discourse has become polluted by confusion over terminology. This is making it hard for people to do the right thing.". To design products that are actually circular is extremely hard to do, and the language pollution is not making it any easier to design plastic products that do not create any pollution or waste (Fairs, 2019). So, as Fairs (2019) concludes: "To end plastic pollution, we first need to eliminate language pollution."

In light of this issue combined with findings from the previous interviews, it seemed beneficial to talk to an expert on CSR and sustainability to discuss the topic of greenwashing in regard to plastic furniture.

Ask the expert: Fritz Lietsch

Method

The expert interviewed is Fritz Lietsch, editor in chief of forum Nachhaltig Wirtschaften, which is the leading CSR and sustainability magazine in German-speaking countries. The interview was semi-structured, conducted via Teams and lasted 30 minutes. Topics and trends from the analysis of the furniture manufacturer interviews were discussed with Lietsch to see how an expert would interpret the findings.

Responsibility

In general, Lietsch said that the industry needs to take more responsibility in order to become more sustainable. He also said that the industry should be responsible for taking back their products. Furthermore, on the topic of certification, when informed about the divided opinions between the interviewees, Lietsch said that the industry should sit together with politicians and supply chain and develop a certification system that they can all agree on. However, on this matter, he said it should be the responsibility of politics to force the industry to develop this. The lack of governmental involvement in the furniture industry seems to be a recurring topic.

Circular systems, services & business models

When talking about circular economy efforts in the industry and how some focus more on longevity whereas others focused more on recycling, Lietsch said that all is important. According to him there is not only one solution, but many different solutions (Lietsch, 2021). Furthermore, he said that product as service systems is very important to give people more flexibility by allowing them to pay for the use of products instead of buying products.

Lietsch was also asked what he thinks the warranty on furniture should be as most of the furniture manufacturers have warranties of 2 or 5 years, with the minority having warranties above 10 years. His reply to this question was interesting, as he said that

> *This is definitely important, but still it's mostly not the problem of warranty, it's mostly the problem of a changing taste so you should not only have a warranty to get things repaired but also a warranty that you can change it. (Lietsch, 2021).*

So, according to Lietsch, the industry needs to have more flexible systems. Making long-lasting products is no longer enough because the user often does not want to use a product for so long. That aligns with what Vestre said about the company's refurbishment program.

When asked about what he thinks is the most important thing furniture manufacturers should do to contribute to a circular economy and to closing loops, Lietsch (2021) responded that profit and business models need to be redefined as he explained that "as long as we define profit to sell as much as possible, to make as much margin as possible, to lower production material cost to the absolute maximum, we will not achieve any real progress and that's the problem."

Recycled plastics

When it comes to the use of recycled plastic, Lietsch pointed out that the industry should not use recycling as an argument to produce throw away products. He said that "recycling is very smart, intelligent and important, but it has to be useful." (Lietsch, 2021). Lietsch also said that there should be less types of plastics and better recyclable plastics. When asked what he thinks about companies that develop their own plastic material and whether that is in line with the circular economy, especially if those plastics are not recyclable because there is no system for them to go to, he answered that it is not. It will not be possible to close loops, according to Lietsch, if everyone is making their own solution or recipe. In fact, that just makes it complicated.

The beacons of the movement

When asked about the noticed trend that some interviewees were reluctant to answer some questions or were vague in their answers and that those interviewees represented companies that did not have publicly accessible sustainability reports online, Lietsch (2021) said that it shows that "they don't want to see what they're doing, it's like closing their eyes and to say I don't see anything bad". It was also explained to him that, on the other hand, those who had online sustainability reports generally were more transparent and elaborate in their answers and could explain exactly what they are doing in terms of sustainability. When asked what that tells him, Lietsch (2021) replied that "they took responsibility a little bit earlier so they are the beacons of the movement [...], some of them take responsibility because they know that they should do it and the last ones only do it if they are forced by law.".

At last, when asked about greenwashing in the furniture industry, Lietsch (2021) responded the following

> *There is greenwashing everywhere [...] but greenwashing also means that one says "I'm very green" and the next says "no, I'm greener" and so the next says "you are not that green, because I'm greener" and so we start a little competition. So, I accept a little bit of greenwashing because the greenwashers at the end have to fulfill what they proclaim, sooner or late. So, greenwashing is not that nice, but it helps to get on the way.*

So, according to Lietsch, a little greenwashing might not even be all that bad, because it in a way pushes the industry forward, and at the end of the day the greenwashers need to make good on their claim.

Concluding Observations

Although some recurring trends were identified and could resemble greenwashing, accusing anyone of greenwashing is not the goal of this thesis. Greenwashing is a complex issue, and as Lietsch explained, present everywhere, therefore probably also in the furniture industry. However, it does not automatically have to be a bad thing. A little greenwashing can create a little competition within the industry, pushing it forward, as long as everyone in the end is held accountable for their claims. Furthermore, there has not been collected enough evidence to make a statement about whether greenwashing in the furniture industry is done on purpose or not, and since exposing greenwashers is not the aim of this thesis, the topic will not be investigated any further. The goal is, however, to see what challenges the industry is facing to become circular and sustainable, and to try to help the industry overcome them with the help of design. So, in order to get a more comprehensive understanding of what the industry is doing, a case study has been conducted and will be presented in the next chapter.

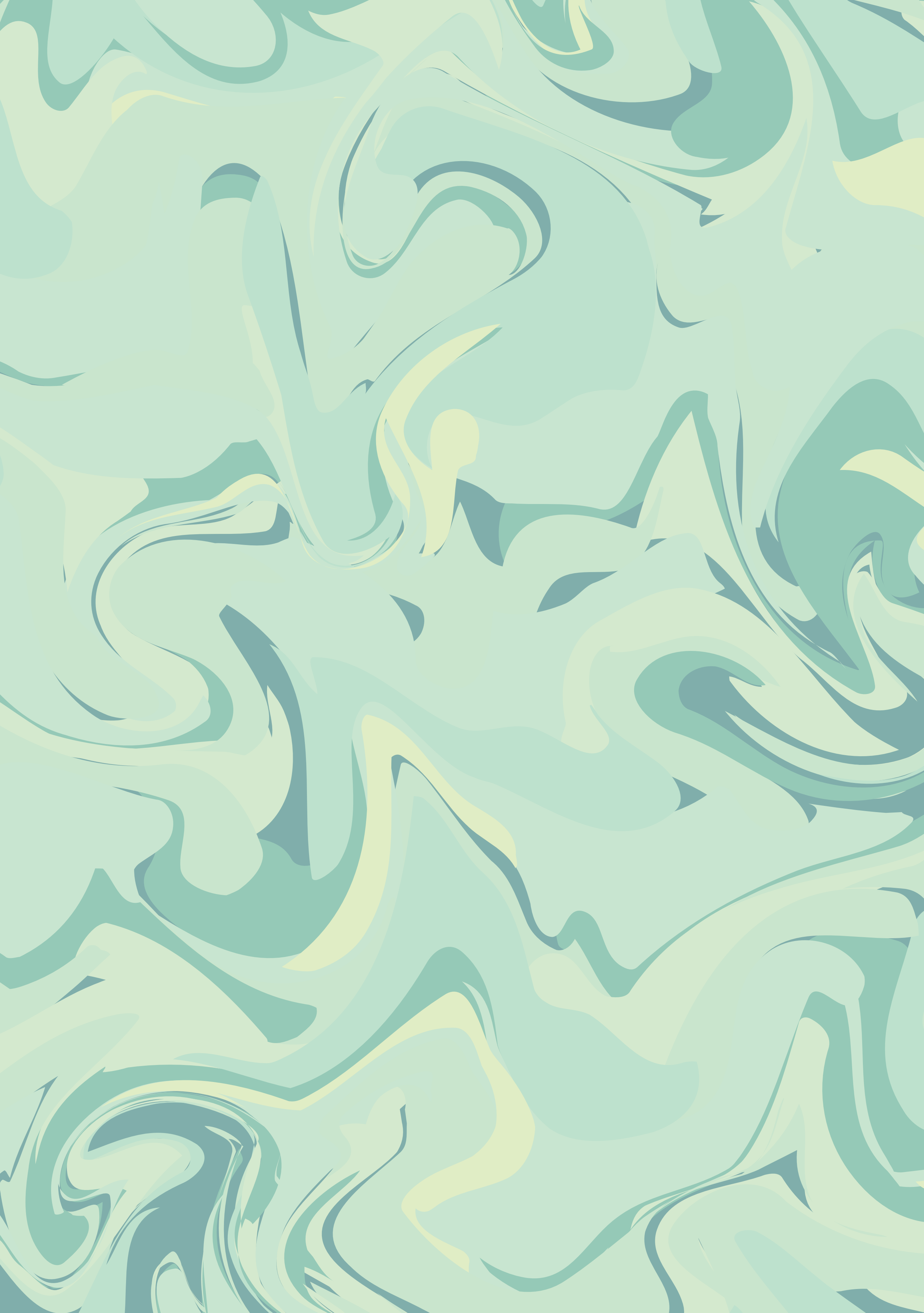
This was somewhat a short introduction to greenwashing, broadly looking at the industry and the interviewed furniture manufacturers. The next chapter will analyze products from the manufacturers to see how circularity is translated to actions. Actions are said to speak louder than words, so one could say that the next chapter is somewhat an extension of the topic of greenwashing, examining whether what the industry does corresponds with what it says it is doing.

Sum up of chapter 3

This chapter has presented the interviews conducted with furniture manufacturer representativs to explore the topics of circular economy & sustainability, use of plastic and design. A couple of interviews with representatives of other companies were also discussed, to get some other points of view on the topic of circular plastics and how it might relate to the furniture industry. At last, the chapter briefly discussed the topic of greenwashing in the industry with a CSR expert. All in all, the chapter has shown what the furniture manufacturers represented in these interviews think about and say that they do in regard to the discussed topics.

What this chapter has shown is that not all manufacturers have the same perception of circularity or the same degree of implementation of circularity in their company. However, what all companies did agree on is that there are challenges to using recycled plastics and to designing circular plastics furniture, although they did not necessarily agree on what those challenges were. The different challenges mentioned by the different companies range from small details like material specific properties to complex problems such as the lack of infrastructure and systems. Furthermore, although somewhat similar, the manufacturers have different strategies for becoming more circular and to solve, or avoid, challenges.

To sum up, there seems to not be a common understanding of circularity in the industry and there is also disagreement about challenges with using recycled plastics. So, it seems advantageous to analyze a selection of plastic furniture products from the manufacturers to see how they have turned circularity into a physical product, to see how circular their use of plastic is.



Chapter 4

The case study

This chapter presents the case study conducted to compare and evaluate some chairs containing plastics that are said to be recyclable or made from recycled plastics. The chairs used in the case study are produced by the manufacturers for which the interviewees work. The case study was done to analyze existing products to see how circular plastic furniture that is currently on the market is and served as a means to understand what solutions work well and where there is room for improvement.

This chapter describes, compares and evaluates the different chairs. Firstly, the scope and method of the case study is explained, secondly each chair is presented, followed by interviews with plastic recycling experts. Following that is an explanation of the method used to compare the chairs as well as the comparison of the chairs. At last, each chair is analyzed and evaluated and the results of the case study are presented.

Scope & method

This case study was conducted to analyze existing plastic furniture products. Initial research for the case study was done by obtaining information about the chairs from the companies' websites and from online articles about the chairs. Based on the collected information, the interview questions for the interviews with the representatives of the manufacturers and/or designers of the chairs were written as a means to get supplementary and more detailed information about the chairs. After collecting more information about the chairs through these interviews, interviews were also conducted with experts on plastic recycling to discuss the different chairs' potential for circularity. 11 seating furniture pieces have been included in this case study, out of which eight are chairs, one is a sofa, one is a stool and one is a bench. The chairs and sofa unit, which can be used as a chair, are the main focus of this case study, whereas the stool and bench serve as alternative examples.

The reason for focusing on chairs, or seating furniture, is that a chair is an archetypical piece of furniture that is relatively easy to compare. There is a long tradition in the furniture industry of making chairs from plastics, and it is also a piece of furniture in which multiple manufacturers have started to implement the use of recycled and recyclable plastics in an attempt to become more sustainable and circular. This trend in creating "seating solutions from recycled plastics" was even recently pointed out in architecture and design magazine Dezeen (Hahn, 2021).

Seating furniture can contain different kinds of plastic materials, such as hard plastics, fabrics or foam. Plastic foam such as polyurethane (PU), which is commonly used for upholstered furniture such as sofas, is as of today not recyclable. Furthermore, plastic fabrics are also widely used for seating furniture. However, the textile industry is an entire industry of its own and not the focus area of this thesis. For this thesis, the type of plastic to focus on has therefore been narrowed down to hard plastics, which amongst others is commonly used for plastic chairs.

The different chairs used in the case study were carefully selected because they each represent different approaches to circularity. However, they all have one thing in common, and that is the premise for why they were selected for this case study, which is that the chair is made with “recycled” and “recyclable” plastics. The reason for this requirement is that, as discussed in chapter 2, recycling seems to be the most effective solution to accelerate the transition to a circular plastics economy. In order to close loops and design out waste, using recycled plastics and being able to recycle them at end of life is of the essence. The aim of this case study is therefore to see if that is currently working in the furniture industry by investigating chairs that are claimed to be made with “recycled” and “recyclable” plastic.

Going forward, to clarify, what is meant with the words “recycled” and “recyclable” is as defined in ISO standard 14021. A standard definition was used to have a clear understanding of the words for the assessment of the chairs.

Recycled material is defined by ISO standard 14021 as a “material that has been reprocessed from recovered [reclaimed] material by means of a manufacturing process and made into a final product or into a component for incorporation into a product.”, with recovered [reclaimed] material being defined as “material that would have otherwise been disposed of as waste or used for energy recovery, but has instead been collected and recovered [reclaimed] as a material input, in lieu of new primary material, for a recycling or a manufacturing process.” (International Organization for Standardization, 2016, p. 15).

The term recyclable, meaning that the product can be recycled, is defined by the ISO standard as “a characteristic of a product, packaging or associated component that can be diverted from the waste stream through available processes and programmes and can be collected, processed and returned to use in the form of raw materials or products.” (International Organization for Standardization, 2016, p. 14).

The Chairs

The last part of the interview with the manufacturer representatives were about the chairs they produce that are used in this case study. For this part of the interview, the interviewees were asked questions about the plastic materials used, such as the composition if it and what waste the recycled plastics originates from. They were also asked about end of life and recycling of the product, and about some design decisions such as why some companies offer a variety of different models or colors. At last, since making a product from recycled plastics and recycling it at end of life is not all there is to circularity, the companies were also asked about the warranty and estimated life span of the chairs to give an indication of how long-lasting the products are.

HAY: AAC ECO 12

30% PIR PP & 70% virgin PP

The first chair is designed by Hee Welling for HAY and is a recreation of HAY's AAC chair, but from a more sustainable perspective. It was launched in 2020 and has the EU Ecolabel. The ECO series also contains a stool and a chair with armrests, but for this case study, AAC ECO 12 will be the main focus. This chair was chosen for the case study because of the angle of recreating an already existing design more sustainably, and because, unlike most others, it is only offered in one color and with one base.

The chair consists of a plastic seat shell made with 30% PIR PP and 70% virgin PP attached to a solid oak base. The seat shell is injection molded and the plastic material is made by a subcontractor. Hay uses its own industrial waste for this chair because it, according to Lindholm (2021), is an "effective circular system and because we can control the quality of the material". Furthermore, the chair is only available in a black color because leftovers in many different colors are used to produce the seat shell, making black a good option according to Lindholm. When asked why they have chosen a wooden base for this chair, Lindholm (2021) said it was because it is a "more sustainable material with a smaller footprint than steel frames, for example". When asked why, in difference to other chairs from other manufacturers, this one is not offered with different bases, the answer was that it is because Hay tries to "offer the one with the lowest footprint as possible, guiding the customer to the most environmentally friendly option" (Lindholm, 2021).

The seat shell is attached to the base with six screws that need to be removed to disassemble the chair. Bushings and glides also need to be removed. When asked about what happens to this chair at end of life and how it would be recycled, Lindholm answered that it is up to the customer. The plastic part is marked with type of material and HAY also makes assembly guides available to the customer, that instruct the customer on how to take the chair apart for recycling (Lindholm, 2021).

HAY: Revolt
30% PCR ABS & 70% virgin ABS (except the black version, which is 100% PCR ABS)

The second chair from HAY is Revolt, a design classic originally designed by Friso Kramer for Ahrend, relaunched in 2020 with a more environmental profile by HAY together with Ahrend. This chair also has the EU Ecolabel. This chair was chosen for the case study because it has an interesting angle of recreating a design classic with recycled plastic, and because it is made with PCR ABS, which most other recycled plastic chairs are not.

The chair consists of two plastic parts, a seat and a backrest made from 30% PCR ABS and 70% virgin ABS, except the black version which consists of 100% PCR ABS. The two plastic parts are attached to a bent sheet steel frame. The seat and backrest are injection molded and the plastic material is made by a subcontractor, as explained by Lindholm. The recycled ABS is made from white goods, according to Lindholm (2021), and the reason why is because "when it is made from white goods it is of very high quality. It is of high quality because it is pure white plastic (white in color) and because white goods are mostly kept indoor". This is the only chair in the case study made with recycled ABS, when asked why the chair is made from ABS, Lindholm (2021) responded that it is because ABS is "a strong type of plastic and the original plastic used for the chair is not allowed anymore due to regulations.". This chair is offered in nine different colors, out of which only the black one consists of 100% PCR ABS. When asked why HAY makes all these colors and not only the black one, Lindholm (2021) replied that "firstly because HAY is a colorful brand and secondly because we wanted to offer the original range of colors the chair was launched in".

The backrest is attached to the steel frame with two screws and the seat is attached with four screws. There are also fittings, bumpers, washers and glides that should be removed before recycling. The answer to what would happen to this chair at end of life and how it would be recycled was the same as for AAC ECO 12, that the customer can disassemble the product and deliver the parts to a recycling facility themselves. (Lindholm, 2021)

The two chairs from HAY have some things in common. Both chairs for instance contain 30% recycled material, except the black version of Revolt. When asked why the recycled content is 30%, Lindholm (2021) responded that it is because they “need a part virgin plastic to ensure the color, as recycled plastic often has color contaminants in it.”. Furthermore, both chairs are existing chairs that the company has tried to recreate in a more sustainable way. When asked why HAY has chosen this approach instead of designing new chairs with recycled plastic, the response was that the company wants to offer design classics in a modern suit (Lindholm, 2021). In addition, both AAC ECO 12 and Revolt have a five-year warranty, but when asked about the estimated life span of the two chairs, Lindholm replied that HAY does not have any lifespan on its product that he knows of. At last, Lindholm was asked what he would have done differently to make the chairs even more sustainable, and he did not mention anything concrete he would change about two chairs.

Fritz Hansen: N02 Recycle
95% PCR PP & 5% color pigment

This chair is a new design by Nendo for Fritz Hansen, it was launched in 2019. Like the two chairs from HAY, this chair also has the EU Ecolabel. There are different versions of N02 Recycle, this case study focuses on the N02-10, the model with tube legs and no armrest, this version has the EU Ecolabel. This chair was chosen for the case study because it is made from household plastic waste and because of its high content of PCR plastic.

N02 Recycle consists of a plastic seat shell made from 95 % PCR PP and 5% color pigment, attached to a steel base containing 50% recycled steel. The seat shell is injection molded. As explained by Langballe, the recycled PP is made from upcycled plastic household waste that is collected in Europe by a company that granulates, sorts and cleans the material and repalletizes it into recycled plastics. So, the material is bought from a subcontractor that recycled it into the material for the chair, it is then shipped to an injection molding company and at last the chair is assembled at Fritz Hansen's factory (Langballe, 2021). A masterbatch, which Langballe explained is a percentage of new colored plastic, is added to the PCR plastic to give the seven different colors. The different colors are, according to Langballe, made for design reasons, to have a color scale which is typical for furniture and because of the market, it is not just the black one that sells. When asked why there are five different models of the chair, the answer was that the chair was mainly seen as a chair for the contract market, and that the client would like to be able to choose from different versions. Langballe (2021) also said that it is "a little bit about creating this family around the product, that's very natural in the furniture industry, to do it that way.".

Although some versions of the chair do have the EU ecolabel, not all do, and that is because

> *some of the materials used are not possible to have eco-certified. So, for example the bases with chrome surface are not eco-certified and that's because*

we will not compromise on the quality of the chrome we use. If we use a chrome that could get EU certified, then the durability of that chrome is not good enough compared to our quality standards. (Langballe, 2021)

So, Fritz Hansen had to compromise and not qualify for the EU Ecolabel for all models of the chair, but instead have the quality the company wants. When asked if it was a goal to create a chair that would get the EU Ecolabel, Langballe (2021) responded that it was "because making a plastic chair that doesn't have an ecolabel doesn't make sense, because you can't sell it in the volume you want to".

An interesting thing about the N02 chair is that Langballe (2021) was very clear on how it was crucial that the chair "was designed somehow with the recycled material aspect as a starting point", so the process of designing this product started with the recycled material and then the product was built from that, and by doing so, all the challenges with using PCR plastics were taken into account and "put into the product design". Langballe also said that if N02 Recycle were to be designed with virgin material that one could reduce the thickness of the material quite a lot, because of the strength of the material. So, for this chair it was, according to Langballe (2021), "the material that somehow determined the design".

The seat shell is attached to the frame with screws. There is a mold in, called a tower, like small recesses or thicker areas of material, where the screws can be mounted in directly. To disassemble for recycling, the screws need to be removed to separate the seat shell from the base and glides also need to be removed. When asked what would happen to the chair at end of life, the answer was that it depends on the customer. Furthermore, N02 Recycle has a warranty of five years, but is tested for strength and durability for 10 years use and can last much longer. Like Lindholm, Langballe also did not mention anything specifically that he would change about the chair. (Langballe, 2021)

NCP: S-1500
100% PCR PP

The S-1500 is a redesign of NCP's R-48 chair by Snøhetta, launched in 2019. This chair does not have an ecolabel, but an EPD. According to that EPD, the carbon footprint of this chair is 9 kg CO_2. There are different versions of S-1500, this case study focuses on the model with four legs. This chair was chosen for the case study because of its unique marbling pattern made without additives and because of the local waste source that would otherwise not be utilized.

S-1500 consists of a 100% PCR PP seat shell attached to a steel base made with 20% recycled steel. Injection molding is used to make the seat shell. The recycled PP is made from equipment used by the fish farming industry such as worn-out nets, ropes and pipes. This material is provided from local fish farming companies Kvarøy Fiskeoppdrett and Nova Sea. The goal was to find a material from a larger industry in the local area of NCP and as Rossi (2021) said "the largest industry with the biggest masses of materials is the fish farming industry". The fish farming companies providing this plastic would normally have to pay to have it shipped somewhere, for instance Germany, for incineration, so for them it is even cost saving according to Rossi. When the fish farming industry no longer needs the material, they send it to a local subcontractor that processes it, color sorts it, fractions, washes and granulates the material (Rossi, 2021). Then, as explained by Rossi, the granulate is sent to the production site and is fed into the injection molding machine and heated to the desired temperature, and a seat shell comes out of the mold.

The chair comes in eight different colors, and what is interesting is that there are no additives in the recycled plastic material. The colors are, as Rossi said possible to make "through good old-fashioned sorting." (Rossi, 2021). As Rossi (2021) explained

> *no color pigments are added, what NCP gets delivered becomes what it becomes. For instance, you can only get 100 red chairs, and then there is no more red plastic, and that's it. And that is quite nice, because it doesn't follow the old mentality of a product designer saying that "this year's color is red", that's no longer interesting. If red is what NCP received, then red is what you get. It reflects what has been used (by the fishing industry).*

That is an interesting approach of utilizing available materials and letting them determine how the product looks, instead of making a design and then finding a material suitable for it.

Furthermore, the chair has a marbling pattern that makes each chair unique. This is something Rossi (2021) focused on developing by, as he says, doing "purely technical, heavy nerding on the machines.". So, what makes it possible to make each chair look unique is that the injection molding machines have been tweaked to not mix the colors to a solid color before injecting the material (Rossi, 2021). This technique has been developed with technicians who know the machines, to translate what was described by Rossi (2021) as a purely aesthetical wish into something that works in production, resulting in no chair being alike because "the pattern comes out a little differently each time".

This chair is offered with two different steel bases. When asked why that is Rossi (2021) answered that it is "what the market wants". Furthermore, according to Rossi, the company is currently working on a third base for the seat shell. The bases are made from steel partly because that is how the original chair was made, but as Rossi (2021) explains also because

> *if we were to make the chair entirely out of plastic, you would struggle with strength, it's quite problematic to make the legs from plastic. Or it's not problematic, but it's a completely different approach. But, at the same time, we also*

had a good collaboration with a company that works with steel in the local area, they make the legs from recycled steel from mines that are only 100 km away. It's a local company that recycles steel.

So, sourcing locally has been of importance for creating this chair, and that has also resulted in it having a significantly lower carbon footprint than similar products made from virgin plastic, as Rossi (2021) explained

I think a lot of it comes from where you source the material from [...]. So, if the distance from the plastic we source is so short that you can see the island or the place where they catch the fish, you understand that it will also lead to good results.

Rossi also explains that distance is quite a large field within an EPD, and that an EPD describes all the different parameters that come into play to constitute the total calculation. As explained by Rossi (2021), an EPD gives a "comprehensive calculation on the entire chair" and gives you "a proper declaration that is not just a stamp" in difference to an ecolabel. Rossi (2021) said he feels that "a lot of times it's sort of wrong to just lean on those labels", he would rather lean on EPDs or LCAs, which is what this chair does.

This chair project can be said to contribute to build a local circular economy. It employs plastic waste, or plastic resources as Rossi (2021) pointed out - "everything is a resource, so I don't call it waste", from the local industry to produce chairs in the same area. When asked what would happen to the chair at end of life, to loop it back into that local circular economy, the answer was that NCP is working on setting up a system to get the chairs back into the industry (Rossi, 2021). The company would be happy to take back chairs, for instance if they are broken, and have them regranulated or remelted to be used again (Rossi, 2021).

To recycle the chair, one needs to remove four screws to separate the base from the seat shell, as Rossi (2021) explained

> *that's also the foundation for keeping it so simple, to be able to take things apart again in different fragments of pure materials. Then it is granulated, NCP has their own granulation machine too, and then it's cleaned and fed back into the machine.*

Furthermore, Rossi (2021) explained the importance of not adding any additives to the plastic material in regard to recycling

> *it is better to have clean fractions, to have a system where you make sure that it can also become something else, the S-1500 could for instance become fishing nets again if that were needed. So, if something else it needed, you can just melt the plastic and create something else.*

So, the seat shell is suited for multiple purposes after recycling because it is 100% recycled plastic, without additives. What could have been done differently to make the chair even more sustainable would be to increase the recycled content of the steel legs, which is currently being worked on (Rossi, 2021).

At last, S-1500 has a warranty of five years, but an estimated lifespan of at least 100 years (Rossi, 2021)

Emeco: Alfi
80% PIR PP, 20% wood fibers

Alfi is a new design by Jasper Morrison for Emeco, and the oldest one of the chairs in this case study, it was launched in 2015. It does not have an EPD, but it does have a carbon footprint declaration, according to which the high back version of Alfi has a verified carbon footprint of 19.01 CO_2 equivalent. There are different versions of Alfi, this case study focuses on the model with a high back and wooden base. This chair was chosen for the case study because of the wood fiber reinforcement and wooden base that differentiate it from other recycled plastic chairs.

The chair consists of a seat shell made with 80% PIR PP mixed with 20% wood fibers, attached to an ash wooden base. The seat shell is injection molded. As explained by Buchbinder, Emeco makes the plastic material in house. The company works with someone who works with collecting industrial waste wood fiber and with material engineers for the recycled PP, but the adjustment of how much wood fiber is used and the colorant is done by Emeco (Buchbinder, 2021). The reason why the plastic material is mixed with wood fibers is because something structural was needed and, according to Buchbinder (2021), "fiber can give it different material properties that actually add strength in the long term.", it was also because of the natural touch feel the plastic gets in difference to if one were to use glass fibers. When asked why post-industrial waste is used for this chair and not post-consumer, the answer was that sometimes it is the only option because post-consumer just is "not consistent enough, like in the case of the wood chips" (Buchbinder, 2021). As explained by Buchbinder, the wood fibers are made from post-industrial waste that would otherwise be scrap that would not get recycled.

Alfi comes in six different colors. According to Buchbinder (2021) "the colorants come in the form of a non-VOC powder and are either mixed beforehand or at the press depending on the product and how the processing is going". The reason for making six different colors is simply a design choice, as Buchbinder (2021) explains "picking colors, it's so fun so I think that's honestly for fun". The chair can also be offered with an aluminum base, to make it outdoor applicable and because aluminum is Emeco's specialty (Buchbinder, 2021).

The estimated lifetime of the aluminum version is naturally longer than the one with a wooden base. The warranty is 5 years, but according to Buchbinder (2021) "realistically the estimated life span is closer to 20 or longer" for the version with the wooden base.

When asked about what would happen to Alfi at end of life, Buchbinder (2021) responded that

> *if someone lets us know that the Alfi's are an issue we can take them back, we can even use the ash itself as our post-industrial waste stream for wood chips in the shell, but same thing with the polypropylene, we can shred it up and remold it.*

To recycle the chair, one must disassemble it first, by detaching the base from the seat and removing the glides. Then, as explained by Buchbinder (2021)

> *being recycled it would just be shredding up the shell, shredding up the base or attempting to fix it but depending on the material or like what's going on. It's an interesting question because that's like the same thing where we're trying to enable someone selling their Alfis to someone local rather than recycling it because of how energy intensive it would be to recycle versus just continue to use, but if we wanted to recycle it, it's fairly straightforward.*

So, it seems that Emeco is looking into enabling reuse of Alfi before recycling.

The wood fibers are not separated from the plastic in the recycling process, so the material is recycled into the same wood fiber reinforced plastic again. When asked if that material can only be used to make Alfi chairs again or to make other products, Bucbinder (2021) said that

> *We could theoretically use an Alfi chair, and I think it's not one to one when you would recycle it, you might have to change the fibers in it or add more recycled polypropylene as a binder or add more colorant, but you could take the shells and turn them into a 1 inch reclaimed or into a Broom chair.*

However, the wood fiber reinforced polypropylene can probably not be recycled in standard recycling facilities. When asked if the material only can be recycled in house or also in standard recycling facilities, Buchbinder (2021) responded that "I think it would be in house just because the Alfi chair is our own individually developed material, I don't know if recycling centers would take polypropylene with wood chips.".

Emeco: On & On
70% PCR PET, 20% glass fibers & 10% non-toxic pigment

On & On is a new design by Barber & Osgerby for Emeco, launched in 2019. As for Alfi, Emeco has also calculated the carbon footprint of On & On, and that is about 17 kg CO_2 equivalent. On & on comes with different seats, this case study focuses on the model with the recycled plastic seat. This chair was chosen for the case study because it is made with PET, which distinguishes it from other recycled plastic chairs, and because the entire chair is made with recycled plastic.

The On & On chair is made from 70% PCR PET reinforced with 20% glass fibers and mixed with 10% non-toxic pigment. The chair is injection molded. This material is the same as originally developed for the 111 Navy chair, but the glass fiber has been reduced and the percentage of recycled plastic has been increased, making it lighter but equally strong according to Buchbinder. The material has also been made even easier to regrind and reinjection mold than the 111 Navy chair originally was (Buchbinder, 2021). This material is as explained by Buchbinder also made in house from post-consumer bottle collection, so Emeco is collecting from bottle centers in the US. The reason why the plastic material is glass fiber reinforced is because some extra structure was needed, but Buchbinder pointed out that they are getting closer and closer to lowering that percentage and how that is done is through R&D and over time adjusting and amending in an ongoing iteration. When asked if Emeco is aiming to make the fiber reinforced materials into 100% recycled plastics, Buchbinder (2021) responded that

> *I think depending, it's definitely a goal to keep lowering the carbon footprint and sometimes the added materials add weight and add energy to it. Lowering the carbon footprint, making them more recyclable and making them more durable, and if that means increasing the amount of recycled*

> *plastic, that's great, and if that means doing something else, that's great. So, it's not always increasing the amount but just optimizing the product itself.*

The On & On chair comes in six non-toxic different colors. The reason for making six different colors is according to Buchbinder (2021) because

> *When you have a variety of colors you have a variety of applications and the whole idea is that it's something that is a flexible product, we're not just making a recycled material in black because that's the easiest color, it's showing the versatility of the material itself and also of the application for the product.*

Furthermore, the different colors are made by looking into ways to naturally color the material because, as Buchbinder (2021) explained "I think a lot of times it's the things like the colors that actually make the materials unhealthy". The black colorant is, for example, made from recycled tires (Buchbinder, 2021). Furthermore, the chair is also offered with plywood or upholstered PU foam seats, as Buchbinder (2021) explains

> *it's a plastic frame but at the same time when you turn the seat to plywood or upholstered, you are kind of changing the application that it can be used. Upholstered seats become more high-end and more residential almost or something where it could be used in an office versus the plastic seats that seem like you're going to use it in like an education facility or like a cafeteria. I think changing the application makes it a lot more flexible.*

The reason for the name On & On is that the chair can be recycled on and on. When asked what would happen to the On & On chair at end of life, Buchbinder (2021) explained that

theoretically we can take it back, take out the stack bumpers and the seat comes off, remove the glides and then it's fully recyclable and if it has the seat on it, we would take out the stack bumpers and we could recycle the seat with it.

The plastic material would then be recycled in house. Buchbinder (2021) was also asked if this plastic material could be recycled in standard recycling facilities, upon which she answered that "right now, it's in house, but I think On & On is more likely, we're pretty close where it could be recycled in another recycling facility as well, which really streamlines the logistics there". So, the plastic material used for On & On could theoretically be recycled into other products.

At last, the warranty for On & On is five years, but it is estimated to last much longer (Buchbinder, 2021).

Buchbinder was also asked if she would have done anything differently to make Alfi and On & On more sustainable. She answered that

I think for both of the chairs, the remaining issue is the logistics, figuring out how to launch a chair that has a baked in system for recycling is going to be the next step and the most important thing, it's not just about launching a chair that has a planned end of life, but figuring out how to make that end of life available for an everyday consumer. (Buchbinder, 2021)

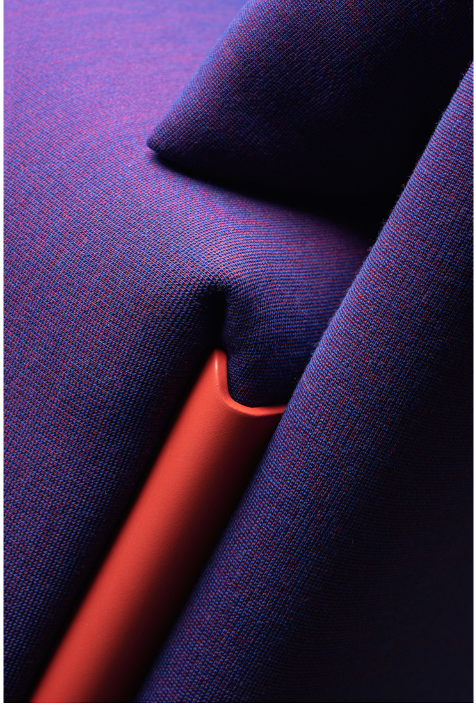
Magis: Costume
99% PIR PE & 1% color master

Costume is a new design created by Stefan Diez for Magis, launched in 2021. It is a modular sofa system that, amongst others, can be configured as a chair. For this case study, the base unit will be the main focus, which with or without two armrests can be used as a chair. This chair was chosen for the case study because it is made from PE using rotational molding technology, because of how it can be recycled in difference to traditional sofas, and because of the circularity aspect of how it is designed to adapt to changes as a means be used long.

One sofa unit consists of a core made of 99% PIR PE with a 1% color master. On top of that core there is a layer of pocket springs and a layer of PU foam, and it is all held together by a fabric cover with elastic loops that are hooked into the bottom of the sofa unit. The core is rotationally molded using a powdered plastic material (Perin, 2021). According to Perin, the plastic material is made from industrial waste from furniture, partly from Magis' own furniture, and from the automotive industry, and the material is procured by a production partner. When asked why industrial waste is used instead of post-consumer waste for the core since it is covered with fabric, making the color of the plastic less relevant, the answer given by Perin (2021) was that

> *for the type of technology used, the material must be polyethylene. With industrial waste, the selection of the material takes place with relative ease, with urban waste the operation is very laborious and expensive, and the result is not always guaranteed.*

The sofa system consists of the base unit, armrest and a pouffe. To interlock multiple sofa units there are also connectors made of virgin PP offered in the three different colors orange, blue and black. Furthermore, the fabric cover for the sofa is offered in three



different types of fabrics. One is made with 100% recycled polyester from bottles, one is a cotton, viscose and wool blend and one is a wool, nylon and polyester blend. There are 24 different fabrics to choose from.

What differentiates this sofa from traditional sofas is as explained by Perin (2021) that "not only does this system use much less foam in manufacturing than conventional sofas – most of the materials used can also easily be recycled". The issue with conventional sofas is as Perin (2021) explained:

> *Up until now there were two ways of constructing a sofa. Either it consisted of a wooden frame with a structure of belts, spring core, foam and upholstery or it was based on a metal frame with built-in suspension, which was filled with foam, covered with foam padding and upholstered. Both variations have one thing in common: it takes a lot of effort and expense to repair them, the materials are difficult or impossible to separate and the sofa contains large quantities of foam that cannot be recycled.*

So, when asked what would happen to a Costume sofa unit at end of life, the answer was that it can be completely disassembled and recycled because no parts are permanently attached to one another (Perin, 2021).

Costume has a warranty of 2 years, but when asked about the estimated lifespan of it, Perin (2021) answered that its life can be extended because all components can be replaced separately. For instance, if new upholstery is needed, it can be replaced, and the fabric can be removed for washing or to replace it with another one if a change in appearance is wanted. Moreover, the base unit can be interlocked in different constellations, allowing for reconfiguration to adapt to different scenarios in life, it can also be

extended with armrests or a pouffe. So, to sum up, all parts of the sofa unit can be replaced separately, and the sofa is designed to adapt to a change in situation or liking, making it difficult to set an estimated lifespan for it (Perin, 2021).

When asked if there is anything Magis would do differently to make the two projects more sustainable, Perin (2021) responded that “all our projects are never considered completely finished. We see them rather as an open construction site, where there is always the possibility of improvement.”. According to Diez, from summer onwards the core will be made from PCR plastic, and the biggest room for improvement is the fabric, which currently consists of composite materials that are difficult to recycle.

Magis: Bell chair

77% PIR PP, 20% glass fibers & 3% color master

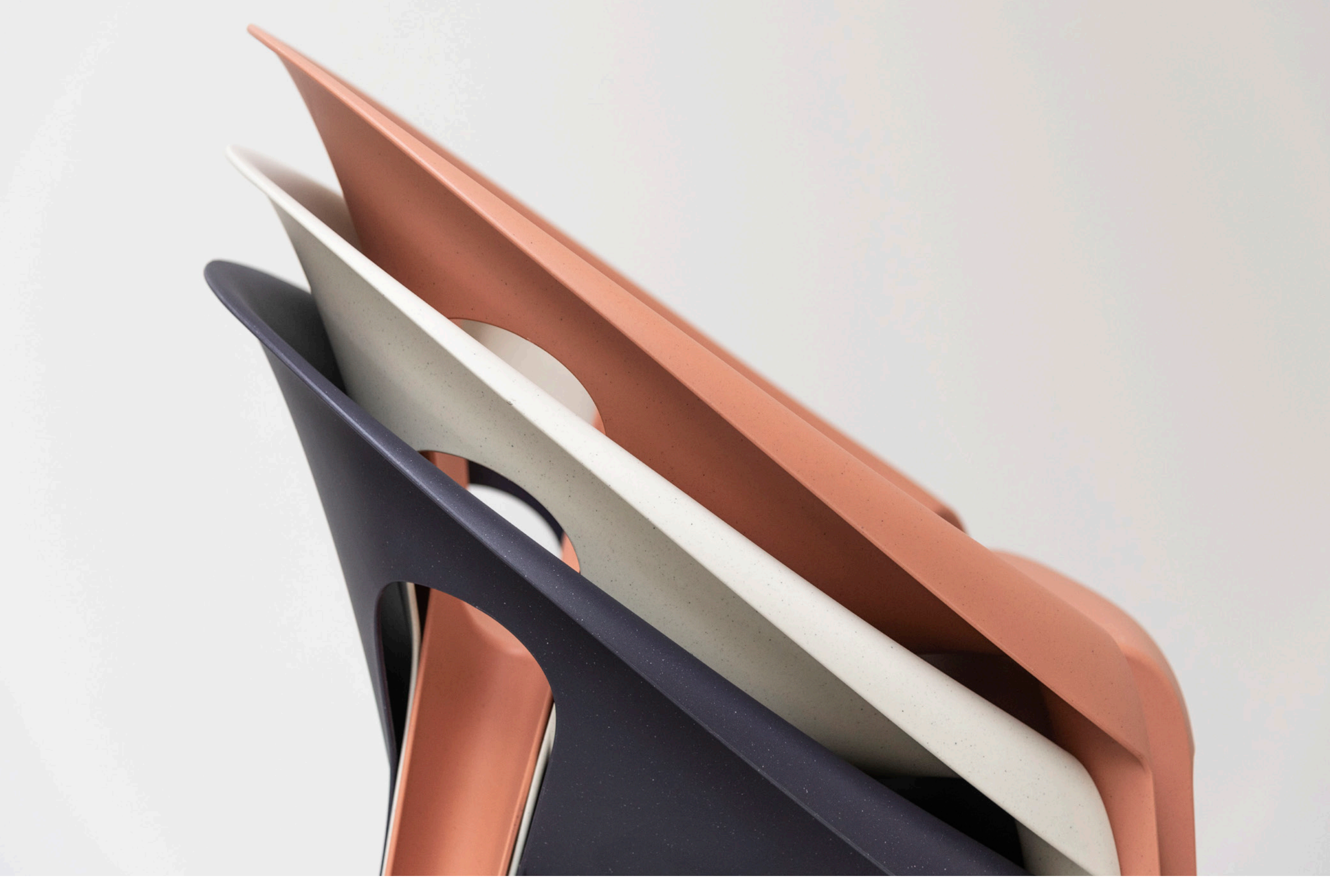
The Bell chair is a new design created by Konstantin Grcic for Magis, launched in 2020. This chair was chosen for the case study because it is a monobloc chair made with recycled plastics.

The chair consists of 77% PIR PP reinforced with 20% glass fibers as well as a 3% color master. The chair is a monobloc, injection molded in one piece (Perin, 2021). According to Perin, the post-industrial waste comes in part from Magis' own furniture and part from the automotive industry. The material is produced and patented by a production partner on Magis' behalf according to Perin (2021). When asked why the chair is reinforced with glass fibers, Perin (2021) answered that "almost every injection-molded chair on the market with polypropylene needs (in different percentages) fiberglass to be strong enough to pass the tests required by the market. Similarly, this specific polypropylene needs it.".

The chair comes in three different colors that have some drops of other colors in them as well. When asked what these "dots" in the color come from, Perin (2021) answered that "the dots represent the impurities inherent in the recycled nature of the material.". The reason for making the three different colors was according to Perin (2021) because of a commercial decision that was "also linked to the optimization of production batches."

Since this is a monobloc chair, it does not need to be disassembled before it can be recycled. When asked what would happen to this chair at end of life and how it would be recycled, Perin (2021) answered that “as already happens for most of the polypropylene goods, where part of the molded material once shredded can be mixed with virgin material for new productions; with Bell it is theoretically possible to completely reuse it to produce a 1:1 new Bell endlessly.”.

The Bell chair has a warranty of two years, but according to Perin, Magis assumes a lifespan of 15-20 years.



Flokk: Capisco Puls made from recycled snow plough markers
100% PCR PP (with some color pigment)

This chair is a limited-edition redesign of the original Capisco Puls designed by Peter Opsvik in 1984, using recycled snow plough markers, released in 2021. This chair was chosen for the case study because it has an interesting angle of finding a waste source and utilizing what is available of that waste source to make a limited-edition version.

The limited edition Capisco Puls is made with a seat and backrest from PCR PP mixed with a few parts per thousand color pigment to give it a more auburn color and not the bright orange color snow plough markers usually have (Lodgaard, 2021). Other materials used are, according to Lodgaard, 95% recycled aluminum for the base, steel, and PU foam and fabric for the seat. The backrest and seat are injection molded. The plastic material is made from discarded and broken snow plough markers. Flokk did a project together with SINTEF to find new sources of waste or "waste problems that haven't been solved", as Lodgaard (2021) explained, and snow plough markers were identified as such a source. The recycled snow plough markers are bought from the Norwegian Public Roads Administration and sent to a facility in Denmark that washes and shreds the material, but the value chain has been set up by Flokk (Lodgaard, 2021). The batch Flokk secured allowed the company to make 200 chairs, but the goal now is to scale it up, as Lodgaard (2021) explained

> *We are going to see if we can make this a steady stream. All these snow plough markers break, about 1/3 of all snow plough markers break in a year, and you can't switch to wood because a lot of places the conditions are too rough, they wouldn't even last a single winter, so then we scale up, and we'll see if it works.*

The chair is made to be disassembled with tools that everyone has at home and sorted in clean fractions, and all components are marked with material type for recycling (Lodgaard, 2021). So, it is the customer, or someone at the facility where the customer delivers the chair, that disassembles it for recycling, as explained by Lodgaard.

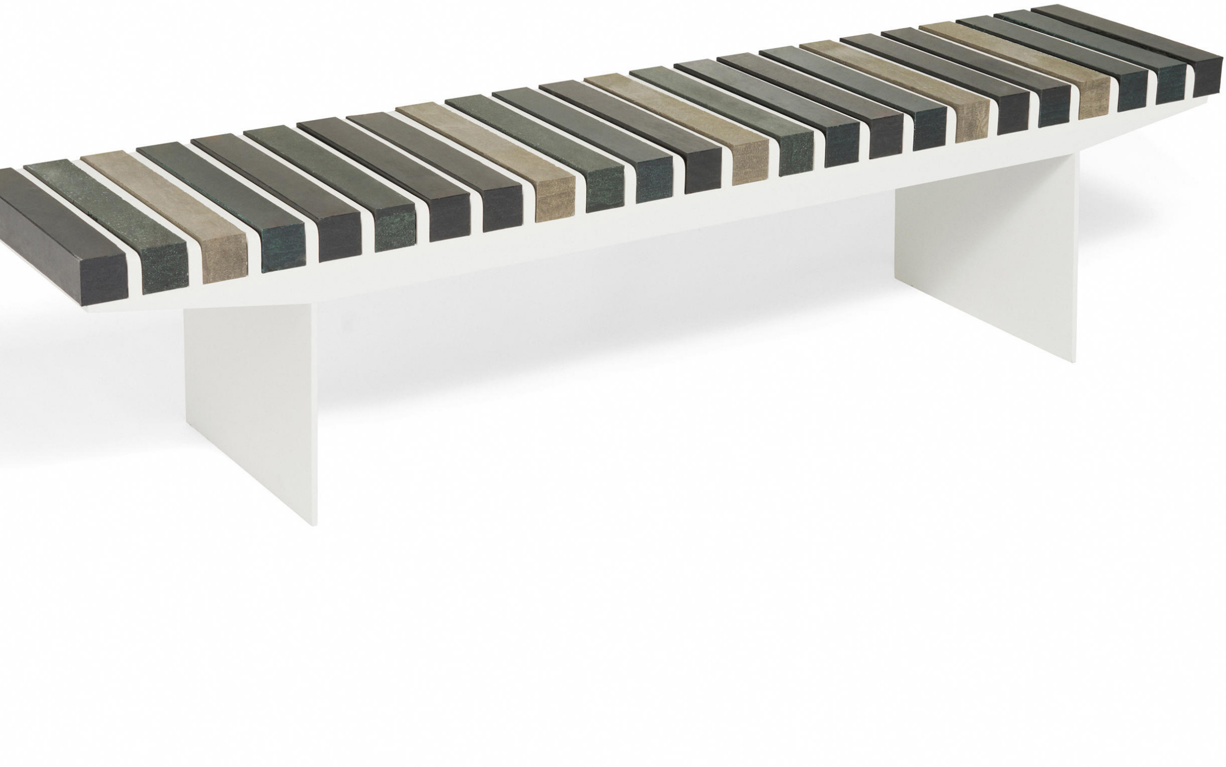
The chair has a 10-year warranty, but lasts much longer, easily 20 years (Lodgaard, 2021). Lodgaard also pointed out that if the fabric is worn out, it can be replaced. When asked if he would have done anything differently to make the chair even more sustainable, Lodgaard (2021) answered that

> *there are some aspects of the chair mechanism that could have been made more sustainable, we're working on increasing the weight percentage of recycled steel for instance, there is a little steel in the middle of the chair underneath the seat that allows you to move in it, and I guess that's probably pretty much where I would change something.*

For this case study, it was considered to choose Capisco, and not the limited edition Capisco Puls, because Capisco has the Nordic Swan label. However, Capisco Puls from snow plough markers was chosen because the chair is made both from recycled plastic and has less PU foam than Capisco. In this regard, Lodgaard was asked why Capisco has the Nordic Swan Label and the standard Capisco Puls does not, given that Capisco contains much more unrecyclable PU foam. To this question, Lodgaard (2021) had a very interesting response.

Capisco Puls is in every way a more environmentally friendly product, even before the snow plough marker story. No matter how you calculate, Puls leaves a lower climate footprint and with less foam, it's also a more robust product. Yet it's true that one has the label and the other one doesn't, and that is because Capisco Puls doesn't meet the Swan label criteria despite that, on all objective scales, it is a more environmentally friendly product. That is because when you create such a labeling scheme that separates products into two clear groups, where one is environmentally friendly and the other one isn't, you always base it on existing solutions, and then you try to find scales for that and for a piece of furniture, the Nordic Swan Label says that the weight proportion of recycled material has to be this much, but we ignore PU foam because it cannot be recycled. So, that means that when we create an innovative product that manages to get rid of almost all PU foam and still has a very good comfort, that doesn't count.

So, it seems that ecolabels do not necessarily say if a product is more environmentally friendly than similar products.



Vestre: The Coast Bench
100% PCR HDPE, PE, ABS and PP (but not mixed together)

The Coast Bench is a new design by Allan Hagerup for Vestre, released as a prototype in 2020. This bench was chosen for the case study because it uses ownerless ocean plastic and because of the leasing business model that serves as an example of how business models, services or systems can be integrated in plastic furniture.

The bench is made from 100% PCR plastic seat panels attached to a steel frame. To make the plastic panels, the recycled plastic is heated and placed in molds that have the shape of the seat panels (Vestre, 2021). The recycled plastic is collected at beach clean-up days, so it can be anything from something that has been in the ocean for a year to something that has been floating in the ocean for 20 years and is degraded by salt and UV light, as explained by Vestre. That is all mixed together, and that is challenging as explained by Vestre (2021), "even if you can sort based on plastic type, you can't sort based on plastic quality in the same way, so that has been and still is a challenge". Furthermore, according to an associate of Vestre who provided the details on the material, the plastic consists of different fractions from ocean plastic, made from hard plastics, such as for instance HDPE, yarn from PE, floats from ABS and ropes made of a mix of PE and PP. However, those fractions are not mixed, so one piece of plastic for the bench is made from one fraction. The plastic is cleaned up by In the Same Boat, a public NGO. From there the plastic is transported to NOPREC on Ottersøy where it is sorted and washed before it is grinded into a granulate and then it is sentto Salpro composite in Fredrikstad where production takes place, according to the associate.

Furthermore, there are no additives in the plastic, it is 100% PCR ocean plastic that is ownerless, meaning, as Vestre explained, that it does not belong to anyone. Nothing has been done to make the different colors of the plastic parts, as explained by Vestre (2021) "they will all be unique every single time, we have no control over that, sometimes they're green and sometimes they're a little brown and so on".

Since this bench is leased, at end of life it comes back to Vestre where the parts will be taken apart and materials will be reused (Vestre, 2021). That is the point of the leasing model, as Vestre (2021) explained "that we legally retain ownership is a way to take back" and make sure the plastic is recycled and does not end up as waste again. Because of the leasing model, the bench is designed so that it is easy to remove the plastic parts from the bench. The steel frame can be endlessly reused, either with new plastic parts or with wood, as explained by Vestre. The plastic that is taken back is shredded and made into granulate again, but as Vestre explained, that depends on what material properties it has after another cycle of recycling.

Vestre explained that the bench has so far only been released as a prototype and the company does not know what the plastic can be turned into yet because it has not yet been tested. However, the hypothesis is, according to Vestre, that it can be used to produce the same thing again and again. Vestre is working with SINTEF to investigate this and do tests. At the beginning of the project, SINTEF meant that some binder or additives, such as glass fibers, were necessary because of the poor quality of the plastic, but Vestre (2021) did not want that, as he described glass fibers as an "environmental nuisance". He did however say that

> *maybe it will have some type of additive in the future, not glass fiber, it has to be something environmentally friendly that makes us extend the life span of it, that might be worth it although the product then might not be as pure. (Vestre, 2021)*

Because as Vestre also explained, it might not matter that the quality is poor if they can control the plastic and recycle it over and over again, but that needs to be investigated and calculations need to be made to see what the advantages and disadvantages are of the life span being shorter if a larger part of the collected plastic is used. However, as Vestre (2021) also explained

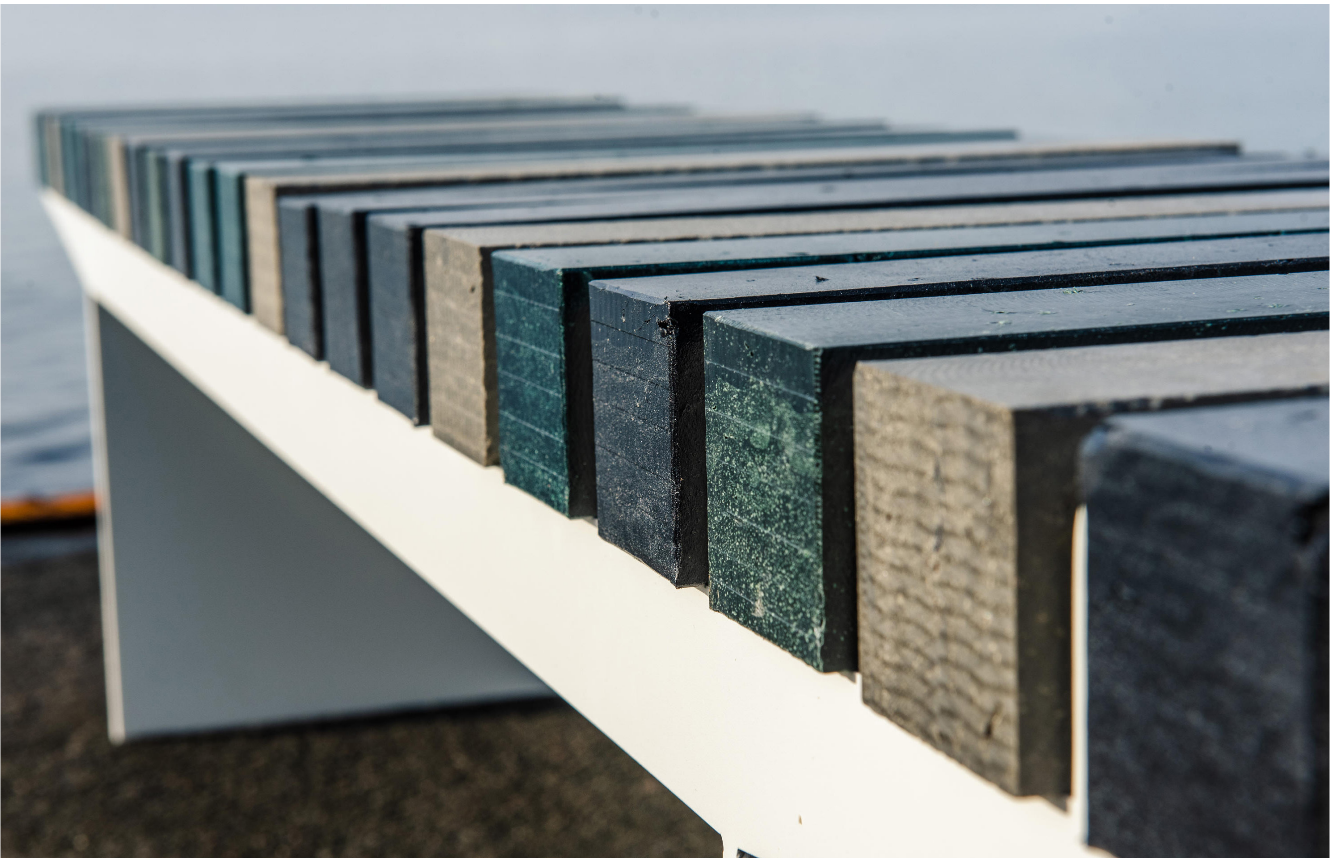
> *if the life span becomes so short that we must use more resources to recycle it again, then we haven't really solved a problem either. Yes, we've collected plastic from the ocean, that's good, but in terms of climate and energy, we haven't solved an issue.*

So, what the best solution will be remains to be seen, but as Vestre pointed out, it is important to emphasize that there is a big difference between collected ownerless ocean plastic of all different sorts of quality and an industrially controlled product that has been with one owner all the time.

Furthermore, this bench connects many businesses. The plastic material used for the bench is owned by one company and tracked by another. The plastic is owned by Ogoori, a company Vestre set up together with Ope, another Norwegian furniture manufacturer. So, Ogoori offers the plastic material as a service, meaning that when Vestre no longer needs the plastic or the lease expires, it is returned to Ogoori and the company can regrind it into granulate and lease it to someone else. The reason for making a separate company was, according to Vestre so that the ocean plastic is not only used for furniture but can be used by other companies and businesses for other product groups as well, also outside Norway. So, with this leasing model, recycling is not an alternative, it is an integrated part of the business model. Furthermore, the plastic is tracked by a company named Empower. All plastics are registered in every single link with blockchain technology. Everything will be registered in an app and the product will have a QR code on it so when the customer scans the code, they will get all the information about the plastic such as where it was collected, how it was recycled and where it has been in the meantime and so on. So, with all these services and systems combined, the plastic is less likely to go astray. (Vestre, 2021)

Since this bench as per now is a prototype in need of further development before it can be upscaled, it is difficult to estimate its lifespan. As explained by Vestre, accelerated tests are currently being done with SINTEF to figure it out. The plastic will, however, probably have a shorter lifetime than the company's other products, but it remains to be seen if that is 5, 10 or 15 years (Vestre, 2021). That is also why the bench is not for sale. The plastic parts in the bench would probably have to be regularly replaced, but how often is also not determined yet as it has not yet been tested how long the plastic can be left out (Vestre, 2021). Vestre did, however, point out that if the plastic has a lifespan that is less than 10 years, he will personally have an issue that, because it is not like Vestre to make products with short life spans. However, in theory plastic is a strong material that does not downgrade like other materials so the plastic parts should in theory not be broken down, according to Vestre's associate.

This bench will not be used in the comparison of the different chairs, as it is still a prototype and not on the market like the rest of the recycled plastic chairs, so there are still some unanswered questions in difference to the other chairs. It will however, like the other recycled plastic chairs, be evaluated separately after the comparison.



FluidSolids: The FS Stool
90-95% post-industrial waste fibers + additives & binder

The FS Stool was designed by Beat Karrer in 2011, and it was the first product made with the FluidSolids material. This stool was chosen for the case study as an alternative to using recycled plastics, and because it uses a bioplastic that is not in competition with food production and that can be home compostable.

The seat for the stool is compression molded out of a biodegradable biobased plastic material consisting in majority of fiber made from for instance cotton, coffee grounds or nutshells, there is also a binder and roughly 10% organic or mineral additives in the bioplastic material (Karrer, 2021). The seat is attached to three wooden legs by positioning them in a pressing mold and then the material is put into the mold and pressed together, as explained by Karrer. That both forms the seat of the stool and attaches the legs all in one process without needing any glue or screws to attach the legs to the seat (Karrer, 2021). The bioplastic is made from organic post-industrial waste, and not from materials that are grown to produce bioplastics, so as Karrer explained, it does not compete with food production. Furthermore, it is also home compostable unlike most bioplastics that are only industrially compostable, according to Karrer.

The bioplastic material is made and compounded like classical plastics, but there are some differences in material properties (Karrer, 2021). According to Karrer, the Fluidsolids bioplastic material is stiffer than almost any petrol-based plastic, but it depends on the feedstock used. Karrer explained that hemp for instance has different qualities than coffee grounds. When asked how different colors are made with this material, Karrer (2021) responded that the different colors come from different fibers, so "If you have nut shells or coffee grounds you get the brown color, if you have paper waste, white paper, then it's almost white, and then we also use mineral colors."



When the stool reaches end of life, it cannot be disassembled as the legs are attached firmly during the production process (Karrer, 2021). When asked what would happen to the FS Stool at end of life, Karrer (2021) explained that "it depends a bit on the end user. This was an on/off series of 10-15 pieces we made, but if it would be produced industrially or in a bigger amount, it could be composted if needed.". The FluidSolids material can also be recycled, but not in standard recycling facilities (Karrer, 2021). If the material were to end up in such a facility it would according to Karrer either be incinerated or alternatively composted if the facility has a separate composting stream. The material can, however, as Karrer explained, be recycled in FluidSolids own facility. So, FluidSolids can take production leftovers or parts that did not pass the quality control and shredder them and mix them with virgin FluidSolids material. Karrer explained that 30% recycled material can be used together with virgin material. If you go higher in recycled content, the quality and stability decreases, like it does with virgin plastic (Karrer, 2021). As explained by Karrer, the more you recycle it, the shorter the polymer chains get and the less quality you get. FluidSolids does not have a takeback system, as explained by Karrer (2021) because

> *if you compare with classical plastics, you have so many different types and you only have a take back system for seven of them. So, it's not realistic that we as a small company are able to implement a take back system worldwide or in Europe, when even the big multi-nationals don't even manage to implement a take back system worldwide.*

When asked what the estimated life span of the stool is, Karrer (2021) responded

> *Forever, as long as you don't put it outside. Like with any of our materials, home compostable means that it has limited water resistance. FluidSolids are, I would say somehow like uncoated wood or MDF, so that is kind of the price you pay for compostability*

The FS stool has never been industrially produced on a large scale and is more an example of a different approach, where the plastic used can circulate in a biological loop instead of a technical one. Furthermore, this is a particularly good example as explained by Karrer (2021), because unlike most industrially compostable plastics that "produce carbon dioxide while you compost it", the FluidSolids material "is feeding the compost.". However, Karrer (2021) himself also pointed out that "I don't have that much of a problem with parts made from classical plastic that are part of let's say furniture that has a lifespan of 10 to 20 or 50 years, because then it has a long lifespan.". So, given that this stool has never been industrially produced on a larger scale or been on the market as the other chairs have, it will not be used in the comparison. The comparison will only focus on the chairs made from recycled plastics that are currently for sale. Furthermore, the FS Stool will not be evaluated, given that it is not intended for sale.

Reflections

Other chairs could of course have been included as well or used instead of the chairs chosen for this case study, such as for instance IKEA's ODGER or Vitra's Tip Ton RE. However, it made sense to contact companies that produce more than just one recycled plastic chair for the case study as those companies hopefully also are more experienced with recycled plastics, and that is why companies such as Emeco, HAY and Magis were chosen. It was also kept in mind to contact companies from different places around the world, and for instance not only use Scandinavian companies, because recycling systems differ from country to country, and greatly globally. It was also a conscious choice to choose chairs made from different sources of plastic waste and with different design solutions, ranging from monobloc to steel or wooden bases to more complex chairs also containing PU foam and fabrics.











Expert Interviews

Before comparing and evaluating the chair, it seemed necessary to interview some experts on plastic recycling to get a neutral opinion about the different recycled plastic materials used for the chairs, given the divided opinions between the manufacturers about what is possible and not in regard to sourcing and recycling. Furthermore, given that most furniture manufacturer said that their chairs are recyclable, but that they do not recycle the chairs themselves, it seemed necessary to talk to someone who knows how recycling works and could assess whether the chairs actually will be recycled or not.

Grønt Punkt Norge

Grønt Punkt Norge

The first expert interviewed was Johannes Daae, head of development at Grønt Punkt Norge. Grønt Punkt Norge is "a privately owned non-profit company responsible for financing the recovery and recycling of used packaging on behalf of the industrial sector.", amongst others for plastic packaging (Grønt Punkt Norge, n.d.). Daae was interviewed because of his expertise on mechanical recycling of plastic packaging, as packaging is an industry that has managed to systemize plastic recycling to quite a large extent, at least in difference to the furniture industry. So, it should be noted that everything Daae said in the interview about how the plastic recycling system works is based on how it works for packaging.

The interview with Daae was semi-structured, an interview guide was made with some general questions regarding contradictory findings from the manufacturer interviews, followed by questions about each chair used in the case study. The interview was conducted via Teams and lasted about an hour.

Fraunhofer Umsicht

The second interview was conducted with research assistant Tobias Rieger who works with recycling technologies in the circular economy department at Fraunhofer Umsicht. Fraunhofer Umsicht, the Fraunhofer Institute for Environmental, Safety and Energy Technology, is part of the Fraunhofer-Gesselschaft which is "the world's leading applied research organization" (Fraunhofer, n.d.). This interview was conducted because Fraunhofer focuses on chemical recycling of plastics, in difference to Daae with whom mechanical recycling of the chairs was discussed. So, this interview was conducted to see if some of the chairs that might not be mechanically recyclable, could be recycled chemically.

No experts on recycling of plastic furniture could be found, most likely because there does not seem to exist any large-scale system dedicated to recycling plastic furniture. So, the interviewed experts are not experts on furniture, but on plastics. All interviewees have given their consent to use their full name, job title and answers to the interview questions in this thesis.

Fraunhofer UMSICHT

SINTEF

The interview with Rieger was also semi-structured, using the same general questions as for the interview with Daae. However, Rieger was only asked questions about the chairs that are fiber-reinforced because the others are mechanically recyclable. Some questions about chemical recycling in general were also asked. The interview was conducted via Teams and lasted about an hour.

SINTEF

At last, senior business developer Susie Jahren from SINTEF was interviewed. SINTEF is “one of Europe’s largest independent research organisations” (SINTEF, n.d.). Jahren is a chemist and expert on sustainable polymer technologies and was also working with Flokk on the limited-edition snow plough marker chair. She was interviewed to get a third view on the matter as Daae and Rieger disagreed on the recyclability of some of the chairs, a natural consequence of the difference between mechanical and chemical recycling. Jahren specializes in polymers and circular economy and was therefore hopefully not as biased by the use of a single recycling technology, but more concerned with the circular economy aspect of the plastics used in the chairs.

The interview with Jahren was also semi-structured, and the interview guide contained the same questions regarding the different chairs as for the interview with Daae. Jahren only had 30 minutes time, so the general questions were omitted. This interview was also conducted via Teams.

These interviews served to get an expert opinion on things the furniture manufacturers disagreed on, such as the use of composite materials, bioplastics or what colors one could get with recycled plastics. It also served to verify or falsify the uncovered challenges with recycled plastics. Furthermore, the different chairs were discussed with and reviewed by the experts to form an opinion about the different sources of recycled plastics and the recyclability of the chairs.

The mystery of the missing system

A tendency noticed during the interviews with the furniture manufacturer representatives was that many said they do not take back their products or take responsibility for assuring that they are recycled because there is no system for it. Daae (2021) was asked if this was true, upon which he replied that

> *My expertise is on packaging, so I don't have a full overview over the furniture streams, but depending on the plastic type, there may be recycling possibilities available, but those systems could have been better facilitated to make it easier for manufacturers to understand how they work.*

Rieger said he could not make a clear statement about the issue as the furniture industry is not Fraunhofer's focus. He did however say that he thinks that one with the right investment will be able to find a suitable technology, but that economic viability in the end will determine whether recycling is possible or if the product will be utilized thermally in incineration. So, systems do exist, but there seems to be obstacles that hinder them from being utilized by the furniture industry.

Furthermore, coming from packaging, Daae (2021) explained how that system worked and how something similar is missing in the furniture industry. The way it works for packaging in Norway is that the one who puts the packaging on the market is obligated by law to be a member of an approved Producer Responsibility Organization, such as Grønt Punkt Norge, and pay a fee per kilo of material they put on the market. As Daae (2021) explained “that fee covers the costs to get the circular economy to work”, and at the moment he does not know of anything similar for furniture, so according to him “as the cost of recycling is not covered by a fee paid by the producer, you will probably need to pay to get it recycled.”. Daae (2021) also said that the industry should go together and make sure that there exists collection and recycling systems that “take into account the product groups that industry represents and puts on the market.”. So, it seems that the furniture industry would benefit from some sort of producer responsibility legislation that could advance the establishment of circular systems.

The “easy to recycle” plastics

Another tendency noticed when searching for chairs for this case study was that the majority of recycled plastic chairs are made from PP, with some being made in PE, PET and ABS. Daae and Rieger were therefore asked if there are some types of plastics that are easier to recycle than others. Both agreed that for PP, PE and PET there exists large scale recycling technologies that work pretty well, that is, as both pointed out for mono-material waste. Daae (2021) also said that “there are also many things that you can do to ensure that it cannot be recycled even if you use a polymer that is recyclable.”. None of them could make a statement about recycling of ABS, Rieger (2021) did however say that he thinks ABS might be difficult to recycle mechanically.

The quality problem

One of the biggest challenges identified in the interviews with the furniture manufacturer representatives was the quality of the material. Daae and Rieger were therefore asked if recycled plastic really is of poorer quality than virgin plastics, and if yes, what qualities make it so. They both agreed that with mechanical recycling there will always be a reduction in quality. That reduction in quality comes in part from the recycling process as explained by Daae (2021), the plastic "will have some quality loss in recycling because something happens to the molecular structure when it is heated up which happens at an extruder, which is the last part of the recycling process", but what mainly creates the problem is pollutants present in the waste. Daae (2021) explained this with an example

> *If you have a small piece of PET on a PP chair for instance, that won't necessarily be separated and then that will go into the recycling process as a pollutant that also pollutes the stream, meaning it reduces the quality, it creates problems in the recycling process.*

So, as Rieger (2021) states "as a rule of thumb for conventional mechanical processes, I think you can say the more impurities that are present in the waste, the worse the quality of the recycled material will be.", meaning that the cleaner the material is, the better quality it will have after recycling. Although, with mechanical recycling, there will of course always be some reduction in quality.

However, Daae (2021) also pointed out that there is another problem regarding the quality of recycled plastics, which is that manufacturers are used to having requirement specs when they order virgin plastic, as he explained

> *if you order virgin plastic that is produced from oil, the plastic manufacturer can make it on a specific spec and it's completely uniform, there is no variation and they can for instance give you a melt flow index that is a precise number. You won't get that in a recycling stream because the material you get in will have a certain variation, how much pollution there is, how clean it is and so on, which results in a span.*

Daae also said that many manufacturers are therefore reluctant to use recycled plastic, because they are skeptical to that span, they want specific numbers. So, if they do not get those numbers, they will not use the material. However, Daae (2021) said that they need to instead

> *look into design choices that make it possible to accept a larger span, maybe they need to increase the wall thickness by a few millimeters or add an extra element in the design to make sure that the strength is good enough despite that there is some variation there, and I think that's a maturation process.*

He also pointed out that especially in the furniture industry, where so many products have a substantial wall thickness, that it should be manageable. According to Daae (2021), furniture "is one of the markets where I think you could really use a lot of recycled plastic.".

Rieger on the other hand could understand the struggle especially regarding special needs in the furniture industry such as color or surface quality, which can be hard to achieve with conventional recycling processes. So, he said that it might be true that the quality is poorer than virgin plastic for furniture. However, Rieger (2021) also specified that he thinks the furniture industry *with its high production capacity has, in principle, a great potential for collection of waste or old furniture, because in principle that could be collected with a relatively high degree of purity without mixing it with other post-consumer waste, so you should be able to control how the composition of the waste should be beforehand and then already at collection you can get relatively pure fractions, which in many other cases just is not possible, so I definitely see potential there.*

So, both Daae and Rieger see potential for the use of recycled plastics in the furniture industry.

The sourcing problem

Sourcing was another identified problem regarding the use of recycled plastics in the furniture industry, the manufacturers simply could not find recycled plastic of the quality they need. When asked if this is a real problem, Daae (2021) gave a clear answer, “I think that’s still a pretty real problem.”. As he explained “it’s one thing to find something available at the moment, but it’s another to find a relatively stable stream” (Daae, 2021). As Daae said, for a production company it is crucial to get deliveries, if not production could stop. Furthermore, if there is too big of a variation between deliveries, that could affect the production equipment also forcing production to stop, even if one has designed in a way that takes variations into account according to Daae. Rieger also agreed that sourcing is a real problem especially for the furniture industry, as he said it partly depends on the capacities needed, and the furniture industry probably needs big capacities. So, it can be difficult to find recycled plastics in large capacities that matches the quality needs of the furniture industry.

Furthermore, Daae (2021) said that it generally can be challenging to find players or suppliers in the beginning, however, at the same time,

> *one of the biggest problems in the circular material loop for plastic is to increase the demand for recycled material, so there is a huge surplus of recycled material on the European market and on the global market, where it turns out that some of the material that could have been recycled isn't because you simply aren't able to sell it.*

So there actually is a lot of recycled plastics out there, and recyclers experience a low demand for their recycled plastic product. That is quite contradictory with the fact that manufacturers find it difficult to find recycled plastic. To conclude in the words of Daae (2021) "there is some work to be done to make it easier to in a way lower the barriers for manufactures to use recycled material".

The cost problem

The price of recycled material was also identified as a barrier to using recycled plastics. Not necessarily the cost of the material itself, but the overall costs it involves in regard to spending longer time and more resources on R&D, to successfully implement the use of recycled plastic in furniture. However, the price of recycled plastics was also mentioned by some manufacturers as an issue. Therefore, Daae and Rieger were asked if the price of recycled plastic is in fact higher than that of virgin plastic. According to Daae (2021) "as of today it's probably quite a real issue that quite a few manufactures experience that if they change to recycled plastic, they get plastic of poorer quality at a higher price", and that of course results in companies not using it. Rieger (2021) said it depends on the quality and type of recycled plastic, but that “price is always an issue, most of the time it’s the biggest one”. So, per now using recycled plastic does not seem to be the most cost-efficient solution, especially compared to the quality one gets. Nevertheless, there are furniture manufacturers who do use it.

The color problem

Given that some interviewees claimed that it was impossible to find white PCR plastics, whereas others produce chair with PCR plastics in a white color, all three experts were asked if there are any limitations to what colors one can get with PCR plastics. Daae said that it is possible to find white PCR plastic. He said that it is possible to sort plastics based on color, so one would be able to sort only white plastic. Daae (2021) did however say that he has “no problem imagining that it might be challenging to get hold of”. So, it seems that the issue is not whether it is technically possible to produce white PCR plastic, but it seems to again be a problem related to sourcing. On the other hand, for chemical recycling there are no color limitations. As explained by Rieger, chemical recycling is independent of colors since chemicals are produced from the material and those chemicals are polymerized into new virgin grade plastic that can be mixed with colorants. So chemical recycling is suitable for all colors. The color pigments are not recycled, but one can “achieve the desired color in virgin grade in the end.” (Rieger, 2021). However, Rieger did say that he could imagine that it can be very difficult to get a very clear white color or transparent with mechanical recycling because of the impurities in the material.

The experts were also asked if all colors are suitable for recycling or if there are some colors that are preferred over others when it comes to recycling. Jahren (2021) explained that *all plastics have a color and the further away you are from white, the less choice the designers have about what colors that can be, so that means that transparent or white post-consumer plastic is much easier because you can add pigments to it and color it so it's much easier to handle and will have a great value in the future.*

Daae (2021) also explained this, saying that if you have transparent plastic, for example, you could color it however you would like, so according to him

the less color the better, so transparent is absolutely the best, then comes light colors and preferably light, non-opaque colors so that it's semi-transparent, so white semi-transparent is better than an opaque white, but an opaque white is better than an opaque red.

He also illustrated it with an example

It's like when you paint with watercolors, if you start with white and mix in a little red you get a somewhat pink color, a paler red, but if you add a little more red, you get red. However, if you start with red and then add white, it's much harder to make a white color. (Daae, 2021)

So, to sum up, light colors are preferred over darker and stronger colors because the stronger the color, the more difficult it will be to color it afterwards. That is also why, as Jahren (2021) explained "a lot of products end up being black today because you can always add black pigments and make it black". However, there is an issue with black color, and that is the carbon black pigment which, as explained by Daae (2021) is not read by near infrared scanners (NIR scanners). NIR scanners are, amongst others, used to separate plastic from non-plastic at recycling facilities, so when the NIR scanners does not pick up carbon black, it results in the plastic going to incineration instead of recycling (Daae, 2021). So, it seems that all colors are suited for chemical recycling, but that there are some challenges with some colors for mechanical recycling.

Established truths

Given that Rossi said that the biggest challenge with using recycled plastics mostly was established truths in the industry, Daae and Rieger were asked if they knew of any established truths about recycled plastics that are not true. Daae answered that there are a lot of them, there are many misunderstandings. Rieger said that there are some especially regarding chemical recycling. One established truth is that mechanical or chemical recycling is better than the other (Rieger, 2021). As explained by Rieger (2021), there is no best, it "is very dependent on the application and the material and the whole utilization chain or the product life cycle of the product you want to recycle and both of these processes are illegible and both are needed". Fraunhofer Umsicht's goal is to "couple chemical and mechanical recycling processes for individual waste streams to combine the pros of both technologies at the right points so that you achieve a better recycling process in the end with combined methods" (Rieger, 2021). Another established truth Rieger mentioned was that chemical recycling is not economically viable. As explained by Rieger, that might be true for some waste, such as mono-fraction PP waste because there are established large scale technologies that work quite well for it and that are simply better and more viable. However, for a lot of waste, especially hard to recycle waste like composite materials, that are difficult or even impossible to recycle mechanically, chemical recycling is needed and economically viable (Rieger, 2021).

Is PIR plastic really recycled?

Given that some manufacturers clearly preferred using PCR plastic over PIR plastic, whereas others only use PIR plastics in their products, it was interesting to ask these experts if they would define using post-industrial waste as recycling. Interestingly, Daae and Rieger disagreed on this question. According to Daae, using post-industrial waste is or is not recycling depending on what is meant by it. Daae (2021) said that in his experience, the use of the term can vary.

> *If you by post-industrial mean that you take your own production scrap and put it back into production it is not recycling. Not doing that is idiotic, and some even try to trick the definition by sending their own production scrap to the neighboring factory and vice versa to be able to say it has left the factory gate, but that is not recycling. Of course, you should do that, I'm not saying that you shouldn't use post-industrial in this way, but you can't claim that it's recycling.*

Interestingly, he also said that he "would never recommend anyone to call something recycled material if it is post-industrial as this term often is misunderstood and sometimes misused, and often not understood as recycling by the public opinion." (Daae, 2021). Whereas Rieger (2021) said that "I would define using post industrial waste as recycling because in common literature it is defined as recycling".

Given this disagreement, Jahren (2021) was also asked the same question, to which she replied "Yes, it is absolutely recycling. It is something that would be waste that isn't going to landfill or energy recycling, instead is being put to good use so it is recycling.". However, she also pointed out that "industrial scrap is smaller volumes than post-consumer waste so if we want to get a full functioning circular society, we can't just look at industrial waste" (Jahren, 2021). According to Jahren (2021), "if we can build up systems and processes and value chains around post-industrial scrap then it will open the doors and make it easier to get post-consumer scrap going", so recycling post-industrial waste is a first step, but it will not answer all problems.

Bioplastics – for better or worse?

Whether or not to use bioplastics was also a topic with divided opinions amongst the furniture manufacturers, as some are counting on it in the future whereas others say it does not come close to being as good for the environment as recycled plastics. Daae and Rieger were therefore asked if recycling is better than bioplastics. It should be noted that their answers might be biased by the fact that they both work with recycling and not with bioplastics.

According to Daae, he would recommend recycled plastic over virgin plastic made from renewable sources. He explained that Grønt Punkt Norge is taking part in several research projects that show that there is no reason to believe in biodegradable plastics, so that type of plastic can be disregarded. When it comes to biobased plastics, Daae (2021) explained that

> *it's good for the world that we use more renewable resources and less non-renewable, that is necessary in a circular economy, but I also experience that it's a little misunderstood that as long as it's renewable it will save the world because it is true that we deplete the earth of non-renewable resources, but we are also depleting the earth of renewable resources.*

According to Daae (2021), there is of course an environmental impact associated with recycling too, but that "it is a contribution to closing the loop on a circular economy instead of extracting new raw materials either from renewable or nonrenewable sources". So, using recycled plastic is better because it is a raw material that is already available. Rieger (2021) said that he thinks "bioplastics have potential to substitute plastics from fossil fuels especially for decarbonization and also reducing CO_2 emissions", but since bioplastics are still in development, it might be difficult to use on a large scale as might be needed in the furniture industry. So, it seems that per now, recycling is the better option as there is so much plastic waste, or as one rather should say, plastic resources, in the world that can be utilized to make plastic materials.

Plastic composites – good or bad?

Plastic composite materials were another topic with strong divided opinions amongst the manufacturers. The three experts were therefore asked if plastic composite materials are recyclable or not, and if they are recyclable, whether or not composite materials are more difficult to recycle than pure plastic materials. Daae (2021) made a clear statement to the topic saying that "in general, composites are death, mono-material is the basis for getting recycled material of high quality.". In contrast to Daae, Rieger said that composite materials can be recycled. He did however say that "especially for mechanical recycling it is harder than pure plastics for sure." (Rieger, 2021). With chemical recycling, on the other hand, which Fraunhofer Umsicht focus on, especially for composite materials, it is possible to recycle them. Jahren (2021) said that it depends, because "you can always recycle one composite chair with a hundred mono-material chairs", but that it is more difficult to recycle composites than pure plastic material. As she explained "adding anything to a pure polymer will make it more difficult to recycle, that's a fact" (Jahren, 2021). So, to sum up it is definitely more difficult to recycle plastic composites than pure plastic materials with mechanical recycling, but it is possible with chemical recycling.

The experts weigh in on the chairs

For this part, Daae and Jahren were shown pictures of the chairs together with the different colors the chairs are available in and brief information about what the recycled plastic material consisted of. Rieger was also asked to weigh in on the chairs, but only the ones that are fiber reinforced and the one made of ABS. The Coast bench and the FS Stool were not discussed with the experts as they have not been on the market like the other chairs that are for sale.

AAC ECO 12
30% PIR PP & 70% virgin PP

When shown this chair and asked why they think it is only 30% post-industrial waste, especially because the color is black, so it probably is not due to a color issue, Daae (2021) responded that “depending on the definition of post-industrial, this is possibly a 100% virgin plastic chair”, and that if someone had asked him for advice, he would not even bother to mention that it is 30% PIR plastic. Jahren (2021) said that the reason for only using 30% might be because of mechanical properties, because

> *with recycled materials the quality and the performance of the material can be a little bit iffy so in order to secure that you have a good enough performance from the material, the more virgin you put in it, the safer you are.*

When asked if this chair is recyclable, Jahren (2021) answered, similarly to what Daae pointed out, that “Yes, it should be recyclable, nicely recyclable, it’s virgin basically”. Daae (2021) said that the black color is a little difficult because “it’s little sought after, it’s more difficult to sell recycled, but if you haven’t added anything else to the PP, then it’s 100% PP, so the seat is recyclable”. He also said that there is the question of how easy it is to remove the wooden legs (Daae, 2021). So, all in all, AAC 12 seems to have a virgin quality PP seat shell that is recyclable although not the ideal color for the secondary raw material market.

Revolt
30% PCR ABS & 70% virgin ABS (except the black version, which is 100% PCR ABS)

The black Revolt is 100% PCR, whereas the other eight colors are only 30%. So, as Daae said, it seems that 70% virgin plastic is needed only to get the specific colors, and not because of for instance strength requirements, as it is a well-known phenomenon that you get better colors if you mix in virgin plastic. Daae also said that he thinks HAY should have considered whether those colors are so important that they could not have used 100% recycled plastics for the other colors as well. He thinks that one in the market now would be able to find customers who "will find that some traces of other colors is something that can be in demand and might even be cool because it shows that it's actually recycled" (Daae, 2021). Jahren said that the 70% virgin plastic indicates that it is technically possible to use all recycled, but that it is not commercially possible, that HAY is not able to source it or secure suppliers of the material. She also said that she has never heard of recycled ABS before, and that there is a "relatively small volume of ABS used" (Jahren, 2021).

Interestingly, when asked if this chair is recyclable, given that ABS can be said to contain more problematic chemical substances than PP or PE when melted, they both pointed out that they do not have enough knowledge about ABS to make a clear statement. However, Jahren (2021) did say that whitegoods typically might be more likely to have things like flame retardants in them. Daae (2021) said that in general, toxins "are something you don't want to have going further in any particular degree, so if there are a lot of toxins, that would be problematic.". In terms of disassembly for recycling, Daae (2021) said it was difficult to determine how easy that is based on the picture of the chair, but pointed out that he would

> *question how easy it really is to separate the different materials, because even though it's good that it's 100 % ABS, the seat and back need to be separated from the steel and if that is very difficult, no one will do it, and you need to remove the seat for it to be recycled.*

Furthermore, given that Daae did not know much about ABS because it is typically not used in packaging, Rieger was asked about the recyclability of the material too, to see if he knew more about it. Rieger said that ABS might be difficult to recycle mechanically, but that he believes it to be suitable for chemical recycling, as ABS for example has high quantities of styrene, which is good to recycle in Fraunhofer Umsicht's process.

So, it seems that recycled ABS is not as commonly used as for instance recycled PP, consequently raising the question of how likely it is that the material will be recycled at end of life, if there are not widespread systems for it. As Jahren (2021) explained

> *we're setting up all these systems for the future and although ABS can possibly be technically recycled, to get the commercial systems up and going you go for the big volumes first, the polyethylene and the polypropylene, and ABS is a material that's quite low volume so I wouldn't expect it to be one of the first volumes that end up being recycled.*

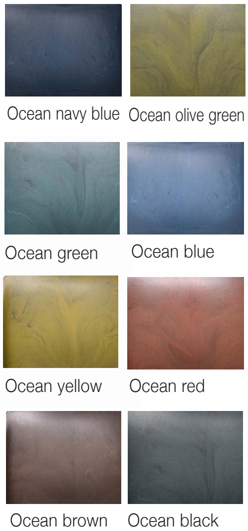
So, all in all, Revolt seems to at least be theoretically recyclable.

N02 Recycle
95% PCR PP & 5% color pigment

According to what was discussed with the experts regarding the possibilities of colors with PCR plastics, it should be possible to make the white version of N02 Recycle with 100% PCR plastic, as Daae said he has no basis for doubting that. Furthermore, he said that this chair is recyclable. Based on the information given about it, Daae (2021) would give this chair “a good recyclability score.”, that is of course if it is easy to remove the steel legs. Then the legs would be recycled with metal and the plastic seat would be recycled with plastic. Jahren (2021) also agreed and said that this chair would be “fairly well recyclable in a pretty standard mechanical recycling system.”. It looks, as Jahren explained, pretty straightforward, except for the pigments, because it is a mono-material. She did however say that she is not sure how the fact that it has already gone through one recycling loop would affect the properties, because

> *you can only recycle plastics maybe nine-ish times as a rule of thumb, so at some point the quality is going to be degraded too much to make it of any use anymore, it has lost all its mechanical properties and so on. (Jahren, 2021)*

So, all in all, N02 seems to be recyclable.



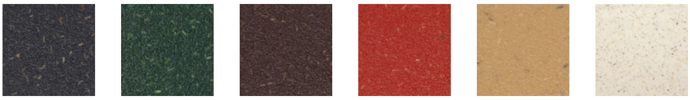
S-1500
100% PCR PP

When it comes to the Snøhetta design and whether or not it can be recycled, Daae (2021) said that "There's no reason to believe that it is problematic to recycle this. Again, the strong colors are more difficult to sell, but it is recyclable.". He also said that he is "under the impression that this is a very good example." (Daae, 2021). Furthermore, Jahren also said that this chair can be recycled, but that it might be difficult to color afterwards. However, she also pointed out that the tolerance for different colors ranges from application to application, and that there are many opportunities because the plastic "doesn't have to stay within the furniture industry" (Jahren, 2021). All in all, S-1500 seems to be recyclable.

Alfi
80% PIR PP, 20% wood fibers

Alfi is reinforced with wood fibers, so it is one of the much-debated plastic composite chairs. When Jahren (2021) saw Alfi, her first response was that "This is a great example of why we need harmonized standardization across the industry, right?". She further went on to explain that if you are mechanically recycling plastic, you heat it up and melt it and typically make it liquid, and in that thermal process at high temperatures, wood would start degrading and loose some of its properties and funny things would happen (Jahren, 2021). The wood would become an additional contaminant that, according to Jahren (2021), "will make it slightly more difficult to use the plastic material the next phase.". However, she also said that she is a polymer chemist and could take Alfi and recycle the chair in her lab, so it is possible to do. Nevertheless, Jahren (2021) emphasized that the definition of whether something is recyclable or not is that there is "a system for it to go into". So, just because the material is recyclable in the lab, does not mean that it is recyclable in the real world, but as Jahren (2021) also pointed out, "just because there isn't a system today doesn't mean there's not a system tomorrow, so it's really tricky.". It is also worth mentioning that Jahren (2021) said that in terms of including wood fiber, she is "not a fan", as she thinks that it "dirties the material flows".

Furthermore, according to Daae, this chair probably cannot be recycled, as he at least is not aware of any recycling stream that can recycle PP with wood fibers. Jahren also shared this view, saying that the chair would probably be used for energy recycling. At worst, according to Daae, if this chair would end up in a recycling facility, the NIR scanner would scan it as PP and it would go through and the wood fibers would contaminate that fraction, which makes the quality of the recycled material poorer, and as Daae (2021) said "at worst so poor that they just dispose of it and that it consequently pollutes a lot of pure PP that otherwise could have been recycled if it had not been mixed with a chair with wood fiber". According to Jahren (2021), the chair could be recycled



DARK GREY GREEN DARK BROWN RED SAND WHITE

because you could always add a bit of contaminated material, but that it would have to "go in with say 90% of homogeneous material from another source and then just a little bit of these chairs".

Rieger could not make a clear statement about whether Fraunhofer Umsicht would be able to recycle PP with wood fiber because they have not yet investigated it. He did however say that the material can have potential for chemical recycling. If chemically recycled, the wood would not be recovered as it is organic material that would be broken down in the process (Rieger, 2021). Rieger did however say that it might be possible to recycle using a combination of mechanical and chemical recycling where the wood could be separated from the plastic before the chemical recycling process. Nevertheless, he could not say when it might be possible to recycle wood fiber reinforced plastics chemically on an industrial scale. So, all in all, it seems that it is difficult to recycle this chair mechanically and that it has not been investigated enough yet whether it can be recycled chemically.

On & On
70% PCR PET, 20% glass fibers & 10% non-toxic pigment

According to Jahren (2021), On & On should be easier to recycle than Alfi because "technically glass fibers are much better to recycle than wood fibers". Glass fiber is a bit more stable, the fiber basically stays as glass fibers at the 200 degrees it takes to melt the plastic (Jahren, 2021). However, as Jahren (2021) said, "it's still a contaminant and if you want to recycle it not in a closed loop, you would have to remove the glass fibers or find an application that wants the glass fibers in", so the glass fibers "just makes another additional complication in the recycling route". Furthermore, Daae said that the chair probably is not recyclable because of the glass fibers, so it will probably either be incinerated or landfilled, depending on the country. He also said he hopes Emeco has not used recycled bottle PET for this chair because there are now manufacturers that want to buy recycled bottle PET to make new bottles, but they cannot get hold of recycled PET because it is starting to be extensively used for other purposes.

Rieger, on the other hand, said that Fraunhofer Umsicht can recycle glass fiber reinforced plastics, and he even explained how it is done. So, glass fiber reinforced plastic can be chemically recycled. The result of that recycling process is a solid residue comprising the glass fibers and an oil fraction which is the main product that can be refined by different methods to get chemicals from it, and from those chemicals it is possible to produce virgin grade plastics (Rieger, 2021). According to Rieger, the recycling also yields a gas product, that can be utilized to provide energy for the process. So, the glass fibers and plastic material are separated. The glass fibers can also be reused, however for now they are downcycled in the process, according to Rieger (2021), who said that "upcycling is possible for the plastic part, but not for the fiber part".

He explained that for a chair, the plastic can be recycled very well, but he could not assure that the fibers in the end would match the needs to produce a new chair from those fibers as the fiber quality will decrease with the process. Rieger also said that there are already commercial scale plants that can recycle glass fiber reinforced plastics. So, it seems that fiber glass reinforced plastic can be chemically recycled but is difficult to recycle mechanically, and that also applies to the On & On chair.

Costume
99% PIR PE & 1% color master

Costume is fairly straightforward to recycle according to Daae and Jahren, as long as it is easy to disassemble. The PU foam is not recyclable as of today, and according to Jahren (2021) there is also “no great solution for recycling of fabrics on scale”. The core is, however, recyclable, as Daae (2021) says “if it’s 100% PE, then this chair will be recyclable.”. So, all in all, the core of Costume seems to be recyclable.

The Bell Chair
77% PIR PP, 20% glass fibers & 3% color master

The Bell chair has some dots in the color, so Daae and Jahren were asked if they had any theory as to why that might be, given that chairs made from PCR plastic, which usually has more impurities, do not have anything similar. According to Daae and Jahren it could simply be because it is a mix of different colored products or plastics with different melting temperatures. Jahren also pointed out that composites could get some surface effects, also some unlucky ones, like more air bubbles or slightly different surface structure.

In regard to whether this chair can be recycled at end of life, there were divided opinions between the experts. Daae (2021) said that he does not think so because of the glass fibers, he would say that “they’ve closed the loop, that the next cycle for this chair is in the incinerator”. However, he did also emphasize that glass fiber is not used in packaging so he is not completely sure if there exist any technologies that could remove the glass fibers. Jahren (2021) also said that it would probably be used for energy recycling, at least in Norway, where “even a pure PP chair couldn’t be recycled now.”. When told that Magis says the chair can be recycled 1:1 into a new Bell chair, Jahren (2021) said “that’s the typical example, yes, we could recycle it in theory but in practice it cannot happen, no”.

Rieger, on the other hand, said that recycling glass fiber reinforced plastics is possible, it is the same as for the On & On chair, that the plastic could be recycled into virgin quality, but the glass fibers would be downcycled. So, all in all, the chair is probably chemically recyclable, but difficult to recycle mechanically.

Capisco Puls limited edition with snow plough markers
100% PCR PP (with some color pigment)

This chair is, according to Jahren, recyclable because it is more or less mono material. Daae (2021) also agreed that it is recyclable, but also said that “the color isn’t optimal because of the strong color, which is difficult to recolor, so the aftermarket isn’t optimal”. So, as Jahren (2021) explained, what it could be used for after recycling, is ”anything in a different shade of red”. Daae also pointed out that the chair of course only is recyclable if one can separate the different materials, which was hard to tell based on the picture shown. All in all, the plastic material used in the chair seems to be recyclable.

Recycled material – go your own way or with the flow?

Given that some manufacturers develop their own recycled materials, Jahren and Daae were asked whether they perceive it is a good or bad solution. Daae said that he would encourage those companies that use glass or wood fiber and say that the plastic material is recyclable to have a takeback system and make sure that it works. Daae (2021) did however point out that he thinks "it's a little stupid that you need to use take-back systems and that it doesn't work in other systems", but at least they have control of the material. Furthermore, Jahren (2021) said that

> *it's a bit chicken and the egg, do you make the materials first or do you make the recycling system first? and it's better that designers are laying the foundation to that this material could be recyclable and then hopefully when the recycling systems are being upscaled and capacity is being built [...] then the chairs are ready to go in.*

She also said that the problem today is that manufacturers are working a bit blind, "all these companies are doing their best to design for recycling without knowing what the recycling is going to be looking like" (Jahren, 2021). So, the problem is, according to Jahren, that manufacturers are trying to design for a system that is not yet built.

Chemical VS mechanical recycling

Daae said that chemical recycling is being talked about a lot these days, but that one currently is working on being able to achieve chemical recycling on an industrial scale. Rieger, on the other hand, working with chemical recycling, is more positive to the technology. Rieger said that the technology is promising, especially for plastics that are hard to recycle mechanically, such as composites or for waste with high impurities.

Regarding furniture, Rieger said that they have not investigated it, but that chemical recycling could be advantageous for products that have a high grade of mixing of different materials. When asked when he thinks that chemical recycling will function side by side with mechanical recycling on an industrial scale, Rieger said that it is difficult to say.

Energy insensitivity is a topic with chemical recycling. When asked about how energy intensive it is in difference to mechanical recycling, Rieger responded that chemical recycling is more energy intensive than mechanical recycling. However, Jahren (2021) said that energy use is often seen as “the nail in the coffin for recycling”, but that keeping resources in a loop is a bit separate from energy use and that you could say that “okay we use energy, but we don’t create litter”. According to her, one needs to look at the bigger system and not just one recycling process.

Jahren (2021) also sees chemical recycling as a solution that could function side by side with mechanical recycling, as she said that there is “not a one size fits all solution” when it comes to recycling. She agreed with Rieger, saying that she thinks that chemical recycling will “have a place for hard to recycle materials” (Jahren, 2021). Jahren explained that chemical recycling could be used to recycle materials that have been recycled mechanically too many times, so the quality has been reduced. One could then “use chemical recycling to take it back again so that we can get back to the constituent parts and start that cascade again” (Jahren, 2021). As explained by Jahren, every time you recycle plastic, you end up adding a new additive package, such as colors, and “the more you add the more contaminant it is”. So, chemical recycling might provide a good solution because you can then remove the contaminants, such as pigments and other additives (Jahren, 2021). All in all, it seems that the two recycling technologies both have challenges, but that they could work well together to close loops.

Concluding observations: Keep it light, keep it clean

It is clear that the experts' answers are colored by the different recycling technologies that they work with, and that is why they on some points have different opinions. In theory, everything is chemically recyclable, it is just not working on an industrial scale yet. Mechanical recycling on the other hand, is working commercially, but the technology has its limit in regard to what it can recycle. However, for mechanical recycling, which is used to recycle products in the real world today, there seems to be some measures that can be taken to ensure recyclability. To sum up, it seems that mono-materials are recyclable and that the lighter the color, the easier it is to find an application for the recycled material after recycling. So, pure plastic materials are definitely recyclable, that is if there is a system for it to go to, which seems to be the biggest issue, and a difficult one to solve through design alone, because, to put it in the words of Jahren (2021), "you're designing for a future that isn't decided".

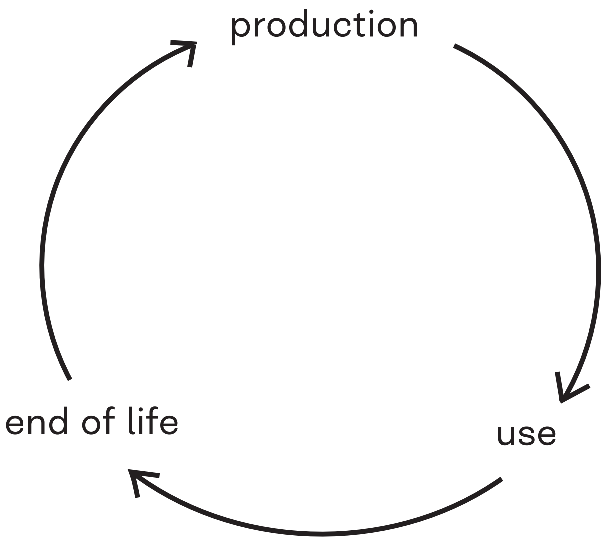
Comparison

Method

The premise for the chairs used in the case study was that they, according to the manufacturers are produced with “recycled” material and are “recyclable” at end of life. However, through interviews with experts, it was uncovered that it is not necessarily true for all the chairs. So, in light of that new information combined with the information from the manufacturer interviews, it seemed beneficial to compare the chairs as a means to compare different ways of using recycled plastics and of using them in such a way that they may or may not be recyclable. In this way, it would be possible to form a picture of which solutions work well in terms of circularity. These chairs are, however, so different that they are not necessarily comparable. The chairs do nevertheless serve to show a variety of different approaches to circularity. So, comparing them would shed light on what approaches have resulted in circular products, and what resulted in yet another linear product.

Comparing these chairs would be like comparing apples and pears. Therefore, after discussion with Diez, it was decided to not use a scientific method to compare them, such as for example LCAs, because the intention of this comparison is not to compare numbers in terms of environmental impact, but to compare to see what approaches or strategies, manifested through these chairs, seem to work to advance the transition to a circular economy. So, the goal is to do a more qualitative assessment of the chairs. The approach to comparing these chairs has therefore been to be more creative, “nonscientific” and pragmatic.

For the comparison, it was important to cover the entire life cycle of the products to see how circular they are. However, it was also important to not make it too complicated. It was therefore decided with Diez that the comparison should focus on the three life phases of production, use and end of life. In production, the focus was on what material is used to produce the chair. In the use phase, the focus was on circular initiatives to extend the life of the product. At end of life, disassembly and recyclability were focused on.



All standard questions that were asked the manufacturer representatives about the chairs, together with the answers for each chair were placed in a spreadsheet. From that spreadsheet, key topics and information were extracted and put into a new simplified spreadsheet that served as an overview with the most important information for the comparison. This spreadsheet can be seen on the next 2 pages. Not all manufacturers present the information about the chairs in the same manner, causing there to be some blank spaces in the spreadsheet.

Furthermore, to actually compare the chairs, they were grouped together in different combinations based on similar traits, and the chairs grouped together were compared to find similarities and differences and observe which chairs seem to be more exemplary. In the beginning, few chairs were compared, either 2 or 3 chairs at a time, and eventually bigger groups of chairs that had something in common were compared and the chairs were also in some cases divided into two groups for comparison.

It should also be mentioned that it was intended to visit some interior stores to inspect the chairs in real life before conducting the comparison. That was, however, unfortunately not possible because all stores were closed due to the lockdown in Vienna.

	PIR VS PCR	Color pigment	% recycled content	Type of plastic	Source of waste	Fiber reinforce-ment	Other materials	Disassembly	Environ-mental label
AAC ECO 12	PIR		30%	PP	Own production waste	none	Solid oak wooden base	6 screws, remove bushings & glides	EU Eco-label
Revolt	PCR	70 % virgin plastic	30 % (black = 100%)	ABS	White goods	none	Steel base	6 screws, re-move glides, bumpers, washers	EU Eco-label
N02 Recycle	PCR	5%	95%	PP	Household waste	none	Steel base (50% re-cycled)	Screws	EU Eco-label
S-1500	PCR	none	100%	PP	Fishing nets, ro-pes & pipes from fish farming	none	Steel base (20% re-cycled)	4 screws	EPD
Alfi	PIR		80%	PP		20 % wood fiber	Ash wooden base	Screws & re-move glides	none
On & On	PCR	10%	70%	PET	PET bottle col-lection	20 % glass fiber	none	Remove stack bum-per, glides & seat	none
Costume	PIR	1 % color master	99%	PE	Own furniture parts + automoti-ve industry	none	Pocket springs, PU foam & textile cover	Remove connectors & elastic loops, separate materials	none
Bell Chair	PIR	3 % color master	77%	PP	Own furniture parts + automoti-ve industry	20 % glass fiber	none	none (mono-bloc)	none
Limited edition Capisco Puls	PCR	some ‰	≈ 100%	PP	Snow plough markers	none	Alumi-num, steel, PU foam & textile	Seperate base, gas lift, seat, back-rest, cushion & fabric	EPD(for regular Capisco Puls)
The Coast Bench	PCR	none	100%	HDPE, PE, ABS & PP (not mixed)	Ownerless ocean plastic	none	Steel base		

Carbon footprint	Warranty	Life expectancy	Number of different colors	Different models (bases, seats, armrests etc)	Take back system	Recyclability	New VS redesign	Year launched
	5		1	Armchair or stool	No	Yes	Redesign	2020
	5		9	no	No	Yes	Redesign	2020
	5	Test for 10 years, can last longer	7	4 legs, sledge base, swivel base with or without castors & armchair	No	Yes	New	2019
9 kg CO_2e	5	at least 100 years	8	Sledge base or 4 legs	Working on it	Yes	Redesign	2019
19 kg CO_2e	5	Close to 20 or longer	6	Ash, dark ash or aluminum base. High, low back or armchair	Can take it back if someone asks	Probably not 1:1, recycling in house	New	2015
17 kg CO_2e	5		6	Plywood seats (ash, oak or walnut), upholstered leather or upholstered fabric seats	Can take it back if someone asks	Recycling in house	New	2019
	2	All components can be replaced --> life extended	1	Different textiles & color of connectors, pouffe & armrests	No	Yes, except PU foam & maybe fabric	New	2021
	2	15-20 years	3	no	No	Theoretically possible to recycle 1:1	New	2020
39.4 kg CO_2e (for regular Capisco Puls)	10	Easily 20 years	1	2 different textiles & 2 bases	Can take back	Yes, except PU foam	Redesign	2021
	Do not know yet	Do not know yet		no	Yes, leasing	Yes	New	2020

The glass fiber reinforced

The Bell Chair and On & On have in common that they both are new designs with 20% glass fiber reinforcement. The dark and strong colors both are available in are not beneficial for the aftermarket after recycling, that is if they were to get recycled, because it is difficult to recycle glass fiber reinforced plastics mechanically. Fewer colors might be better in terms of not having so many colors mixed in recycling, so Magis' three colors might be preferrable to On & On's six different colors. Furthermore, PCR plastic is to be preferred over PIR, but if that is bottle PET used for On & On that could have been used for closed loop bottle recycling it is not beneficial either.

In theory, a monobloc chair is good to recycle because it does not need to be disassembled. So, in terms of preparing the chair for recycling, the Bell Chair might be better than the On & On where the stack bumper and seat need to be removed. However, the fact that On & On is offered with different seats makes it more fit for longer use, because it can be replaced if it breaks or one simply wants to change the appearance, in difference to a monobloc chair like Bell, which will always remain the same. On the other hand, one could also argue that it might not be good to offer different seats, especially with PU foam that cannot be recycled, because it makes the chair more complex in terms of recycling. At last, On & On has a three year longer warranty than the Bell chair. All in all, it is difficult to say if either one of these chairs is better than the other. What can however be said is that they both are difficult to recycle mechanically because of the glass fibers.

The composites

For this comparison, Alfi has also been included, together with the glass fiber reinforced chairs as all three chairs have in common that they are made from plastic composites. Like the glass fiber reinforced chairs, Alfi also comes in different colors, out of which the majority are dark and strong colors. What separates Alfi from the two others is different fibers, but also that Alfi has a base made of another material so that it might be easier to disassemble Alfi for transportation for reuse, refurbishment or remanufacturing. However, as mentioned previously, in terms of recycling, Bell chair would be easier to recycle as it needs no disassembly. According to the experts, it seems that the glass fiber reinforced chairs, in theory, would be easier to recycle than Alfi, as wood fiber reinforced plastics as of today do not seem to be recycled. So, all in all, what can be said about the composites is that glass fiber reinforcement, at least in terms of recyclability, in theory might be slightly better than wood fibers, but all composite chairs have in common that they are difficult to recycle mechanically, or at worst are not recyclable.



The steel base

Revolt, N02 Recycle and S-1500 have in common that they all have a steel base, they are all made with PCR plastics, and all have a five-year warranty. S-1500 and Revolt are redesigns, whereas N02 Recycle is a new design. Revolt is made from ABS and consists of both a backrest and a seat, in difference to N02 Recycle and S-1500 which are both seat shells made from PP. S-1500 and N02 Recycle both also have recycled steel in the base, N02 Recycle has the highest content of recycled steel. In terms of disassembly for recycling, Revolt is probably a bit more tedious to disassemble than N02 Recycle and S-1500. Furthermore, S-1500 stands out from the others because of the innovative marbling pattern that makes each chair unique, a factor that theoretically could possibly result in emotional attachment to the product because the user knows that their chair is one of a kind, which in turn could lead to the product being used longer. S-1500 is also said to last 100 years in difference to N02 Recycle which is tested for 10 years use, but can last longer, and Revolt for which there is no estimated lifetime.

All chairs have recycled plastics sourced from different sources, Revolt is from white goods, N02 Recycle from household waste and S-1500 from the fish farming industry. Household waste is a source that one might expect to be recycled, so one might argue that it is not that "groundbreaking". Regardless, it is close to being actual trash, and is a source of waste that should be utilized. White goods are bulky waste, a problematic waste stream that is often landfilled or incinerated, so it is also a source that is close to being actual trash. The fish farming equipment might be a more controlled stream, since it is post-consumer waste from an industry instead of from households but would also have ended up as waste had it not been used for this chair. So, it is difficult to assess if one of these sources is better than the other.

Furthermore, what all have in common is that they come in different colors. S-1500 comes in eight dark or strong colors, however it should be said that S-1500 is the only chair in the comparisons that does not add any additives, that also means no colorants. N02 recycle comes in seven different colors, out of which most are also dark or strong colors, and Revolt comes in nine different colors, also with the majority in strong or dark colors. So, most of the colors are not necessarily the best for application after recycling, except for some colors on Revolt or N02 Recycle that are lighter or even close to white. For Revolt, all colors except from the black Revolt, consists of 70% virgin plastics in contrast to S-1500 and N02 Recycle, where all colors are 100% and 95% PCR. So, in terms of closing the loop by using recycled plastics in production, N02 Recycle and S-1500 are better. All three chairs are recyclable at end of life, although ABS does not seem to be recycled on a large scale like PP. So, all in all, it seems that N02 Recycle and S-1500 overall are better suited for circularity as all different color-versions are made from 100% PCR plastics, and from a type of plastic that is widely recycled.

It is however difficult to determine if N02 Recycle or S-1500 is a better example. S-1500 uses no additives and has an innovative aesthetic, but the dark and strong colors are not that well suited for application after recycling. That does however seem to be the tradeoff if one wants different colors without adding any additives. Whereas if one takes the white N02 Recycle, it would be very well suited for application after recycling, but all the other colors the chair comes in, that are not optimal for the secondary raw material market are more questionable. So, one could maybe say that the dark and strong colors in S-1500 can be justified because it refrains from additives that make recycling more difficult, whereas if one finds a good source of PCR plastic that can make a white color like the one in N02 Recycle one should refrain from adding pigment to make dark or strong colors that make the material less sought after in the secondary raw material market. So, it seems that the use of additives should be adapted to the waste source used, to keep the plastic material circulating at highest value.

The wooden base

AAC ECO 12 and Alfi have in common that they both consist of seat shells that contain PP attached to a wooden base, and they both also have a five-year warranty. A difference between the chairs is that Alfi is a new design and AAC ECO 12 is a redesign, and Alfi has an estimated lifetime of closer to 20 years or longer, whereas there is no estimate for AAC ECO 12. Another difference is that AAC ECO 12 is only available in one color, black, whereas Alfi is available in six different colors. The biggest differences, however, are the percentage of PIR PP and the fact that Alfi is a composite seat shell whereas AAC ECO 12's seat shell is made of a mono-material. Alfi has a higher PIR content, which is good in terms of using more waste materials to close loops. However, AAC ECO 12 is much easier to recycle than Alfi because it is a mono-material plastic. As the experts said, the plastic material in AAC ECO 12 is essentially virgin PP, which is easy to recycle in difference to Alfi, which with currently available technologies is probably not recyclable. So, to conclude, none of the two chairs are perfect. AAC ECO 12 is recyclable, but essentially only uses virgin material, which will not close loops. Alfi, on the other hand, does use more waste materials, but is most likely not recyclable at end of life, which will also not contribute to closing any loops.

The different bases

For this combination, the wooden base chairs and the steel base chairs are compared, and they all have a five-year warranty. The HAY chairs have no expected life span, N02 Recycle can last 10 years or longer, Alfi can last around 20 years, and S-1500 can last at least 100 years. Two of the different base chairs are new designs and three are redesigns. Capisco Puls is not included in this comparison because it is a more complex product consisting of more parts and more different materials. So, all the seat shells are made from PP except Revolt, which is made from ABS and is also the only one that consists of two plastic parts and not one seat shell. It is also worth noting that the two chairs from HAY have the highest virgin plastic content out of the chairs with different bases, except for the black Revolt which is 100% PCR ABS.

Furthermore, there is the question whether wood or steel is the best option in terms of both environmental impact and circularity. An argument for steel could be that, like plastic, steel also goes into a technical cycle, so the entire chair would be recycled in technical loops. However, wood is a renewable source, that could possibly be more environmentally friendly, but would go into a biological cycle. The steel base chairs all use PCR plastics, whereas the wooden base chairs use PIR plastic, and one of the wooden base chairs, Alfi is also a difficult to recycle composite. All in all, the steel base chairs, which all use PCR plastic, seem to be better in terms of using recycled plastic that is closer to being actual waste, and they are also all recyclable at end of life.


The complex ones

For this combination, the new design Costume and the redesigned limited edition Capisco Puls are compared because they are the most complex chairs used as they also include materials such as PU foam and fabrics. To first state the obvious, one is a sofa and the other one is an office chair, so they are intended for different uses and are thus also constructed differently. Furthermore, Costume is the only chair out of the ones used in the comparisons that is rotationally molded.

Another quite big difference worth pointing out is that Costume only has a two-year warranty in difference to Capisco Puls which with its ten-year warranty has the longest warranty of all the chairs in this case study. Costume is however built to have its life extended because all parts are replaceable, and can therefore, in theory, be used indefinitely. Capsico Puls also has a good life span of easily 20 years, and is also built for parts to be replaced. So, although both are complex, they are made for dis- and reassembly. The biggest difference, however, is how much the product can be changed. Parts can be replaced in both, but there are limited possibilities for changing the appearance of Capisco Puls in difference to Costume. One could maybe change the swivel base and the fabric on Capisco Puls, but the auburn color of the plastic will remain the same. Costume is different because the plastic part is just the core so the entire appearance can be changed by changing the fabric, and alternatively also the connectors.

Costume is made from post-industrial waste, whereas Capsico Puls is made from PCR plastic that would otherwise be incinerated, so the environmental impact from these chairs in terms of sourcing is quite contrasting. The limited edition Capisco Puls and Costume are both recyclable, at least the hard plastic and metal parts. The PU foam is not recyclable as of today and fabrics can also be challenging to recycle. Both are, however, made from polyolefins, which are widely recycled. Costume is essentially 100% virgin PE, whereas Capisco Puls is made from PCR PP. Furthermore, both are dark in color, so the aftermarket after recycling is not optimal. All in all, in terms of using waste materials, Capisco Puls is the more circular one, however in terms of the use phase, Costume is more inclined to be used long because it is designed to adapt to a change in taste. So, it seems that both are made with circularity in mind, made for recycling at end of life. However, besides focusing on end of life, it seems that Capsico Puls focuses more on the production phase in terms of using waste materials, whereas Costume is more focused on the use phase in terms of extending life.

The ones with a carbon footprint

For this combination, the chairs can be compared a bit more scientifically because they are in fact compared based on kg CO_2 equivalent. However, not all manufacturers have measured the carbon footprint on their chairs, so unfortunately not all chairs can be compared. The ones that can be compared are the two Emeco chairs and S-1500, all measured from cradle-to-gate. The regular Capisco Puls also has a measured carbon footprint, but that might be different than that of the limited-edition version, it is therefore not included. Besides, the carbon footprint for a regular Capisco Puls is also double, if not triple of that of the others, and that might also be connected to the fact that this is a more complex chair containing multiple materials, so it is not suited for comparing with the other "simpler" chairs.

The two new designs from Emeco have quite similar carbon footprints. Alfi has the highest carbon footprint of 19 kg CO_2e, and the On & On chair has a carbon footprint of 17 kg CO_2e. So, there is not a big difference in the footprint between a glass fiber reinforced chair and a wood fiber reinforced seat shell with a wooden base. Contrastingly, redesign S-1500 has by far the lowest carbon footprint with its 9 kg CO_2e, which is more or less half of the carbon footprint of the composite chairs. It is difficult to determine why that is, but it is at least interesting to see that the mono-material seat shell with a steel base and no additives has a lower footprint than two plastic composite chairs that are also noticeably more difficult to recycle. So, it seems that S-1500 is the better example based on carbon footprint.

The ones with the EU ecolabel

The chairs from the danish manufacturers all have the EU Ecolabel, that is the two redesigned chairs from HAY and the new design N02 Recycle. They all have a warranty of five years and are made for disassembly. Two of them, AAC ECO 12 and N02 Recycle are made from PP, whereas Revolt is ABS. Furthermore, Revolt and N02 Recycle both have steel bases, whereas AAC ECO 12 has a wooden base. However, what is the most interesting, is that AAC ECO 12 with its 30% PIR plastic qualifies for the same ecolabel as N02 Recycle with its 95% PCR plastic. So, the EU ecolabel makes no distinction between a chair with 95% PCR plastic and one that essentially is a virgin plastic chair. This comparison resulted in saying more about the shortcomings of the EU Ecolabel than about the chairs, but it was an interesting discovery, and one that will be further investigated after the evaluation of each chair.

The PPs

These are the chairs that in theory, since they are made from PP, one of the plastics for which there exists large scale commercial technologies, should be quite easy to recycle. The chairs containing PP are AAC ECO 12, N02 Recycle, S-1500, the limited edition Capisco Puls, the Bell chair and Alfi. All of them are offered in some dark or strong colors that are not that sought after in the secondary raw material market. S-1500 is the only PP chair without colorants added to the plastic, in fact the only one without any additives. Half of them are new designs and half are redesigns. Furthermore, half of the PP chairs have a metal base and one third has a wooden base, Bell is the only PP chair made only from a plastic material. It may be worth noting that Capisco might take a bit longer to disassemble than the other chairs, but since it, unlike the others, is an office chair and therefore more complex, the aspect of disassembly is not really comparable. Capisco Puls however has the longest warranty, and the Bell chair has the shortest warranty, all the others have a five-year warranty.

In terms of waste source and recyclability, one third of the PP chairs, the Bell chair and Alfi, are both made from post-industrial waste and are difficult to recycle because they are fiber reinforced. Whereas, two thirds of the PP chairs, AAC ECO 12, N02 Recycle, S-1500 and the limited edition Capisco Puls are all recyclable because they are made from mono-materials. AAC ECO 12 is the only one of the mono-material PP chairs that is not close to using 100% PCR waste, in contrast, it is essentially virgin PP, using only 30% PIR waste. The three chairs that are made from PCR mono-material plastic and are recyclable, N02 Recycle, S-1500 and the limited edition Capisco Puls all originate from different waste sources. N02 Recycle has sourced waste from households in difference to the two Norwegian chairs that use post-consumer waste that is equipment used by industry or institutional facilities. It is however difficult to determine if any of the two approaches is better than the other, as they are all sources of waste that if not utilized for these chairs would be incinerated or landfilled. So, all in all, N02 Recycle, S-1500 and the limited edition Capisco Puls prevail as the best examples amongst the PP chairs as they use close to 100% PCR plastic in production and are recyclable at end of life.

The other plastics

This comparison was done to compare the remaining chairs that are not made from PP. That is Costume, Revolt and On & On which are all made from three different types of plastics. Costume and On & On are two new designs made from PE and PET, two types of plastics for which there exists closed loop recycling systems. However, with the glass fibers added to the PET in On & On, it is difficult to recycle. Whereas the core of Costume essentially is virgin quality PE that is easy to recycle. ABS, which is used in Revolt is a plastic that is less frequently used and therefore not as commonly recycled as the two others, although recyclable. Furthermore, Costume is the only one that uses PIR plastic, the others use PCR plastic, which is preferable, but only if recyclable. These chairs have in common that they are different, so it is difficult to draw any conclusions. However, the black Revolt is a good example in terms of using 100% recycled PCR plastic and being recyclable, but that is not the case for all the other colors, which contain 70% virgin material. Furthermore, Costume is a good example of a chair that is both recyclable and made for extended use, although it is the one with the shortest warranty out of the three.

The PCR plastics

All chairs either fall into the category of being made from PCR plastic or PIR plastic. Given that for so many of the comparisons PCR plastic versus PIR plastic has been a topic, the chairs within the two categories were also compared. The chairs made from post-consumer waste are the three redesigns Revolt, S-1500 and the limited edition Capisco Puls and the two new designs N02 Recycle and On & On. All the PCR chairs have a five-year warranty except from the limited Capisco Puls, which has a twice as long warranty. All PCR plastic chairs are available in some colors that can be difficult to find an application for after recycling. N02 Recycle, S-1500 and the limited edition Capisco Puls are all made from PP, Revolt from ABS and On & On from PET. On & On is the only PCR plastic chair without metal legs. It is also the only one that is made from a composite material, making it substantially more difficult to recycle mechanically. All the other PCR chairs are recyclable because they are mono-material plastics.

All the different PCR plastics are made from different sources of waste. Revolt is made from white goods, N02 Recycle from household waste, S-1500 from fish farming equipment, On & On from PET bottles and the limited Capisco Puls is made from snow plough markers. There might however be some resemblances between some of the waste sources. The fish farming equipment and the snow plough markers are PCR sources of waste from industrial or institutional facilities, in difference to PET bottles and household waste, and probably also white goods, which is waste from private consumers. It is difficult to say if one source is better than the other, other than that using PET bottles that could be used for closed loop bottle recycling instead, might be a bit problematic. Once again, it seems like the three PP chairs S-1500, the limited edition Capisco Puls and N02 Recycle are the best at using the highest content of PCR plastic, unless you only count the black Revolt. Furthermore, since ABS is not as commonly recycled as PP, it seems that S-1500, N02 Recycle and the limited Capisco Puls serve as the better examples, at least in terms of utilizing existing recycling infrastructure.

The PIR plastics

The PIR plastic chairs are AAC ECO 12, Alfi, and the two chairs from Magis. All the PIR plastic chairs are made from PP, except Costume which is made from PE. So, all PIR plastic chairs are made from polyolefins, but from different waste sources. Most of them use their own production waste, but half also use waste from the automotive industry. Half are made in one piece of plastic and the other half have wooden bases. Furthermore, half of them are fiber reinforced. Interestingly, there seem to be more chairs that combine PIR plastic with fiber reinforcement, which is contrasting to the fact that most interviewees said that PCR plastic has the biggest issue with structural fragility, and that is why one would need to add fibers to it or would have to use PIR plastic. In addition, half of them have a two-year warranty and the other half a five-year warranty. It is interesting that overall, the PIR plastic chairs have a lower warranty than the PCR plastic chairs, given that one of the biggest issues with PCR plastic was its quality and to make it durable enough. Only AAC ECO 12 is a redesign, the rest are new designs.

In terms of color, they all are available in some colors that are challenging to find an application for after recycling. However, AAC ECO 12 and the core of Costume are recyclable as they are essentially black virgin quality plastic. Bell and Alfi are, on the other hand, difficult to recycle because they are fiber reinforced. In terms of recycling of the entire chair, AAC ECO 12 might be the best, as the PU foam and fabric on Costume are difficult to recycle, if not even unrecyclable. However, Costume has the highest content of PIR waste, followed by Alfi, in contrast to AAC ECO 12, which has the highest content of virgin material. So, if one only looks at the core of Costume in terms of recyclability and use of waste material, that might be the best example, also given what has already been mention in regard to the design for extended use.

The new designs

The new designs are the two chairs from Emeco with a five-year warranty, the two chairs from Magis with a two-year warranty and the chair from Fritz Hansen, also with a five year warranty. Only two of the new designs have a seat shell attached to a base from another material. Three are made from PP, one from PET and one from PE, so all are made from recycled plastics for which there exist large scale commercial recycling technologies. Furthermore, three of them are composites, which are hard to recycle. So, the majority of new designs use recycled plastics for which recycling systems exist, but they reinforce the material with fibers that make it difficult to recycle. All new designs are all available in some colors that are not that well suited for the secondary raw material market. However, what is possibly the most interesting is that three of them, the majority, are made from PIR plastic. One might expect there to be more PCR plastic amongst the new designs as it was said in the interviews that one has to start with PCR plastic and design based on the material to succeed at using it. Regardless of that, out of the new designs, N02 Recycle and Costume seem to serve as the better examples, as the plastic used in both are fairly straightforward to recycle. N02 excels in terms of using the most PCR waste and making the chair recyclable as well, and Costume in terms of recyclability of the plastic core and design for extended use. It is however difficult to say which one of them is best because they are so different, especially because one is a classic chair and the other one a sofa.

The redesigns

The recreations of already existing designs are just under half of the chairs and includes the two chairs from HAY and the chairs from the Norwegian manufacturers NCP and Flokk. All the redesigns have a base from another material, three in metal, out of which two in steel, and one is a wooden base. Two of them have a separate seat and backrest and two consist of a seat shell. All except Revolt are made from PP and all except AAC ECO 12 are made from PCR plastic, which is quite interesting given that it was mentioned in the interview that it is difficult to apply PCR material to already existing designs. Based on these chairs, it does however in fact seem doable. So maybe it is, as was also mentioned in the interviews, a knowledge issue. Furthermore, the two chairs from HAY, except for the black Revolt, contain 70% virgin plastics, whereas the limited edition Capsico Puls and S-1500 contain close to 100% PCR plastic. So, it goes without saying that in terms of using waste material, S-1500 and the limited edition Capisco Puls are better examples. In addition, S-1500 and AAC ECO 12 might be a bit easier to disassemble than the two others, but all the redesigns are recyclable as they consist of mono-materials. That is another interesting finding, that all redesigns are made using mono-material, in difference to the new designs where a majority uses composites. So, all in all, S-1500 and the limited edition Capisco Puls seem to be the better examples in terms of both using waste materials and being recyclable. Furthermore, Capisco Puls is also built for easy replacement of parts in the use phase, whereas S-1500 has the uniqueness that might create emotional attachment and thus prolong the use phase.

The polyolefins

Since PP and PE belong to what you could call the same plastics family, polyolefins, for which there exists large scale commercial recycling technologies, Costume was also compared with the PP chairs. With Costume being a new design, there is a majority of new designs amongst the polyolefin chairs. Costume is more complex, like Capisco Puls, but the core is more similar to a monobloc, like the Bell chair. Costume is made from PIR plastic, like one third of the PP chairs, and made from a mono-material like two thirds of the PP chairs, and therefore also recyclable. There is more PIR plastic in Costume than in AAC ECO 12, which is good, but Costume cannot measure up to S-1500, N02 Recycle and the limited edition Capsico Puls in terms of closing the loop by using post-consumer waste. Costume does however on the other hand excel at extending the use phase. In terms of being the most innovative amongst the polyolefins, S-1500 with its marbling pattern that makes each chair unique and no use of additives to make different colors as well as Costume's innovate rethinking of the sofa makes them worth noting as inspiring examples.

Evaluation

Method

After making the spreadsheets and comparing the different chairs, each chair was analyzed and evaluated separately. The evaluation was based on the information about the given chair obtained through the interviews and on the findings from the comparisons. Positive and negative aspects were listed and weighted against each other. The chairs were given an evaluation of whether the overall impression was that the chair is on the right track to circularity, if the product still has some way to go to become circular, or if it was unclear based on the information at hand. It is worth noting that, although the evaluation does consider the entire chair, it is especially focused on the plastic part of it.

AAC ECO 12
30% PIR PP & 70% virgin PP

To start with the positive, AAC ECO 12 is made for disassembly and recyclable, and likely to be recycled because there exist recycling systems for PP. It is also positive that HAY tries to recreate existing designs in a more sustainable manner. However, the effect of that is limited as long as the virgin plastic chair is offered alongside with this one, and in a variety of different versions, in fact as many as over 40 different versions, and that is only counting the ones with the same base as AAC ECO 12. The AAC ECO 12 chair is only one of many different versions of the same chair, and just because this one is offered as an alternative does not meant that people will not buy the virgin version. It may be an example of what Lodgaard called rather counterproductive because it creates the illusion that one is doing something when one really has not done much. If this chair were to have an actual impact, it should be the only one offered. Furthermore, this chair contains 70% virgin plastic, so it is quite close to being a virgin plastic chair as well. There is only 30% of HAY's own production waste that makes this a more sustainable chair. One could also argue, as has already been mentioned by some experts and manufacturers, that using PIR plastic is not impressive, not using it would in fact be to throw out raw material to buy new from somewhere else.

However, given that this chair is made for disassembly and is recyclable, which cannot be said for all chairs in this case study, it is unclear whether it is overall on the right track or still has some way to go. It depends on what one defines as more important, whether it for example is the use of waste materials, recyclability or the change it can impact. What can however be said is that this chair has very limited impact in terms of advancing the circular economy of plastics in furniture, other than being recyclable, which could be said to be the absolute minimum requirement for circular products. So, there is definitely room for improvement.

Revolt
30% PCR ABS & 70% virgin ABS (except the black version, which is 100% PCR ABS)

This chair from HAY is a better example of how one can take an already existing design and make it more sustainable, at least the black version which is very positive with its 100% PCR plastic. Furthermore, it can be seen as positive that this chair is made from white goods, a type of bulky waste, which is a waste source that is otherwise typically landfilled or incinerated. It is also positive that the chair is made for disassembly and that it is recyclable. However, the fact that it uses ABS in difference to other plastics for which large scale commercial technologies exists, could be less positive. Although ABS is recyclable, there is the question of if there are readily accessible system for it to go to. What is however the biggest negative aspect is the fact that 70% virgin material is needed to make eight of the different colors this chair is available in, and that most of those colors are dark or strong.

Overall, this chair is a step in the right direction of making already existing designs more circular and sustainable. Had all colors been made from a majority of PCR plastic, it would have been overall positive. However, when the reason for using 70% virgin plastic is color, those colors should not be dark or strong, but rather light as to make it easier to find an application for the plastic material after recycling. In other words, this chair contains more than 2/3 of virgin material and is colored in colors that are not optimal for application after recycling, which is not very circular. So, it is unclear whether this chair is overall on the right track or still has some way to go. It seems that the compromise of using virgin plastic was done because of aesthetics in terms of colors, not because the structure of the design did not allow for more PCR plastic. So, for this chair to be more circular it would be advisable to rethink the aesthetics and use colors for which one could use a higher content of PCR plastic.

N02 Recycle
95% PCR PP & 5% color pigment

N02 Recycle is made from 95% PCR plastic made from household waste, which is close to being actual trash and therefore having an actual impact, which is very positive. What is more, it is made for easy disassembly and from a mono-material plastic, PP, for which large scale commercial recycling technologies exists, so it is fully recyclable. One thing that can however be said to be negative about this chair is the 5% masterbatch that is used to make many strong and dark colors that are difficult to repurpose after recycling. What is also worth noting about this chair is that it was designed with the material in mind from the beginning, so the material determined how to design this chair, and that seems to have been a strategy that works quite well in terms of creating a product that is closer to being circular. So, this chair seems to overall be on the right track to circularity because it is a step in the right direction of using and thereby reducing waste while at the same time being recyclable because systems to recycle the plastic used are widespread, although some of the colors can be problematic.

S-1500
100% PCR PP

S-1500 is the chair in this case study that contains the most PCR plastic because there are no additives in it, not even colorants. This chair demonstrates how one can get many different colors only through the use of sorting technologies, a promising strategy for future circularity as additives such as pigments make plastic more difficult to recycle. Furthermore, the marbling pattern that makes each chair unique is also an interesting approach to circularity, that might even tap into the aspect of extending life and resisting obsolescence through emotional durability because the user might form a bond with the chair as it is one of a kind. Anyhow, the pattern illustrates a creative approach to aesthetics when designing with recycled plastics. What seems to be the only negative aspect is that the colors are dark or strong and therefore not the best for application after recycling. However, since additives makes recycling more difficult, adding pigments to lighten the colors might not be a good solution either.

In addition, one could argue that since S-1500 uses waste from an industry that it is a more controlled source that might be easier to work with, and it definitely is if you compare it to ownerless ocean plastic. However, it still is a source of waste that if it had not been utilized for this chair would have been incinerated. So, it does turn waste into value. Furthermore, the chair also, by far, has the lowest carbon footprint of the ones that had measured it, and the longest estimated lifespan of all the chairs. S-1500 is also easy to disassemble and fully recyclable as it is made from PP, for which recycling systems exist.

So, all in all, S-1500 seems to overall be on the right track. The chair is innovative in many ways in terms of doing much with little. No additives are added, yet there are eight different colors and each chair has a unique pattern. Those colors are not the best for application after recycling, but that seems to be the compromise one has to make when not using additives. S-1500 uses waste materials in a way that makes them recyclable at end of life and is innovative in appearance, which might extend the use of the chair.

Alfi
80% PIR PP, 20% wood fibers

A positive aspect about Alfi is that it is easy to disassemble the chair. However, it is difficult to recycle because of the wood fibers, even more difficult than glass fiber reinforced plastics. Furthermore, it is available in many dark and strong colors that would not be easy to find an application for after recycling, if it were possible to mechanically recycle the chair. It would probably be possible to recycle one Alfi chair mechanically together with a lot of pure PP, but the wood fibers would pollute the waste stream, and degrade the quality of the plastic it was mixed together with. One could in theory maybe chemically recycle it, then colors would also not be an issue. However, that is not widespread at the moment, at least not as widespread as for glass fiber reinforced plastic. Then there is also the question of if it is environmentally justifiable to make a chair from PIR plastic, that most likely would need energy intensive chemically recycling technologies to be recycled, and the wood fibers cannot be recovered with chemical recycling.

However, it should be noted that this is the oldest of the designs used in the comparisons, and that might also make a difference. One positive thing worth mentioning is that Alfi has a measured carbon footprint, so it is transparent in terms of environmental impact. It should also be said that Emeco can recycle the chair, which is good, but per now it seems to be difficult to recycle in any other way. So, if Emeco were to create an extensive take-back system for Alfi, recycling would not be a problem. However, Alfi could only become Emeco chairs again, the plastic material could probably not be used for anything else.

All in all, without a takeback system for Alfi, the chair overall has some way to go because it is a composite material with wood fibers which is even more challenging to recycle than glass fiber reinforced plastics, and it comes in many different colors that have a limited aftermarket. Although it may last long, it is not designing out waste or keeping materials in use long by looping them back into the system, at least not based on normal recycling facilities.

On & On
70% PCR PET, 20% glass fibers & 10% non-toxic pigment

The On & On chair uses 70% PCR plastic, which is positive, but it also contains 20% glass fibers, which makes it difficult to recycle mechanically. Furthermore, many of the colors the chair is available in are dark or strong colors that have a limited aftermarket. The chair could however be recycled chemically, then the colors would not matter. The glass fibers would however be downcycled in the process and there is the question of whether it is environmentally justifiable because chemical recycling is energy intensive. Furthermore, if it is made from bottles that could be used for bottle-to-bottle recycling instead, it is a bit problematic as this chair is difficult to recycle mechanically at end of life and cannot be mechanically recycled into PET bottles again because of the glass fibers and color pigments. However, another positive thing is that Emeco can recycle this chair on and on. So, the chair can be recycled, but most likely only by Emeco or with chemical recycling. If Emeco were to have a take back system for On & On it would not be problematic as they could recycle it into new glass fiber reinforced chairs. It is however worth noting that the plastic material probably cannot be used for anything else than Emeco chairs again, unless chemically recycled, and Emeco does not have such a take back system yet. Another positive thing is that the chair has a measured carbon footprint.

All in all, this chair seems to still have some way to go if it is to become circular, as it is a composite material that is difficult to recycle mechanically and comes in many different colors that are difficult to find an application for after recycling. Using waste materials has a positive effect if the chair can be recycled again at end of life, and the On & On is difficult to recycle with existing recycling technologies. Although it is good that Emeco theoretically can recycle the chair, it is not recyclable at any given place with readily available recycling technologies. So, for this chair to become more circular, it at least would need a take-back system.

Costume
99% PIR PE & 1% color master

Costume is a modular design that is versatile in many ways. It can be dis- and reassembled and all parts can be replaced. Furthermore, if the reason for ceasing to use the product is not due to breakage, but because of a change in taste, the cover can be changed, changing the appearance of the product. Moreover, as a sofa, the base unit can be combined in multiple ways to adapt to a change in needs. So, this might be the most circular design out of the ones in the case study in terms of focusing on keeping the product in use, circulating at the highest value for as long as possible by enabling multiple circular strategies, such as for example reuse or refurbishment before recycling. Costume is also recyclable as it consists of pure PE plastic, a type of plastic for which there exists established closed loop recycling systems.

However, the PE is only made from post-industrial waste, so the impact is limited in terms of designing out waste. Furthermore, the connectors are made from virgin PP and in colors that are not well suited for application after recycling. Costume also consists of unrecyclable PU foam, which could be negative, but there does currently not seem to be any good alternatives to it either and the amount used is a bare minimum. What might be the biggest minus for Costume is the fabric cover, which is difficult to recycle because it is a composite material. Being able to change the fabric is an important part of the circular aspect of this design, so the fabric should also be capable of circulating in closed loop to justify changing the cover, if not, a change in cover would generate waste, not design out waste. However, compared to normal sofas that are typically not recyclable at all and instead landfilled or incinerated, Costume is definitely a step in the right direction, even though it still uses some PU foam, is only made from PIR plastic and the fabric is as of today difficult to recycle.

What is more, the negative aspects mentioned are currently being worked. From summer onwards, the core will be made from PCR plastic. It is also worth noting that since this design is modular, parts of it can be improved along the way, such as switching from PIR to PCR or changing the fabric. That is a good strategy for creating products that take a step towards circularity and can be improved to become more circular along the way, as for instance new technologies develop. Furthermore, this design has also solved the issue of colored recycled plastics quite cleverly as it uses recycled plastic in a way that makes it independent of the color, and therefore theoretically removes the need for colorants.

Overall, the positive seems to outweigh the negative, especially considering that the core will be made from PCR plastic in the near future. Costume goes beyond rethinking the sofa in terms of design for recyclability and is heavily focused on design for product integrity. Even with PIR plastic, it is overall on the right track because of the innovative design for extending the use phase. It is not yet fully circular but is constructed to become more circular with time.

The Bell Chair
77% PIR PP, 20% glass fibers & 3% color master

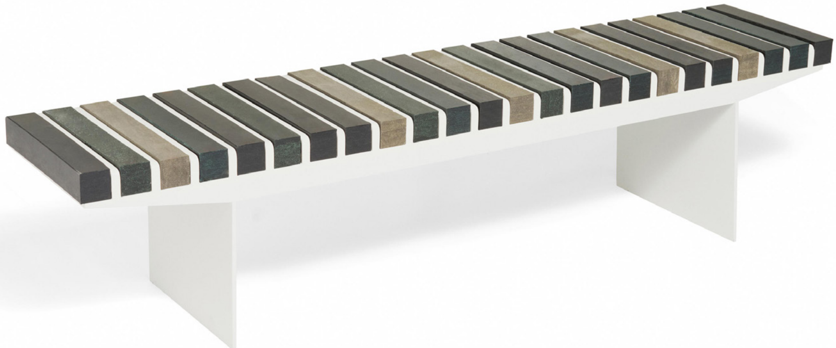
A monobloc chair would in theory be quick and easy to recycle as there is no disassembly needed and it only consists of one material. However, when mixed with glass fibers, that is no longer the case. So, what could have been a positive thing about the Bell chair, that it is a monobloc that in theory is easy to recycle, is cancelled by the fact that it consists of a composite material that is difficult to recycle mechanically. Furthermore, the plastic material used is PIR plastic, so the choice of waste source has a limited impact in terms of designing out waste. In addition, two of the three colors are strong or dark and not well-suited for finding an application after recycling, that is if the chair is recycled. The dots in the color can be difficult to sort out and could become color pollutants in the recycled material. The chair could, however, be recycled chemically, and then the colors would not matter. However, then there is the issue of whether chemical recycling is sustainable in terms of energy use, and the glass fibers would be downcycled in the process.

Moreover, a classic cheap white virgin PP monobloc chair is in theory easier to recycle than the Bell chair and the white color of a classic monobloc is also sought after on the secondary raw material market. It should however be said that according to Magis the chair can be recycled 1:1 into a new Bell chair, so if Magis were to have a take-back system for the chair, these things would not be negative, but as of today Magis does not have a take back system. So, all in all, the Bell chair overall still has some way to go. It does not contribute substantially to designing out waste in the front end and, given how difficult it is to recycle, will probably not be recycled on the tail end, so it is not close to being circular.

Limited edition Capisco Puls
100% PCR PP (with some color pigment)

This chair is different than the others because it is an office chair. It therefore consists of more different parts and materials, such as a PU foam cushion and fabric cover. The PU foam is not recyclable, which might be negative, but only a bare minimum is used and there does not seem to exist any good alternatives to the foam. Another thing that could be negative about this chair is the color that is not easy to repurpose after recycling. However, what is positive is that the chair is designed as a modular construction that is built for easy dis- and reassembly by the user, and parts can be replaced to extend the use of the product. This is also the chair with the longest warranty, which indicates durability, as well as long access to spare parts so one might be more inclined to repair the chair if something were to break. However, if the reason for ceasing to use the product is a change in taste, there is not much that can be done other than maybe changing the fabric or the base, the plastic parts will remain in the same color. Furthermore, it is positive that the plastic material consists of 100% PCR plastic from a waste source that would have been incinerated had it not been utilized for this chair. The material is also a mono-material plastic with only a little color pigment, so it is recyclable mechanically. Since it is PP, recycling systems for it also exist.

So, all in all, the limited edition Capisco Puls is overall on the right track, because it is a step in the right direction of using and reducing waste and being recyclable at the tail end too, not to forget that it is also constructed with long and extended use in mind. So, it can be said to be designing out waste and keeping the product and material in use, although the color can be problematic.



The Coast bench
100% PCR HDPE, PE, ABS and PP (but not mixed together)

For the evaluation, the Coast bench was also included. It is a prototype in need of much testing, but the overall idea can still be evaluated.

The plastic material used for this chair, might be the one that has the biggest positive environmental impact out of the sources of waste used for the chairs in this case study, because it cleans the ocean of waste. Furthermore, there are no additives, not even color pigments, so it is recyclable. However, since the source of waste is ownerless ocean plastic, the quality between the plastics collected can vary a lot, depending on how long the plastic has been in the ocean. So, the issue with this plastic material is that there are still a few unanswered questions in terms of quality. It might not matter if the quality is poor as long as it can be recycled, however if the quality is so poor that the life span becomes so short that more resources need to be used to recycle it again, that will not solve a problem either. Of course, it will contribute to collecting plastic from the ocean, but it will not solve any issues in terms of energy and climate.

If, however, the quality is sufficient, this bench will contribute to create a value chain that makes ocean plastic a resource, within a controlled system. The innovative blockchain technology used to track the plastic makes it transparent and easy for users of the bench to get information about the product's journey from recycled plastic to finished product, they only need to scan the QR code on the product. Furthermore, Vestre is tackling the problem upfront by only making this bench available for leasing, so the company retains ownership of it. It is however not Vestre that owns the plastic, that is Ogoori, another company that leases the plastic material to Vestre as a service. With this setup of the value chain and business models, the manufacturer is incentivized to control what happens to the product, because they also need to answer to the company that provides the material. So, recycling is no longer just an option at end of life, it is an integrated part the product's business model. This is an innovative way of solving the issue of accountability in the industry and of remaining in control of what happens to the plastics used in their products at end of life.

The bench is also made for disassembly and the plastic parts can be replaced when that is needed, extending the life of the product. With Vestre's new factory, it will also be put into systems that the product can be sent back for refurbishment or repair, also contributing to extending life and keeping the product is use longer, possibly also by switching users.

So, all in all, this bench is probably on the right track, but remains to be seen as it depends on the estimated life span of the plastic material, but if that is adequate it is definitely on the right track to circularity. The only downside here is that there are some unanswered questions left regarding life expectancy due to differences in quality between the plastic parts cleaned out of the ocean. There is a fine line between having a poorer quality and therefore a shorter lifespan but being able to control it and recycle it over and over, and too poor quality and a too short lifespan that would result in needing to recycle the product so often that it would use more resources and not be environmentally preferable. So, hopefully the lifespan and quality of the plastic material will be adequate to justify recycling the material, because the rent model combined with blockchain technology is a very promising innovative way of tackling the plastic waste problem upfront, controlling what happens to the material to ensure its circularity in closed loops. So, this bench is worth keeping an eye on in the future because the services and systems used could potentially solve one of the biggest issues in the furniture industry, which is for manufacturers to remain in control of what happens to their plastic products. That could in turn enable manufacturers to ensure that the products and materials remain in use, not to forget that if scaled up, using this plastics material could speed up the ocean clean up, contributing to designing out waste.

Result

Questions to evaluate the circularity of a furniture product made from plastic waste materials

Through the comparisons and evaluations there were some topics that recurred as important and decisive to be able to say something about the circularity of the chairs. Those decisive factors that were emphasized in the analysis were summarized into a set of questions for each life phase of any given plastic chair. These questions were based on the information at hand about the chairs that could aid in assessing the circularity of them. So, this set of questions in a way reflect how the chairs were evaluated. Furthermore, these questions also serve to reflect what was learned through this case study. They can be said to be a collection of what was uncovered in this case study as important to assess the circularity of plastic furniture. It is however important to point out that these questions were only based on the available information about the chairs, so they are not an extensive list of all circular aspects, but only of those circular aspects that information was available on. What is however the most important takeaway about this set of questions is that they consequently served as the starting point for the next phase of the thesis, which was to develop the circular design guide for the use of plastic in furniture.

The questions used to evaluate the circularity of a furniture product made from plastic waste materials can be found in the appendix.





The best examples

The evaluation of all the chairs goes to show that to create long-lasting products is not enough for them to be circular, neither is only using waste materials or making recyclable products from virgin materials. The chairs that seem to have the longest way to go to become circular are the composites. Whether a product or material is recyclable is defined as if there is a system for it to go to, which there, if any, are very few of for fiber reinforced plastics at least in terms of recycling and not downcycling.

In the comparisons, some chairs repeatedly occurred as more exemplary, and based on the evaluation of each chair separately, some shone through as better examples once again. The chairs that were the best examples are N02 Recycle, S-1500, Costume, the limited edition Capisco Puls, and the Coast Bench. These seating solutions that seem to be on the right track to circularity, have some things in common too. First of all, they use mono-material plastics, so they are easy to recycle, and recycling systems do exist for the types of plastics used. Furthermore, most of them are made from PCR plastic. It seems that those chairs that are designed with the material in mind from the beginning have a higher content of PCR plastic, so it seems that they are designed to make using PCR plastic work. At last, some of the best example chairs are made for extending the lifetime of the product. So, it was observed that the best examples are either made from recycled plastics in production, made for extending the use phase or made for recycling at end of life. It is also interesting that three of them are new designs and two are redesigns, so it seems to not only be possible to create new circular designs from scratch, but to also recreate old designs in a more circular manner.

To assess if these chairs that were perceived as best examples truly were the best ones, all ten evaluated chairs were cross referenced with the three circular design methods of design from recycling, design for product integrity and design for recycling to see how many of those design methods seemed to be applied to the the chairs. This was done to assure that the evaluation was not biased or had overlooked anything, but that those chairs in terms of circular design could be said to be the better examples. Based on this assessment of whether the chairs could be said to be designed from recycling, for product integrity or for recycling, a connection was discovered. The chairs that had been labelled as the better examples, could all be said to use two or three out of the three circular design methods, whereas the chairs that were deemed as unclear or having some way to go to become circular, only applied one of the three and that was mostly design for recycling, whereas design for product integrity beyond only creating durable products was applied by the fewest. These discovery resulted in a design model. However, before explaining the design model, it would be reasonable to explain which design methods seem to be used for the best example chairs. It should be noted that it was not said specifically by the manufacturers that these methods were used for the chairs but based on the information from the interviews about the chairs and the analysis of them, traits were identified that resembled those of the three design methods.

N02 Recycle seems to be designed from recycling, as the recycled household waste was the starting point for the design of the chair and determined how it needed to be designed. Furthermore, N02 Recycle is designed for recycling. In terms of product integrity, nothing specific was noticed, at least not in terms of extending the use of the product.

S-1500 also seems to be designed from recycling. The design is determined by the use of the recycled plastics material, especially since it does not use any additives, so for instance the colors are solely determined by the plastic material. Furthermore, S-1500 is designed for recycling. Whether it is designed for product integrity is difficult to say, the marbling pattern could possibly create an emotional attachment with the user, but to make a statement about that, it would need to be researched further, which is not in the scope of this thesis.

Costume is designed for product integrity, as it is designed to resist, postpone and reverse obsolescence. It is possible to change or replace all parts either if they break or people grow tired of the appearance, and as a sofa, it can adapt to different needs by being put together in different constellations. Furthermore, Costume is designed for recycling. Costume is made with PIR plastic, so it is probably not designed from recycling as the material is essentially virgin plastic and does therefore probably not require that many special considerations, at least not in the same way as PCR plastic does.

The limited edition Capisco Puls seems to be designed from recycling. Flokk seems to generally design with PCR plastic as a prerequisite, focusing on how one has to design based on what the recycled plastic material can and cannot do. Furthermore, the chair is designed for recycling. At last, it also seems to be designed for product integrity, because all parts can be replaced if they were to break, and it also has the longest warranty of all chairs in this case study.

The Coast bench seems to be designed from recycling, as the material was the prerequisite for making this bench. Furthermore, it is designed for recycling. At last, it seems to be designed for product integrity because it is only leased, guaranteeing take back both for reuse and recycling, Vestre also offers to replace the plastic parts.

	Positive aspects	**Negative aspects**	**Something special**
AAC ECO 12	Disassembly, recyclable & only one color	70% virgin, only 30% PIR	Only 1 color and 1 base
Revolt	A more sustainable version of a design classic + the black version	70% virgin plastic for all colors except black + strong & dark colors	Only ABS chair & made from white goods + redesign of a famous classic
N02 Recycle	95% PCR plastic, recyclable & easy disassembly	Many dark & strong colors	Household waste
S-1500	100% PCR plastic, no additives, marbling pattern, easy disassembly & recyclable	Many dark & strong colors	Marbling pattern, different colors w/o additives + source of waste
Alfi	Easy disassembly & measured carbon footprint	Composite, PIR & dark/strong colors	The oldest + only one w/ wood fibers
On & On	Easy disassembly & PCR plastic	Composite & dark/strong colors	Only one w/ PET
Costume	Repairable& adaptable both for change in taste or needs --> extend life	PIR plastic + difficult to recycle fabric cover	Rotationally molded w/ PE + rethin-king the sofa
Bell Chair	Monobloc = easy to recycle in theo-ry (no disassembly needed)	Composite, PIR & dark/strong colors	Monobloc
Limited edition Capisco Puls	close to 100% PCR, long warranty & repairable	The color	Unique waste source
The Coast Bench	Leasing & material as service = guaranteed recycling, 100% PCR, no additives, cleaning the ocean	Unanswered questions regarding quality	Cleaning the ocean, material as ser-vice & blockchain technology

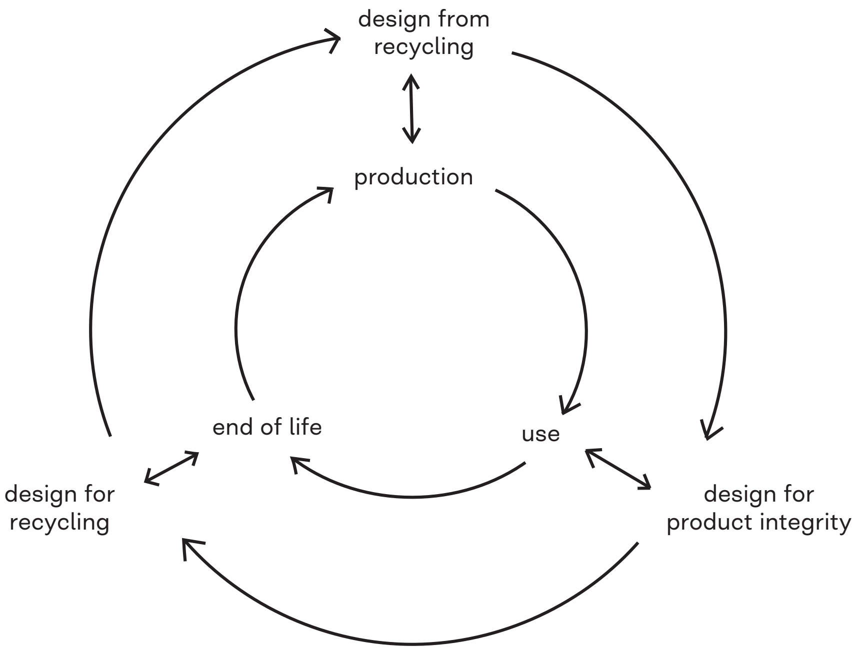
Design from recycling	Design for product integrity	Design for recycling
Not really	Only maintenace guide & 5 year warranty, so not really	Yes
Not really	Only maintenace guide & 5 year warranty, so not really	Yes
Yes, seems like it, the material was the starting point	Only maintenace guide & 5 year warranty, so not really	Yes
Yes, seems like it	The marbling pattern could possibly create emotional attachment becau-se each chair is unique	Yes
In a way yes, more so than design for recycling	Only maintenace guide & 5 year warranty, but lasts around 20 years, so nothing more than physical durability	Composites are diffi-cult to recycle
In a way yes, more so than design for recycling	Only maintenace guide & 5 year warranty, so not really	Composites are diffi-cult to recycle
To a certain point, but the starting point was to rethink the sofa	Yes, all parts can be replaced if something breaks or because of change in taste, can also be recon-figured with changing needs --> extend life	Yes
Not really	Only 2 year warranty, although can last for 15-20 years, monobloc is easy maintenance. So, nothing more than physical durability & easy maintanace	Composites are diffi-cult to recycle
Yes, seems like it (for all products because of circular design criteria)	Yes, 10 year warranty & lasts 20 at least + and all parts can be repla-ced --> extend life	Yes
Yes, seems like it, the material was the starting point	Yes, only available for leasing & plastic parts can be replaced	Yes

The design model

The illustration to the right illustrates the connection between the three different product life phases and the three circular design methods. For a plastic product to be circular, it should apply all three design methods.

If a product is only made from plastic waste materials, but not for recycling, it is a linear product. Yes, it uses waste, but at end of life it generates waste. So, only using waste materials is not sufficient. Furthermore, to use plastic waste and design a product to last long is also not yet circular. If a product is designed to last long and be used long, it counteracts obsolescence, but at one point all products will become obsolete, and for a recycled plastic product that becomes obsolete to be circular it should go into a technical loop of recycling again. Furthermore, to use virgin plastic materials and create a long-lasting product, but one that is not recyclable is clearly to create a linear product. It depletes the earth of resources and eventually generates waste. If a product is recyclable but made from virgin plastics and not designed to live long, it is also not circular. First of all, it is depleting the earth of natural resources and secondly, recycling also requires resources such as energy. So, to make short lived products from virgin plastic is not environmentally friendly nor circular. As stated by den Hollander et. al. (2017, p. 520), if a product is only designed for recycling, its product integrity is lost. A step in the right direction, on the other hand, is to design long-lasting products. However, although a product is designed to live long and is recyclable, if it is made from virgin plastic, it is still depleting the earth of resources and does not reduce or design out waste.

Furthermore, to make a product from plastic waste materials and design it to be recyclable at end of life does contribute to closing loops. However, both production and recycling demands resources, and in a circular economy, products should circulate at the highest value for as long as possible, meaning that they should also retain product integrity for as long as possible. Making durable, long lasting products is a step in the



right direction, but it is not a guarantee for that they will be used long. So, for a product to be circular it should also be designed to enable extending the product lifetime, by resisting, postponing and/or reversing obsolescence.

With all three design methods combined, a product would theoretically be designed to design out waste and keep products and material in use, circulating at the highest value for as long as possible. Design from and for recycling combined would in theory design out waste and ensure closed loops, retaining material integrity, and design for product integrity would ensure that the product lives as long as possible before it is looped back into the system.

Certification : the double-edged sword

For the comparison and evaluation of the chairs, environmental labels used by the manufacturers were investigated to see if they could aid in saying something about the circularity of the chairs. They could say something, but that was quite limited. Instead, this investigation resulted in uncovering issues with environmental labels. This section describes the three different ecolabels used by the furniture manufacturers that produce the chairs and explains why none of them are perfect.

The EU Ecolabel

The EU Ecolabel is a type 1 environmental label that was established in 1992 by the European Commission and it is a voluntary label. The EU Ecolabel is said to "reflect the best environmental performing products on the furniture market." (The European Commission, 2016). Furthermore, it "promotes the circular economy by encouraging producers to generate less waste and CO_2 during the manufacturing process. The EU Ecolabel criteria also encourages companies to develop products that are durable, easy to repair and recycle." (EU Ecolabel, n.d.)

Some relevant criteria for the EU ecolabel are that a product needs an extended product guarantee for a minimum of five years, and provision of spare parts for at least five years (The European Commission, n.d.). Products should also "be designed for ease of disassembly for repair, reuse and recycling" (The European Commission, n.d.). The EU ecolabel is however largely focused on materials used and their environmental impact. It has, amongst others, strict demands for chemicals that are harmful to the environment or health. Furthermore, for plastic, "If the total content of plastic in the furniture product (excluding packaging) exceeds 20%, then the average recycled content of all plastic parts combined must be at least 30% (on a weight by weight

basis).” (The European Commission, n.d.). So, there is a minimum demand for recycled plastic content.

The EU Ecolabel is used by the danish manufacturers, and through comparing the different chairs, some shortcomings with the EU Ecolabel were discovered. Both AAC ECO 12 and N02 Recycle have the EU Ecolabel and no distinction is made between the two although one is close to 100% PCR plastic and the other one essentially is a virgin plastic chair using only 30% PIR plastics. So, the EU Ecolabel only says if you qualify for the label or not, and if you have minimum 30% recycled plastic, be it PIR plastic, that is good enough. That essentially also means that there are no incentives to go beyond the minimum demand of 30% recycled plastic if no distinction is made between the chairs that qualify for the label. If a consumer were to only look at the ecolabel and not the actual content of recycled plastic in the chair, AAC ECO 12 and N02 Recycle would seem to be equal, which they in terms of circularity and environmental impact are far from being. So, one could almost go as far as to say that the EU ecolabel seems to be beneficial for less good products because there is no distinction made between the products’ actual environmental impact or level of circularity.

All in all, it is good that the EU Ecolabel has a criterion for the use of recycled plastics, but the minimum demand of only 30% recycled plastic, that could also be PIR plastic, is not going to make circular products. In fact, there are not many circular criteria, at least not in terms of criteria for product integrity beyond the minimum demand of 5-year guarantee and spare part access. There does not seem to be a focus on requirements for circular initiatives such as refurbishment or remanufacturing, the EU ecolabel is more focused on repair and recycling. Furthermore, it a binary system where you are either in or out and no distinction is made between the products that classify for the label, and there are therefore no incentives to go beyond the minimum criteria.

The Nordic Swan Ecolabel

The Nordic Swan Ecolabel, also a type 1 environmental label, was established in 1989 and is a voluntary label managed by the Nordic Council of Ministers (The Nordic Swan Ecolabel, n.d. -a). The objective of the Nordic Swan Ecolabel is “to reduce the overall environmental impact of consumption” (The Nordic Swan Ecolabel, n.d. -b). Furthermore, like the EU Ecolabel, the Nordic Swan Ecolabel promotes circular economy, and a Nordic Swan ecolabelled furniture “has a circular design where opportunities for repair, recycling and use of materials that have been recycled and / or renewable are promoted “ and it has “documented good quality, strength and safety through international tests, which promote a long useful product life.” (The Nordic Swan Ecolabel, n.d. -c). That sounds very promising, not to forget that the Nordic Swan label also “makes the best possible use of society’s current framework of circular economy”. That means “that the starting point is the existing resource loops in the form of the approach to raw materials and waste management systems in the Nordic region.”, also an interesting and promising approach (The Nordic Swan Ecolabel, n.d. -b).

The Nordic Swan Ecolabel has some requirements that are similar to those of the EU Ecolabel, such as requirements for the use of plastic, but the Nordic Swan Ecolabel requires a higher content of recycled plastic: “if plastic is included with more than 10% by weight in the product: min. 50% by weight must consist of recycled materials“ and “if plastic is included with more than 30% by weight in the product: At least 50% by weight of the plastic must consist of recycled material. A minimum of 20% of this must be post-consumer (The requirement to a minimum of 20% by weight of post-consumer/ commercial plastic applies regardless of the total amount of recycled plastic.).” (The Nordic Swan Ecolabel, n.d. -c). Furthermore, the Nordic Swan Ecolabel also has requirements regarding warranty, spare parts, disassembly, repairability and chemical content, similar to the EU ecolabel.

The Nordic Swan Ecolabel also has circular design requirements, unlike the EU Ecolabel. However, only two of five points must be met, so it is likely that manufacturers will not aim for the points that are the hardest to implement, such as “the manufacturer offers to take back the furniture for upgrade/repair/renovation”, but rather aims for points that are easier to fulfill, such as for instance avoiding glue and making a product where materials can be separated (The Nordic Swan Ecolabel, n.d. -d). One of those five points for circular design is also worth noting: “The furniture/fitment consists of pure materials that can be recycled more easily. Composite materials e.g. fiberglass-reinforced plastic is not used.” (The Nordic Swan Ecolabel, n.d. -d). In fact, wood fiber reinforcement plastic is prohibited (The Nordic Swan Ecolabel, n.d. -d). So, it seems that using composites is not seen as circular design according to the Nordic Swan Ecolabel.

Although the Nordic Swan Ecolabel seems to be a bit more progressive in terms of circular criteria, it is still not without flaws as illustrated with the example from Flokk, where Capisco qualifies for the label and Capisco Puls does not although objectively speaking Capisco Puls is a more circular and environmentally friendly product, as Lodgaard explained. So, if the Nordic Swan Ecolabel would be used as basis for which of the two chairs one should buy, one would buy the chair with a shorter service life, lower recycled content and higher greenhouse gas emissions. This example illustrates another issue with binary ecolabels, which is that they are based on existing products. So, it can happen that products that are actually more circular or environmentally friendly fall outside of the label because the criteria are not designed to take those examples into account.

All in all, the Nordic Swan Ecolabel is a step in the right direction as some of the criteria are stricter than those of the EU Ecolabel and the Nordic Swan Label also includes more circular design criteria. However, the most progressive circular design criteria are not mandatory, so the effect is likely to be limited. Like the EU Ecolabel this is also a binary system where one is either in or out and it is based on existing products, so a new innovative product that objectively speaking is more circular or sustainable, could end up not classifying for the label.

Based on the criteria for the two ecolabels, it seems that they in general are focused on the use of recycled content in production, but mostly seem to focus on end of life in terms of disassembly, separating materials, marking parts and so on. In terms of the use phase, the focus largely seems to be on warranty, spare parts, maintenance guides and repairability.

Environmental Product Declaration

An Environmental Product Declaration (EPD) is not a certificate like an ecolabel, but an environmental label of type 3. It is a third party verified document that can be used compare environmental performance (The International EPD System, n.d.). EPDs are like nutritional values for a product's environmental impact (Vestre, n.d -b.). An EPD does not necessarily "imply that the declared product is environmentally superior to alternatives - it is simply a transparent declaration of the life-cycle environmental impact" (The International EPD System, n.d.). Furthermore, an EPD gives transparent and comparable information for products within the same group (The International EPD System, n.d.).

The good thing about an EPD is that it promotes transparency by showing documented numbers that allows for comparing environmental performance, such as energy use and carbon footprint. However, the issue with EPDs is that in order to say something about how good or bad a product is, one needs another EPD to compare it with, and it is not mandatory for products to have an EPD. Furthermore, in order to compare two products based on an EPD, the products need to be comparable. The EPDs to compare need to be calculated the same way, it does for instance not make much sense to compare an EPD cradle-to-gate with one that is cradle-to-grave. So, comparing EPDs can also seem to be easier said than done.

Concluding Observations

To sum up, the problem with ecolabels is that they are binary systems based on already existing products with no incentives to go beyond the minimum criteria. Whereas the issue with EPDs is that one needs another EPD to compare with, that is calculated the same way for the same type of product, to say anything about whether a product is better than others.

It seems that what is needed in terms of certification is something that indicates if the product is circular in the first place, as an ecolabel does in terms of environmental performance, but then one also needs an indication of how good it is, in terms of either placing it on a scale, like for example the energy label scheme for white goods, or having some numbers that are comparable, like in an EPD. So, what seems to be needed is a two-step certification system in order to truly inform the consumer and say something about how circular a product is. Furthermore, the binary requirements should be stricter, and they should also be more focused on circular design, not only in terms of product quality and recycling, but on implementing circular systems or services as part of the product to extend its lifetime.

At last, it is worth noting that these are ecolabels and not circularity labels. In fact, there does not seem to exist circularity label, at least not to the same extent as ecolabels, which there are many of. With no certification for the circularity of products, it is also difficult for manufacturers to navigate what is important in order to design circular products. Some of the manufacturers mention that they use ecolabels as a guide on how to design sustainable products, and since there does not seem to exist any circular economy labels, at least not any that are as widespread as the EU ecolabel and the Nordic Swan ecolabel, it is also difficult for manufacturers to know what is expected of them in regard to circularity. There is no label they can use as a guide on product circularity. This lack of circular economy labels can be due to the fact that circularity so far has been more of a vision than reality. However, to make circular economy a reality, manufacturers need to know how to design products for circularity. So, there should either be circularity criteria incorporated in existing ecolabels or a type of circularity certification should be developed to account for circular products. Regardless, some guidelines on how to design circular plastic furniture seem to be needed.

Sum up of chapter 4

This chapter has presented the case study conducted to compare and evaluate some chairs that claimed to be recyclable and made from recycled plastic. Whether those claims were true was investigated through interviews with plastic recycling experts. Furthermore, based on the information gathered both from manufacturers and experts, the chairs were compared and evaluated to form a picture of what approaches seem to create more circular products, to find the best examples and determine what made them more circular than the other chairs in the case study. The analysis of the chairs resulted in a design model combining three design methods, a set of evaluation questions and uncovering the limitations of existing environmental labels. All in all, the chapter has illustrated that based on these plastic chairs currently on the market, there is still work left to do to create fully circular plastic furniture.

What this chapter has shown is that there are some aspects that are crucial to make plastic furniture circular. A circular plastic product is not just durable, recyclable or made from recycled plastics, it is more complex than that. As seen through the case study, few manufacturers have managed to extensively implement circular design throughout all life phases of a chair. The efforts are mostly focused on the front end of using waste materials in production or on the tail end in terms of making a chair that, at least theoretically, is recyclable. Furthermore, in terms of the use phase there is little focus on designing the chair to enable extending its lifetime, most chairs are only designed to physically last long, and there generally are few circular initiatives offered in connection with the plastic chairs. Moreover, through this case study, it was made clear that there are some specific measures that can be taken to at least design products that are more circular, if not yet fully circular.

To sum up, the case study served to highlight what is needed to design a circular plastic product, not only in theory, but in real life. So, the natural next step in this thesis is to transform the obtained knowledge into a set of guidelines that can help designers navigate the complexity of circularity in order to design fully circular plastic furniture products. The first step towards the circular design guide is therefore to sum up the overall main findings of the interviews and case study combined, which will be done in the beginning of the next chapter.

Chapter 5

From Linear to Circular: Circular Design Guide Research

This chapter is in some way an introduction to the circular design guide that is the result of this thesis as the chapter presents research done to develop the guide. This research was conducted as a means to gain insight into how to develop a design guide for a future scenario, that future scenario being the circular economy. Secondly, research was done to find inspiration on how to structure a circular design guide and lastly to find inspiration on what to include in the guide, especially in regard to what is relevant for plastic furniture.

This chapter first sums up the overall most important findings from the interviews and case study, followed by a description of an ideal scenario for a circular future based on those overall findings. Then, research on existing circular design guides is presented, followed by interviews with practicing designers. At last, the main takeaways from the circular design guide research and designer interviews that are of importance for the circular design guide for the use of plastic in furniture are presented.

Overall findings so far

Many findings were made through the interviews with manufacturer representatives and the case study. Those findings have been explained in detail in the two previous chapters. This, on the other hand, is an overall assessment of the findings from the two previous chapters combined.

Overall, the furniture industry's efforts in regard to sustainability are typically to create durable quality products, but for a circular economy, that is far from enough. Some manufactures are starting to catch onto that and are starting to implement the use of recycled and/or recyclable plastic materials.

Through the case study, some plastic chairs were found to be better examples than others of more or less circular plastic furniture, one might even call them good examples. However, there is not one chair that can be said to be exemplary, at least not yet. To be a bit strict, it seems that the promise of the furniture industry regarding recycling of plastics was not fulfilled. There does not yet seem to be any 1:1 plastics recycling happening in the furniture industry, as it does for example in packaging with PET bottles. That does not seem to exist in the furniture industry, a plastic chair is not recycled into another chair again, at least not on a large scale. On the contrary, what the furniture industry seems to be doing is to make linear products from recycled materials, because after adding additives, recycling becomes noticeably more difficult, if at all possible with existing recycling technologies, not to forget that additives also limit the aftermarket. At best, the furniture industry gives the recycled plastic material one more use cycle before going to incineration or landfill, but plastic furniture products do not seem to exist in a closed loop where they are recycled over and over again. So, the description of the topic of this thesis seems no longer to be "the circularity of plastics in the furniture industry", a seemingly more accurate description is "the **non-existing** circularity of plastics in the furniture industry".

The three biggest issues

Three issues that recurred throughout the industry insight phase and case study were identified as the overall biggest challenges. These were definitions, additives and reversed logistics.

Definitions

In regard to the issue of definitions, it seems that the terms “recycled” and “recyclable” are being misused. Whether that is on purpose or not is difficult to say. Either way, it creates challenges. A product is per ISO Standard 14021 recyclable if it can be “diverted from the waste stream through available processes and programmes and can be collected, processed and returned to use in the form of raw materials or products.” (International Organization for Standardization, 2016). So, for a product to be recyclable, there needs to be recycling systems for it to go to. A product cannot be defined as recyclable if it can only be recycled in theory or in a lab, it needs to be recyclable in the real world with its existing systems. Furthermore, using one’s own production waste is quite questionable in terms of whether it can be defined as recycled. Some do define using post-industrial waste as recycling, but in order to advance the circular economy, it should not be defined as recycling. Using post-industrial waste is as old as the industrial revolution, it is simply common sense and good housekeeping. There is so much post-consumer plastic waste in the world that needs to be utilized for waste to be designed out to create a circular economy. So, going forward, this thesis will not define using post-industrial waste as recycling.

Additives

The next big challenge is additives. This is a tricky one, as it seems that most manufacturers and designers might not even be aware of how big of a challenge this poses for recycling. It seems that they are more focused on mechanical or aesthetic qualities of the plastic material, than on its recyclability at end of life. For instance, fiber reinforcement is typical for plastic furniture, however, if fibers are added to recycled plastic, it is extremely difficult to recycle with mechanical recycling, and if at all recyclable, the fibers will pollute all other plastics in the recycling stream, which could result in downcycling, if at all recycled. Furthermore, color is a big issue that the furniture industry does not seem to be aware of as a range of colors is mostly made because it is “fun”. However, when color pigments are added to make dark or strong colors, the aftermarket after recycling is not optimal because those colors are difficult to color again after recycling. Of course, one could argue that these are not issues if one uses chemical recycling. With chemical recycling, the furniture industry could continue their business as usual, and would not have to change how they design products. However, chemical recycling has the issue of being very energy intensive, in fact so energy intensive that it cannot really be rendered as a sustainable technology. So, although it is positive that the furniture industry uses waste materials and recycled plastics, it has a tendency to add additives that render products difficult to recycle and/or find a high quality application for after recycling.

Reversed logistics

At last, there is the issue of reversed logistics. There simply is no comprehensive system for recycling plastic furniture. This is a complex issue, and probably the most difficult one to solve. It requires systemic change, not only from the side of manufacturers or designers, it requires infrastructure and involves other players such as policymakers. Manufacturers could definitely become better at taking accountability for their plastic products at end of life, but without governmental incentives, that is not likely to happen anytime soon. Take back systems might be a solution, but when manufacturers sell products all over the world, the carbon footprint of transportation for take back becomes ridiculously high. So, one could say recycling in local recycling facilities is a better option, but then plastic furniture must be made in such a way that it is easy for recycling facilities to understand what materials the products consist of and how to recycle them properly, and the products need of course to, in the first place, be recyclable in such facilities and not only by the manufacturers.

To sum up, the issue of the seemingly non-existing circularity of plastics in the furniture industry is so complex that there is not just one problem with one solution, there are many problems and many potential solutions. So far, what can be said to be true about plastic furniture products is that they at best are circular-ish.

From circular-ish to circular

The current situation is circular-ish

The term circular-ish was coined by Joe Iles, Circular Design Programme Lead at the Ellen MacArthur Foundation, and it describes circular design efforts (The Ellen MacArthur Foundation, 2021). In the Circular Economy Show's episode called Circular-ish: the messy reality of circular design, Iles described the state of the current situation as it was also uncovered in this thesis. Some circular economy efforts

> *are well-intended, but they might just be a bit more of an efficiency on today's linear model. Some innovation, let's face it, is kind of in the wrong direction, it may be products where materials are completely mixed up and are inseparable even though they might contain recycled material for example. (The Ellen MacArthur Foundation, 2021).*

So, this seems to be an issue for products in general, and not exclusively for furniture. In this time of transition from linear to circular there are no clear guidelines for what can be said to be a step in the right or wrong direction. However, as explained on the show, the thing about circular-ish is that it is about encouragement, that one at least has started on the journey by for instance making durable products or looking at waste materials (The Ellen MacArthur Foundation, 2021).

Furthermore, it was mentioned on the show that materials are a place where most designers or businesses start their journey towards circularity, as they look at the mountains of waste and decide to do something with that (The Ellen MacArthur Foundation, 2021). It was, however, questioned whether one should turn waste into something just because one can, as it might lead to unintended consequences, as there is the danger that one legitimized waste and creates demand for waste streams, which would not be to take a step towards circularity (The Ellen MacArthur Foundation, 2021). So far in this thesis, using waste materials has been seen as a positive thing to accelerate the transition to a circular economy. However, it should be noted that in a circular economy, there is no waste. So, using waste materials can actually be said to not be circular economy (The Ellen MacArthur Foundation, 2021). Nonetheless, as explained on the Circular Economy show, as of today there is a 200 year legacy of the linear economy that has created enormous amounts of waste, and to take that waste and turn it into a valuable resource is still a good thing although maybe not circular by definition (The Ellen MacArthur Foundation, 2021).

Another interesting topic that was discussed on the show and that taps into one of the three biggest issues identified in the furniture industry was if whether a product that uses good materials and is made for disassembly, but does not have a take back system, is circular. The answer to this question was “no, it is not completely circular, circular is circular by definition” (The Ellen MacArthur Foundation, 2021). So, if there is no take back system for the product, it is not circular by definition. It was however also said that if one however managed to take a linear system and give it a bit of a U-bend, one has done something good and is contributing. That seems to describe the current situation in the furniture industry quite well, although the products are not circular, they at least avoid incineration or landfill for one more use cycle, creating a slight U-bend to the linear system.

All in all, although not yet fully circular, circular-ish products can be said to be better than linear products because it is a step in the right direction. It seems that not just the furniture industry, but all industries trying to design circular products, are designing for a future no one yet knows exactly how will look. The current situation is a linear economy, and the goal is a circular economy, but how to design our way to that future is rather unclear. To sum it up as a quote from the Circular-ish: the messy reality of circular design episode: “We know that the circular economy starts with design, but how do we start designing for a circular economy?” (The Ellen MacArthur Foundation, 2021). This is an important question, which the remainder of this thesis will try to answer, particularly for plastic furniture.

Linearity to circularity - designing for transition

It is not an easy task to design products for an unknown future. Many products designed for the presence, even fail to fulfil their purpose. Nevertheless, design can be said to be “the process of deciding on and then realizing preferred futures” (Tonkinwise, 2015, p. 7). So, it seems that design has the potential to be a powerful tool to build a circular future. The preferred future is the circular economy, and to realize that, one needs to design for the transition from linearity to circularity. To design for transition, is an approach also known as transition design.

According to Tonkinwise (2015, p. 1), “Transition Design assumes that the dominant, or at least dominating, ways of living today are not sustainable.”, which aligns with the observation that the current linear model of take-make-dispose is not sustainable. Furthermore, “Transition Design assumes that designing must play a central role in the systems-level change that our societies need to undertake.” (Tonkinwise, 2015, p. 3). A system-level change is indeed needed to implement a circular economy for plastics in the furniture industry, as systems for closed loop recycling of plastic furniture are absent and reversed logistics seems to be one of the biggest issues, not to forget the absence of other circular initiatives in the furniture industry such as reuse, refurbishment or remanufacturing. Furthermore, design seems to play an integral role as products can be designed to fit into future systems, not to forget that those systems also need to be designed. At last, “A Transition Designer designs something not to be an end-unto-itself, a final solution to a problem, but to open up subsequent opportunities.” (Tonkinwise, 2015, p. 11). That is an important statement that taps into the aim of the circular design guide this thesis will result in. It is a guide that aims to advance and ease the transition to a circular economy. It is not a guide for when a circular economy is already in place, but a guide that can hopefully open up the opportunity for circularity of plastics in the furniture industry and enable designers to design circular plastic furniture.

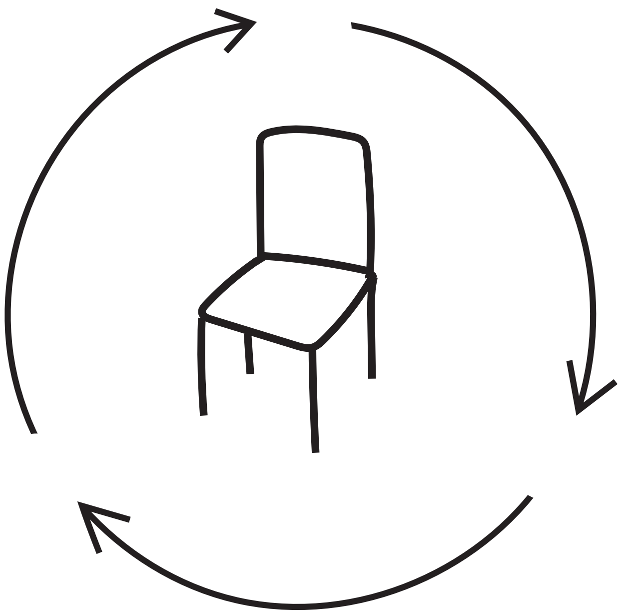
Since transition design is about designing to realize a preferred future, that preferred future needs to be defined. The overall idea of that future is a circular economy, but what that ideal future might entail for plastics in the furniture industry needs to be further investigated before a set of guidelines to design for said future can be developed.

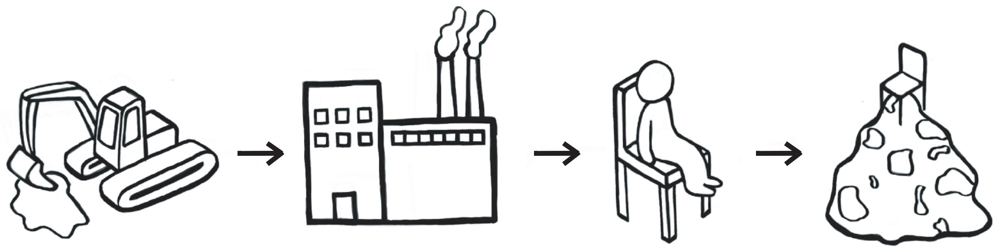
An ideal scenario for the circularity of plastics in the furniture industry

Before a set of circular design guidelines for plastic furniture can be defined, the preferred future of circularity in the furniture industry needs to be described. This section describes the preferred future and changes needed to achieve it.

Method

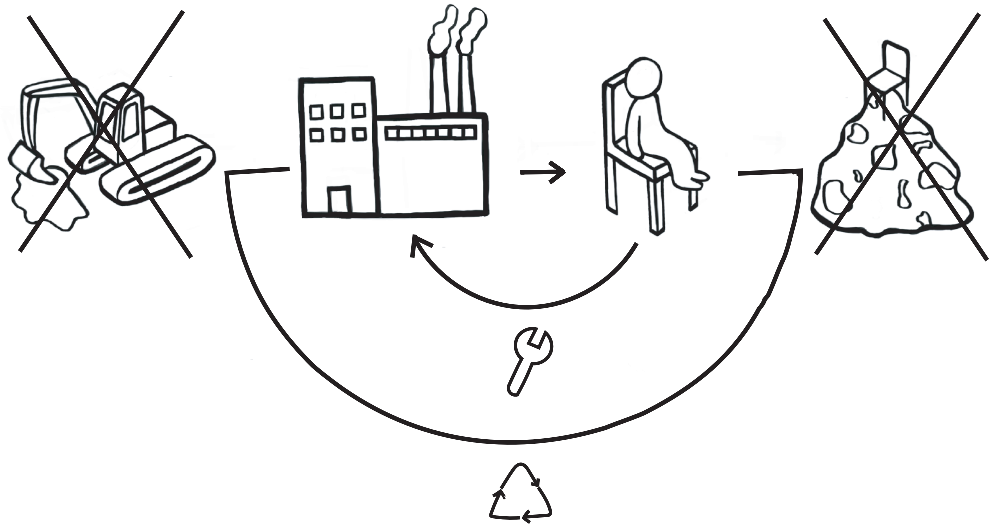
At first a worst-case scenario of a linear model of take-make-dispose was sketched up in order to get a picture of the current situation one wants to change. Then, this sketch was edited to symbolize a circular best-case scenario, the preferred future. Based on this sketch, the needed changes to get from worst-case to best-case scenario were identified and grouped based on what part of the value chain they applied to, such as consumer/user, manufacturer or policymakers and so on. Some literature was also read, to form a picture of measures that would help to implement the needed change and some good examples of more or less circular products, services or systems outside of the furniture industry were found to serve as an inspiration for how to implement circularity in the furniture industry.





The worst-case scenario

This is the absolute worst-case scenario, where fossil raw materials are extracted and used to produce short-lived virgin plastic furniture that is disposed of in landfill, incinerated, or at worst leak into nature. In this scenario, furniture is designed in a way that makes it impossible to recycle, for instance by adding additives or attaching parts from different material together in a way that makes them inseparable at end of life. Furthermore, plastic furniture is either purposely designed for a short life or designed in a way that results in the furniture being disposed of before it has to be, because the furniture is not flexible enough to adapt to changes, for example because it is no longer perceived as fashionable.



The best-case scenario

In the best-case scenario on the other hand, there is no fossil raw material extraction, the raw material used is secondary raw material, meaning recycled plastic. Plastic furniture will not be designed with additives that make it difficult to recycle at end of life, such as fiber reinforcement or dark or strong colors, and furniture will not only be designed for disassembly for recycling, but also for reassembly to allow for repair, refurbishment and remanufacturing. At end-of-life, plastic furniture products will first go into multiple use cycles, before at last, when there is no other option, they will be recycled 1:1 or even upcycled. So, both plastic products are recovered and looped back into the system and plastic material is recovered through recycling and looped back into products again. The use phase is also extended by design, so that plastic furniture is used for as long as possible.

The good examples

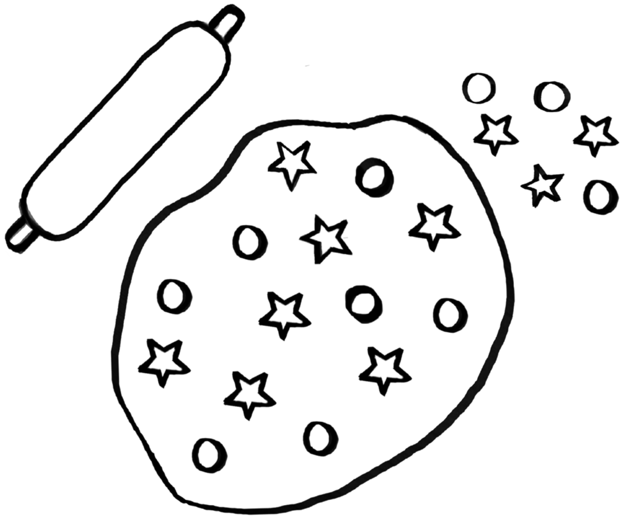
Since there were some good examples in the furniture industry, but none that were exemplary, other examples were looked for in other industries or fields that could provide some inspiration for the future circularity of plastics in the furniture industry. One example of a product, one of a service and one of a system were found.

A product

The product is a packaging product. In general, it seems that packaging is the only industry with good examples of 100% PCR plastic that is recycled 1:1 and not downcycled. It is also worth noting that packaging, unlike furniture, has extended producer responsibility legislations which have contributed to the development of a functioning system.

Frosch is a German cleaning and care products brand produced by manufacturing company Werner & Mertz (Frosch, n.d.). The bottles are made from 100% PCR plastic, and so are the caps (Initiative Frosch, n.d.). Bottles made from 100% PCR plastic are not that revolutionary, but caps are usually made of virgin plastic. So, a Frosch packaging consists entirely of 100% PCR plastic, illustrating that it is possible to create a product from 100% PCR plastic.

Interestingly, Frosch only defines using PCR plastic as recycling. The company speaks about “right” and “wrong” recycling, saying that the only type of recycling that is actually beneficial for the environment is PCR (Initiative Frosch, n.d.). According to Initiative Frosch (n.d.), PIR plastic is essentially new plastic that has never been used, it is simply pragmatism in production. Initiative Frosch (n.d.) refers to Environmental Action Germany (DUH) who explain the use of PIR as when you bake cookies. After cutting out the shapes for the cookies, the remaining dough is rolled out again to make more cookies



until the leftovers are used up, and no one would ever refer to that leftover dough as recycled dough (Initiative Frosch, n.d.). Furthermore, the amount of post-industrial waste has hardly increased over the past few decades in difference to the amount of PCR plastic, which has exploded and still is increasing (Initiative Frosch, n.d.). According to Initiative Frosch (n.d.), it is PCR plastic that needs to be utilized for the environment to benefit, as it is not PIR plastic that is polluting the oceans and nature. PCR plastic needs to be kept in closed material cycles to counteract littering and its unwanted environmental impact. However, the issue is that, as the ISO Standard 14021 illustrates, officially, PIR plastic is defined as recycling. Consequently, every recycled plastic, be it PIR or PCR is also referred to as recyclate without any distinction being made, although the difference in making an environmental impact between the two is huge (Initiative Frosch, n.d.).

A service

Furthermore, a good example of a service was also found, and that is what may be the first ever material as service (Ogoori, n.d.). Ogoori was already mentioned in connection with Vestre's Coast bench. The company offers recycled ocean plastic on a subscription model, with a digital passport using blockchain technology, providing 100% guarantee of origin (Ogoori, n.d.). This material as service model is very interesting as it guarantees closed loop recycling and would tackle the problem facing the furniture industry regarding reversed logistics upfront. If manufacturers can only lease plastic and not buy the material, they will be more inclined to introduce business models such as leasing or renting to secure that they get the products back at end of life because they are accountable for returning the leased plastic material to a company like Ogoori. It would motivate manufacturers to care for end of life because they are obligated to do so, since the used plastic material will have to be returned to the lessor. If plastic material could

not be bought, but only leased by manufacturers, it would probably also change how they use it, they would have to assure that the products are recyclable at end of life.

A system

At last, the Norwegian bottle collection system Infinitum is used as an example of a system. Bottle collection in Norway can be said to be a well-functioning recycling system, as 95% of all bottles are collected and recycled (Infinitum, n.d.). This goes to show that reward driven recycling can be very effective and could also be applied to furniture in the form of a deposit refund scheme where one pays a little extra for the product upfront and get that amount back if one returns the product to the manufacturer at end of life. It is however worth noting that the time factor is quite different for a piece of furniture than for a PET bottle in terms of how quickly one would return the product, and how that would affect or be affected by a deposit refund scheme is difficult to tell. Furthermore, Vestre's new factory the Plus is also worth mentioning as a new approach to putting other circular strategies such as refurbishment into system and integrating it as part of production in the manufacturing company. It should be noted that this has not yet been proven to work, but if it does and is economically viable it is a step in the right direction of integrating circular strategies in manufacturing.

The needed changes

The previous examples highlighted some strategies that could be of interest to building a circular economy for plastics in the furniture industry. However, in order to achieve the best-case scenario, some changes are needed in all steps of the value chain. Overall, it needs to be said that although recycling will definitely contribute to circularity, it will not solve all problems. The overall consumption needs to be reduced and plastic needs to be used in a way that respects and restores its material value.

A change in mindset

To start with the consumers, or users, as one rather should say in a circular economy, they need to change their mindset from "how can I dispose of this product?" to "how can I repurpose this product?", so that when the consumer/user wants to dispose of a product, they consider ways of extending its use if the product is still fully functioning. First of all, however, for that to happen, the consumer/user needs to invest in longer lasting products and there needs to be available circular initiatives that enable reusing the product or its parts.

Furthermore, the manufacturers of the products need to reduce the speed at which they offer new products and instead offer circular services or systems such as repair, refurbishment, remanufacturing or take back. So, manufacturers need to change from a "business as usual" business model that pushes new products, to offering circular services, systems or business models as part of their products. First of all, the products need to be made from recycled plastic, for recycling and with a long lifetime, but although the design of the product is important for its circularity potential, it is essentially "the business and/or consumption model that determines if this potential is fully realised over its complete life-cycle.", so the service that is offered in connection with the product is in fact “as important as the product itself” (European Environment Agency, 2017, p. 40). Furthermore, “If products are part of a service, there are incentives to return them to the provider after use, avoiding stocks of obsolete products in households, or illegal dumping.” and “As products are part of a company’s assets, cost minimisation drives product longevity, reuse, reparability and remanufacturing.” (European Environment Agency, 2017, pp. 14-15). So, in a future circular economy for plastics in the furniture industry, circular business models, services and systems are an integral part of the product in order to keep value within the system (RSA, 2015, p. 11).

Carrot and stick

To motivate the furniture industry to implement such business models, services and systems, changes are also needed at governmental level. There needs to be an extended producer responsibility for furniture manufacturers. “Extended producer responsibility rules create incentives for companies to internalise end-of-life management. Governments provide basic infrastructure and fiscal measures supporting reverse logistics”, which would contribute to systemizing and scaling recycling of plastics in the furniture industry (European Environment Agency, 2017, p. 15). Products should be seen as assets for the manufacturer and end of life of products should be regulated in a way that making products that are not recyclable or not recycled is a financial burden. If products are assets “minimising life-cycle costs is an implicit incentive for a company, inducing a search for the best economic equilibrium between reusing, repairing, remanufacturing and recycling products.”, so it would even encourage other circular initiatives than recycling (European Environment Agency, 2017, p. 14). This does not necessarily mean that all furniture manufacturers should have their own take back systems, but that all manufacturers at least “contribute to the costs of repair or recycling” (RSA, 2015, p. 19). It may be even better if plastic furniture could be recycled in standard facilities, but for that to happen, an extensive and unified standard recycling system is needed, not only at country level, but for example in the case of Europe, at a European level.

Furthermore, what is needed in terms of legislations is a ban on planned obsolescence and short-lived products. As stated by URBANREC, "the concept of a longer lifetime for products is currently not explicitly present in policies and regulations in the EU", with the minimum imposed guarantee being 2 years. Furniture already has a lifespan that is longer than two years, so this guarantee is "ineffective to these products" (URBANREC, 2020, pp. 59-60). So, for circularity in the furniture industry, longer warranties should be provided to encourage longevity (RSA, 2015). Furthermore, the technical lifetime of products, "which is part of the intrinsic properties of the product", should be disclosed by manufacturers (European Environment Agency, 2017, p. 40). Generally, there should be more transparency in the industry, and policymakers can promote that by for instance making it a legislative requirement to state the technical lifetime of products and not just the warranty (European Environment Agency, 2017, p. 41). That would increase transparency and would enable policymakers to create "criteria such as minimum guaranteed lifetime" for products, that in turn could prevent short lived products from being produced (European Environment Agency, 2017, p. 41). So, in a future circular economy, manufacturers are more transparent regarding the lifetime of their products and they encourage longevity through longer warranties, displaying the technical lifetime of products and having services or systems in place to assure that the functional lifetime, "which is determined by the conditions that are created around it", matches that of the technical (European Environment Agency, 2017, p. 40).

Policymakers should also offer incentives to use recycled plastic instead of virgin plastic to advance the transition to a circular economy for plastics by increasing the use of recycled plastic, which in turn also would ensure the needed quality for recycled plastic to be able to compete with virgin plastic.

Circular definitions & information

Another important thing policymakers need to address is definitions in regard to circular economy. EFIC (2020) acknowledges the issue, stating that clear definitions at EU level are needed, amongst others a definition of "recyclable". Furthermore, the European Environment Agency, states that there is currently a "Lack of standardisation and traceability to determine what is considered recycled." (European Environment Agency, 2017, p. 51). That needs to change, and in a circular economy for plastics in the furniture industry, only PCR plastic should be considered recycled.

As was illustrated in the previous chapter, the environmental labels currently in use are not contributing enough to circularity, it would be better if there existed a unified certification system for the industry that is informative, comparable and focused on circularity. A harmonized information tool is needed both to encourage informed consumption and to provide waste managers with needed information about the products to recycle. This type of information should be offered in the form of a bill of materials or a material passport. For waste managers it is of importance to know exactly what materials a product contains and what additives are in those materials in order to optimize reuse and recovery (RSA, 2015, p. 25). Sometimes products will contain problematic additives, or so-called legacy substances, that undermine "the future treatment of the material", and lacking information about those substances is hindering recycling (EFIC, 2020, p. 7). At worst, those substances are recycled and continue to circulate uncontrolled. It is therefore important to know what a material contains. For the future circularity of plastics in the furniture industry, the use of additives that make recycling difficult should be restricted or at the very least avoided by manufacturers. Furthermore, it would be more efficient to have standards and a certification system for recyclates instead of entire furniture products (URBANREC, 2020, p. 60). This way recyclers would need to provide information about origin and composition of the plastic material to the furniture manufacturer, who in turn could display the information in a material passport available to consumers and waste managers.

The future use of circular plastics

Furthermore, furniture manufacturers should not buy recycled plastic but lease the material from material as service businesses, because although products are made for recycling, there will always be some products that end up not being recycled if they are sold and disposal is up to the consumer. Material as service would encourage furniture manufacturers to control end of life of products and ensure recycling, as it is an integrated part of the arrangement. This would probably contribute to streamlining logistics and make sure that the plastic material is tracked and all information about it needed by waste managers is made available. In addition, in terms of waste management of plastic furniture, waste management companies should cooperate with reuse services or systems to ensure that fully reusable plastic furniture is reused before it is recycled (RSA, 2015). In addition, it should generally be easier to reuse and recycle furniture, such as for instance transporting furniture to reuse or recycling stations. Moreover, those return stations should also be designed to encourage consumers to go there to properly dispose of their products, that is for older products that have been bought and not leased or rented.

There has previously been much talk about using waste materials in production, but in theory, in a future circular economy for plastics in the furniture industry there will be no waste, and manufacturers will no longer have to look for new sources of waste. However, in the real world there will always be some waste and loss of resources, so manufacturers should still strive to upcycle waste and turn it into valuable products that are again recyclable at end of life. In the future, the furniture industry should make products that can be mechanically recycled in local recycling facilities, and when those products have been recycled so many times that they can no longer be mechanically recycled, there will be large scale chemical recycling technologies in place to upcycle the material and start the cascade again, ensuring closed loop recycling.

Furthermore, furniture should be sorted based on color. One should probably limit the number of colors to use, but it is not realistic to say that furniture can only be black or white. So, color sorting will be key for furniture recycling in order to ensure that all colors can find an application after recycling and that not all colors end up as black, because different colors mixed together in recycling result in not very appealing colors. So, one can divide colors into three groups. White or semitransparent colors that should be kept that way and not added additives to. Colored plastics should be sorted based on color and the color one gets from that sorting is the color one will use, and then there is black color, which will be the final color for all, because everything can always become black, but black cannot become other colors again.

In an ideal future circular economy for plastics there should not be much, if any, virgin plastic, so recycled plastic would be able to compete with virgin plastics on price, but it should also be able to compete in terms of quality, which will be possible when you have functioning closed looped systems for recycling. In the future there should exist infrastructure for large scale recycling of plastic furniture, and sourcing should no longer be an issue because one will have easy access to high quality recycled plastic in reliable streams. Plastic furniture should be recycled, it does not mean that a chair has to be recycled into another chair, but 1:1 recycling will be possible in terms of recycling furniture into products of equal quality. So, in a future circular economy for plastics in the furniture industry there should both be a well-functioning recycling system and a well-functioning secondary raw material market.

What about the designer?

The question arises of how products will look if all of the above were to be in place, and what the role of the designer is in making all of the above happen. It seems that designers will also have to change how they think design, as most products today are linear by design. Designers also need to change their mindset from being concerned with how a product looks, to being more concerned with how it can function in a circular context. Designers need to change how they perceive a product and broaden their field of expertise to also cover circular systems. So, the next step would be to answer the following question: What would a design guide for all this look like?

As stated by the European Environmental Agency: “Product design determines to a large extent the longevity, reparability, recyclability, proportion of recycled and renewable material in the product, and its suitability for refurbishment or remanufacture. Product design therefore determines the circularity potential of a product” (European Environment Agency, 2017). A design guide is needed that can help designers design plastic furniture products that fully realize their circularity potential.

At last, it should be said that two strategies are needed to make plastic furniture circular, one for products already on the market and one for new products that have not yet been designed, as explained by EFIC: “A different approach will be needed for products that have already been manufactured (today’s waste) and products that will be manufactured in the future (tomorrow’s waste)” (EFIC, 2020, p. 8). Going forward, the circular design guide presented in this thesis will focus on the latter, as the approach for tomorrow’s waste is more focused on the actual design of products. Today’s waste already is waste in difference to tomorrow’s waste that can still be prevented. It therefore seemed more important for designers to prevent tomorrow’s waste, although a solution of course also is needed for today’s waste.

Research: What does a circular design guide look like?

Method

Based on the interviews and case study, a picture had already been formed about what is important for circular product design. Nevertheless, before writing the circular design guide for plastic the use of plastic in furniture, which is the result of this thesis, research was done to form a picture of already existing design guides, especially circular design guides. This was done to find inspiration on how to shape and structure the guide and for inspiration on what to include in it. It is worth noting that no circular design guide that was specific for plastic furniture could be found. Therefore, other guides that seemed relevant were found, such as guides for furniture, plastic or circular economy in general.

23 different design guides were read. Not all of them were specifically defined as design guides, some were called strategies, criteria, principles, frameworks, standards or approaches. Some of them focused generally on product design, others on circular design and a few on eco-design. Circular design and eco-design are not necessarily the same, as eco-design focuses on improving the present whereas circular design focuses on designing for an ideal future that has not yet been realized. However, given that EU agencies refer to eco-design in regard to design for a circular economy, some sources on eco-design guidelines were included as well.

The reviewed guides range from being rather general in terms of design to being meant for a specific product group or material. Most guidelines were generally for the full life cycle of a product, whereas a few were mainly focused on the use phase or end of life. Furthermore, theoretic guides written by academics were included as well as guides from organizations/projects, manufacturing companies or designers. This research was purposely not done as a literary review restricted to academic literature, as the result of this master's thesis is meant to be a circular design guide for practicing designers working for the industry, and as this thesis previously has shown, what is possible in theory is not necessarily doable in the real world. So, since this guide is meant to be used in the real world, it should not only be based on theory.

The different guides

The Academics

Seven sources from academics were included, these were

- → Design Guidelines to Develop Circular Products: Action Research on Nordic Industry (Shahbazi and Jönbrink, 2020)
- → Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy (Mestre and Cooper, 2017)
- → A product design framework for a circular economy (van den Berg and Bakker, 2015)
- → Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms (den Hollander et. al., 2017)
- → Use to use – A user perspective on product circularity (Selvefors et. al., 2018)
- → Design of resilient consumer products (Haug, 2016)
- → Six Design Strategies for longer lasting products (den Hollander, 2021)

These sources were either focused on circular product design or on design for products to last and be used long. They were read to understand the theory of circular product design and how to design products that both last and remain in use for long, which from the findings in previous chapters seemed to be a topic worth investigating further. Furthermore, guidelines written by academics were read because academics most likely are the least biased. Guidelines from manufacturing companies are probably designed to profit the company, and organizations or projects often have a specific purpose, and possibly also an underlying agenda. So, reading academic guidelines gave an impression of what in theory are the most important guidelines.

Some of the guides were quite simple, understandable and to the point with clear guidelines and even design models to illustrate them, whereas others were quite elaborate and complicated with rather confusing design models. For example, A product design framework for a circular economy (van den Berg & Bakker, 2015) had a good and understandable structure with models that helped to illustrate and understand the guidelines. Another good example is Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms (den Hollander, et al., 2017), which has previously been used in this thesis for the theory on product integrity, it explains the theory of circular design in an understandable manner, accompanied by a simple and understandable model. All in all, the overall takeaway from reading the academic guides was that the circular design guide developed for this thesis should not be too academic, it should resemble popular science literature in order to be something designers can benefit from using while actually designing a product.

The Organizations / Projects

Furthermore, five sources from different organizations or projects were read, these were

- → Guidelines for circular product design and development (CIRCit Norden, n.d.)
- → Strategies for Circular Design (The Ellen MacArthur Foundation, n.d.)
- → Circular Product Design Framework (Circle Economy, n.d.)
- → Qualitätsstandards für Circular Design (Gründl, et al., n.d.)
- → Ecodesign Guideline (URBANREC, n.d.)

The last one, which is an ecodesign guideline and not for circular design, was included because it is meant for bulky products, amongst others for furniture. These sources were all in all a bit more popular science based than the academics, and some of these seem to be meant as tools for practicing designers as well.

Overall, some of them were too simplified and not detailed enough to the point where it might become confusing if the designer has no background knowledge of circular economy, whereas others that did have very precise guidelines ended up being too long and elaborate. Some of these guides also had a set of specific guidelines for the use of recycled materials or materials in a technical cycle that were very useful. For instance, CIRCit's guidelines were very precise and understandable, but the guide has 49 pages, which is quite a lot. Whereas for instance the Ellen MacArthur Foundations strategies for circular design were short and understandable. What both these had in common which was also helpful was that they used examples to illustrate the guidelines. All in all, the main takeaway from reading these guidelines is that the guide needs to be detailed enough to make it understandable, but it should not be too long.

The Industry

Some industry specific guidelines were also included, three from the furniture industry and three from the textile industry. The textile industry was also included as it faces some similar issues to those of the furniture industry, such as composite materials that are difficult to recycle. The textile industry guides were

- → 10 Principles of Circular Design (NIKE, n.d.)
- → TEDs Ten (Politowicz & Earley, n.d.).

The three furniture guides were

- → Circular Product Design Guide (IKEA, n.d.)
- → Eco Design Criteria (Flokk, n.d.)
- → Design principles (Wilkhahn, n.d.)

The guides for the textile industry had some industry specific guidelines that are not as important for furniture, but the overarching topics were more or less the same. The furniture manufacturers' guides can be said to reflect what is important to the specific company. Nevertheless, it was important to also look at some guides that are in fact used in practice in difference to the academic guides, to see what manufacturing companies, for which designers will design products, find important in terms of circular design. Especially IKEA and Flokk's guides were used as an inspiration as they both had simple, understandable guides and both companies also happen to produce plastic furniture. All in all, the main takeaway here is that the guides used in the industry are quite simple and short, yet specific and understandable, and so should the circular design guide for the use of plastic in furniture be, but it should not be too commercial, the focus should rather be more educational.

The designers

Furthermore, three guides by designers or design studios were included as well, these are

- → 10 principles for good design (Rams, n.d.)
- → Circular design guidelines (Diez, 2021)
- → Åtte designprinsipper for en mer sirkulær verden (Norwegian Trash, 2021)

When talking about design guides it seems almost mandatory to include Rams' 10 principles, and Diez's guide is so to speak a remake of Rams', but for a circular economy. These guides served to give an impression of what designers themselves find to be important, and to get a picture of how that has changed over the last decades. Especially Ram's and Diez's guides were used as an inspiration. These guides were good in terms of shape and structure and were also taken especially into consideration since they are made from designers for designers. All in all, the main takeaway from these guides was the way they are written and structured. The guides written by designers are simple and helpful, explaining what is important for the designer to understand. Furthermore, they are simple in structure, which separates them from many of the other guides that were quite complex, if not even complicated, because they consisted of overarching guidelines with an elaborate set of more guidelines for each of the overarching ones, or they had multiple design models in addition to the guide. The guidelines designed by designers were, on the other hand, to the point, with no extra fuss.

Plastics

At last, three guides specific for plastic as a material were read as well since no guides meant specifically for plastic furniture could be found. Two of these guides were for packaging, since that is the industry with the most well-functioning plastic recycling systems. The plastic guides were

- → Basic Facts Report on Design for Plastic Packaging Recyclability (Grønt Punkt Norge, 2017)
- → Circular Packaging Design Guideline: Design Recommendations for Recyclable Packaging (FH Campus Wien, 2020).
- → For Better not Worse: Applying Ecodesign Principles to Plastics in a Circular Economy (ECOS, 2019)

The packaging guides were extremely long, with 60 to over 70 pages each. The good thing was however that they in detail focused on designing for recyclability of the plastic material. ECOS's guide was also rather long but had an understandable model and corresponding guidelines. Moreover, what made ECOS's guide especially interesting was that it was not only meant for packaging, but also for other longer lasting plastic products and the guidelines focused on the entire lifespan, not only on recycling. All in all, the main takeaway from these guides was the importance of certain guidelines for designing plastic products.

Other sources

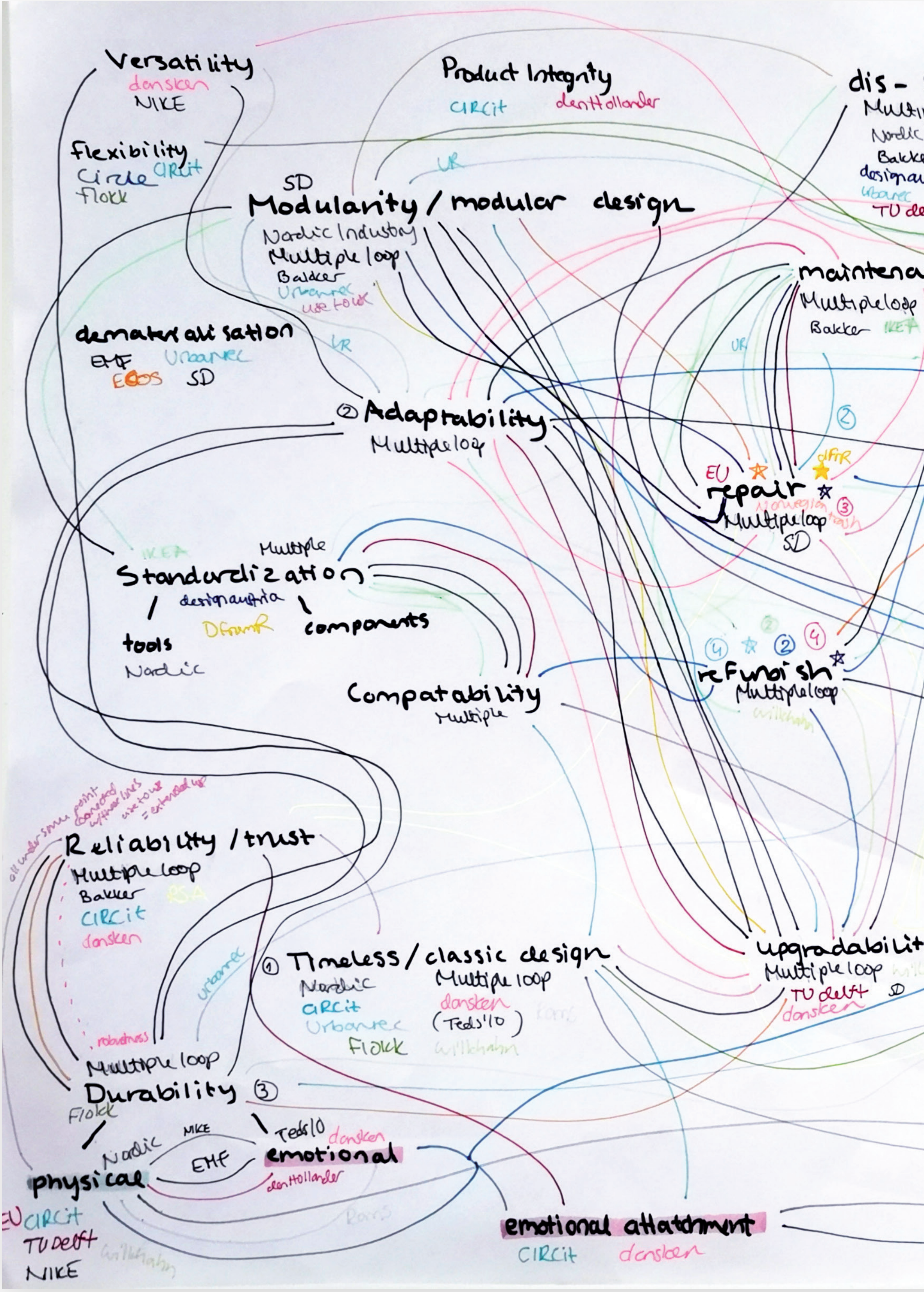
In addition, some other sources that were not necessarily defined as circular design guides, but were relevant to either plastic or furniture, such as

- → The Design from Recycling Manual (Du Bois, et al., 2018)
- → Rearranging the Furniture (RSA, 2015)
- → Circular by Design: Products in the Circular Economy (European Environment Agency, 2017)

were also used as an inspiration for the circular design guide.

Analysis

While reading all the different design guides, recurring overarching strategies or topics of guidelines were written down. After reading all sources, similar topics were combined and in total 34 main topics were identified. These were written down and lines were drawn between the ones that were mentioned in connection with each other, meaning for instance that one guideline could be about both adaptability and upgradability, then a line was drawn between the two main topics "adaptability" and "upgradability". If a guide mentioned one topic not in connection with another, a remark was written close to the topic. Every design guide had a different color, to also have an overview of which guides connected what topics. The order the different main topics were mentioned in as guidelines in a guide was also marked by writing the number that guideline had in the guide in the color of that design guide next to the main topics. After this mapping was done, the number of times the topics were mentioned, both in connection with other topics and alone were counted. A distinction was made between those that were mentioned more than ten times, those that were mentioned between five and ten times and those that were mentioned between three and five times. Furthermore, how many times a topic was mentioned as the first, second, third and so on guideline was also counted.


Versatility
danskan
NIKE
Product Integrity
CIRCit
denHollander
Flexibility
Circle
CIRCit
Flokk
SD
Modularity / modular design
Nordic Industry
Multiple loop
Bakker
Urbanrec
use Folk
dematerialisation
EMF
Urbanrec
ECOS
SD
UR
Adaptability
Multipleloop
maintena
Multipleloop
Bakker
IKEA
EU
repair
Multipleloop
SD
Standardization
Multiple
IKEA
designaustria
DfRMR
tools
Nordic
components
Compatability
Multiple
refurbish
Multipleloop
Reliability / trust
Multiple loop
Bakker
CIRCit
danskan
Timeless / classic design
Nordic
CIRCit
Urbanrec
Flokk
Multiple loop
danskan
(Teds'10)
Wilkhahn
upgradabilit
Multiple loop
TU delft
danskan
SD
Multiple loop
Durability
Flokk
Nordic
NIKE
EMF
Teds'10
danskan
emotional
denHollander
physical
EU
CIRCit
TU Delft
NIKE
Wilkhahn
emotional attachment
CIRCit
danskan

ECOS DfromR
reassembly
easy
quick
Teds10
Flokk
(re)cyclability
EU
recycled
designaustria
Urbanrec
NIKE
DfrR
ECOS
Flokk
DfR
recyclable
Norwegian trash
Aesthetic
Teds10
Safety / safe materials
EMF NIKE Ted's10 Flokk Willkhahn
SD Norwegian trash ECOS Nordic Circit
reuse
Multipleloop
sourcing / raw materials
CIRCit ECOS Urbanrec
Technical cycle
Urbanrec designaustria
Willkhahn
changable parts
all 3 connected
SD long life
repurpose / recontextualize
Multiple loop
use to use
Lifetime / lifespan
technical
CIRCit
designaustria
EU
functional
Urbanrec
aesthetic
CIRCit
remanufacture
Multipleloop
IKEA
Monomaterials
Bakker
Circle Urbanrec
Teds 10 NIKE
Color
Urbanrec
GP FH Wien
Additives
FH Wien
Circit
Services
Multipleloop
EMF
designaustria
Teds 10
SD
Business model
Urbanrec EU
Quality
Norwegian trash
Willkhahn Flokk
design austria EU
Circular potential
Nordic
longevity
Teds 10
technical
subjective

Result

The overarching topics that were mentioned ten times or more were:

- → durability
- → modularity/modular design
- → adaptability
- → timeless/classic design
- → dis- & reassembly
- → maintenance
- → repair
- → refurbish
- → upgradability
- → remanufacturing
- → (re)cyclability/recycling
- → safety/safe materials.

The terms that were mentioned between five and ten times were:

- → standardization
- → reliability/trust
- → reuse
- → repurpose/recontextualization
- → compatibility
- → emotional attachment
- → lifetime/lifespan
- → mono-material
- → longevity
- → services
- → business models
- → repair and maintenance

Furthermore, the following connections were mentioned between three and five times:

- → standardization and compatibility
- → reliability/trust and durability
- → adaptability and upgradability
- → dis- & reassembly and refurbishment
- → modularity/modular design and upgradability
- → modularity/modular design and repair
- → modularity/modular design and remanufacture

Reuse or refurbishment were usually mentioned in one of the first guidelines, followed by remanufacturing, whereas recycling was usually used as one of the last guidelines.

The mapping served to show that circular strategies such as repair, upgrade, refurbishment, remanufacturing, reuse and repurpose/ recontextualization are important to design circular products and that they are connected to how the product is constructed in term of for example design for modularity and dis- and reassembly. Furthermore, less tangible traits are also important for circular products, such as reliability/trust, emotional attachment and timelessness. All in all, multiple product characteristics were important to design a circular product, such as durability, adaptability and modularity. In terms of plastic, using safe mono-materials that are recyclable were important according to the sources. It should however be noted that the minority of the sources were focused on plastics, and that is why plastic related topics were not mentioned that often.

Based on the mapping and counting times the different topics were mentioned, a picture could be formed of what seemed to be the most important overarching topics to include in a circular product design guide. Furthermore, it served to give an overview of how different guidelines combine different strategies, and to see which were the more common combinations. So, this analysis served as an inspiration on how to combine different strategies or topics under one overarching guideline. In other words, it served as an inspiration on how to structure guidelines that could be important for plastic furniture. An assessment was made of which of the topics would be relevant for plastic furniture, and these were included in further work on the circular design guide for plastic furniture.

Reflections

There are many other sources on the topic that could have been included in this research, but the main focus was on guidelines specifically focused on product design. Therefore, guides that were more focused on the business side of circular economy were not included since the circular design guide that is the result of this thesis first and foremost is meant for designers to design circular products, although designers of course also can and should propose new business models as an integrated part of circular products.

Designer Interviews

Theory and practice are not necessarily the same thing, so after conduction the research on relevant circular design guides, some practicing designers were interviewed as well to see what is being done in practice to contribute to the circularity of plastics in the furniture industry. These interviews were conducted in order to see what experienced product designers find important and how they implement circularity in their design practice, to learn from them and include it in the circular design guide for the use of plastic in furniture.

Method

The interviewed designers are either experienced with designing plastic furniture, some have also designed plastic furniture from recycled plastics, and/or have developed a circular product design guide. For all interviews there were some general questions about design for the circularity of plastics in the furniture industry and design of circular products. Then, for those that had experience with designing plastic furniture, there were some questions regarding experience with recycled plastics. Furthermore, those that had designed circular design guides were asked questions about those guides.

All interviewees have given their consent to use their full name, job title and answers to the interview questions in this thesis.

The interviewees

Kjersti Kviseth

Kjersti Kviseth was the first designer interviewed. She was the first sustainability manager at Flokk and has been working with circular design and sustainability ever since. Kviseth designed Flokk's circular design guide, that is still in use today, in the nineties. She was interviewed about that design guide, which even after almost thirty years, is still relevant. The interview was conducted via Teams and lasted about an hour.

Konstantin Grcic

Konstantin Grcic is a well-known, award-winning industrial designer who has designed famous plastic furniture products, and his latest plastic furniture design was the Bell chair for Magis, which was used in the case study in this thesis. He was interviewed because of his experience with designing with plastics. The interview was conducted via Teams and lasted about 30 minutes.

Francesco Canesi Lissoni

Francesco Canesi Lissoni is a designer and partner of Lissoni & Partners. Lissoni & Partners is experienced with designing plastic furniture and was therefore interviewed. The interview was conducted via email.

Stefan Diez

Stefan Diez has already been introduced in the first chapter of this thesis. The topic of this thesis has been discussed with Diez along the way, but a formalized interview was also conducted to get his opinion on the topic, not only as my external supervisor, but as a professional designer. Diez was interviewed both because of his experience with designing plastic products and because he has consciously been designing for circularity for years and based on many years design experience has developed a circular design guide. The interview was conducted via Teams and lasted about an hour.

Jasper Morrison

Jasper Morrison is one of the most influential industrial designers of the last decades and he has also designed famous plastic furniture. Amongst others, he designed Alfi for Emeco, which was used in the case study in this thesis. Morrison was interviewed because of his experience with designing with plastics. The interview was conducted via email.

The designer's role

All interviewees were asked how they think designers can contribute to building a functioning circular economy for plastics in the furniture industry. Kviseth (2021) said that designers "have an amazing opportunity to be part of creating good change, we have both the responsibility and opportunity because designers have the skills that are so to speak the hub of the wheel". Furthermore, she said that designers need to "expand their area of expertise to also apply to sourcing of recycled material, and to choose something that can live another life after the chair. Planning systems becomes more important than designing a chair." (Kviseth, 2021). Kviseth explained that the designer's role is no longer that of a stylist, but that designers need to understand how plastics circulate in society and be more interested in fields such as chemistry and material science. She also pointed out the importance of working in interdisciplinary teams. Furthermore, Lissoni (2021) mentioned that products need to be designed to last long, both functionally and aesthetically. He also pointed out that "Plastic is an amazing material if used correctly and is not an enemy per-se.", one needs to however use it for products with a long lifetime.

Morrison (2021) started answering the question with an interesting statement:

> *I think it needs to be said from the start that furniture is one of the more positive industries for the use of plastic. Products have a long useful life and can mostly be recycled at the end of it. Plastic furniture is at the other end of the scale to single use plastics and other oil-based products like gasoline. Having said that there are more and more recycled and reclaimed plastics available for use in manufacturing furniture and these are already being widely adopted as interesting materials by designers. I think the design industry is on course for a healthy and sustainable future and has a lot less to do than the fashion industry.*

In terms of what the designer can do, Morrison (2021) said that “Designers can propose the use of recycled and reclaimed plastics but it is essential that the companies accept to use them, so I think designers need to encourage manufacturers to adopt such materials.”. Diez (2021) also shared this view, saying that “designers should use plastics that come from recycling processes”, and make sure that one chooses plastics that have circular material cycles.

Furthermore, Diez (2021) said that products should be built for easy disassembly, because “the easier that is, the better it is for recycling”. He also mentioned that designers can consider how to make it easy to bring plastic products back into the material cycle. It might not be that connected to the product itself, but according to Diez (2021) designers could also “design the recycling stations”. He thinks it is necessary to design the places where people bring back their products, as those are places that trigger consumer behavior, similar to how one has designed shopping malls, the places where people buy products. Furthermore, designers can also propose systems where products remain in the ownership of the manufacturer, but as he said designers cannot create such a system alone without the company. Similarly, Grcic (2021) said that “the designer is kind of an intelligence in that system, so the designer’s voice should be the kind of voice that is a form of corrective, but the designer alone can’t change the system.”. So, it seems that to build a circular economy for plastics in the furniture industry, designers should of course influence the circularity of products they design, but should also contribute to designing the systems those products will exist in.

The biggest obstacle

All interviewees were also asked what they perceive to be the biggest obstacle to get plastics to circulate in closed loops in the furniture industry. Grcic said that the quality of recycled material for the use in furniture is an obstacle, because it is just not the same as virgin plastic. Kviseth also mentioned quality and said that an obstacle is to find a resource that you can recycle to be used again and that you have a reliable access to that material. Furthermore, she mentioned that “chemical content, colors and additives are huge challenges in order to have clean materials” (Kviseth, 2021). Kviseth (2021) explained that one often does not know what a specific color contains so when that colored plastic is recycled, “you continue to put possible problematic substances back into circulation and spread it even more and that is a huge challenge”. Lissoni (2021) also tapped into the issue of additives saying that the use of composites is an obstacle, explaining that “with fiberglass reinforced plastic chairs, we can’t separate the two components and basically, we can only trash the broken product.”. He also said that disassembly is another issue, that many products are designed in a way that makes it impossible to separate different materials.

Morrison (2021) said that “the biggest obstacle is how to deal with the ensuring that once a plastic product reaches the end of it’s useful life, that it gets recycled.”. Diez (2021) also addressed an end-of-life obstacle saying that “currently the biggest obstacles are missing plastic material cycles.”. He explained that plastics is usually downcycled in the recycling industry. Another obstacle Diez (2021) mentioned was that “recycled plastic is usually more expensive or very similar in price to a new plastic because the recycling process is relatively expensive and the oil price is relatively low, so if you asked the industry they would prefer new plastic.”. So, it seems that the biggest obstacles are the quality of the recycled plastic material, additives that are added to it that complicate recycling and to ensure that the product is actually recycled at end of life, meaning that there exist systems for recycling it.

Designing for a non-existing system

The designers were also asked what their advice would be for designing products for a system that does not exist yet, since there currently does not seem to exist a circular economy for plastics in the furniture industry and systems for recycling plastics furniture are not yet established, at least not on a large scale. Lissoni recommended to not use composites, to apply modular design and to make disassembly easy. Morrison (2021) also addressed the topic of easy disassembly saying that

> *The recycling industry is far from perfect at present but in 20 or 30 years when oil resources are more scarce the value of a plastic chair to the recycler will be much higher than it is today, so I try to design for long life and easy disassembly and hope that things will be better organized by the time my products reach the end of their lives.*

Diez (2021) on the other hand, said that he would "suggest designing kind of more a vision than a product, I mean something that's not existing yet but we have somehow even a vague idea about how it could look is for me a great starting point".

Grcic (2021) replied that "Well, we have to work on designing that system". Furthermore, he said that it addresses everyone, because everyone is part of the system. He explained that

> *As a designer, I have to anticipate and build this into the product, as the producer I have to kind of enable this system by saying yes I am responsible, I put it out, I also take it back, the consumer has to be the one who is willing to bring it back or take it somewhere and sort of adopt to these systems. (Grcic, 2021)*

Grcic (2021) also pointed out that "the main responsibility is certainly on the producers, and they should be the ones made responsible for bringing back products that they have produced.". Kviseth (2021) also said that we need to design the collection systems and infrastructure, and pointed out that it is not something designers can solve alone, "both social, political, economic and cross-industrial measures are needed". She also, in that regard, pointed out the importance of material passports because "it will take 10 to 20 years before there are any systems in place and then no one will remember what was in that chair" and it will no longer be given that the additives in that chair should be reused (Kviseth, 2021). So, it seems that the products should be designed so that once systems are in place, they are ready to circulate within those systems. What is more, those systems also need to be designed.

Design to prolong life

The designers were also asked how they design to prolong the lifetime of their products. They all found this challenging, because predicting the future is difficult, as Lissoni (2021) explained, they try to design

> *objects with a precise identity but at the same time silent and not too related to temporary vogues. Said this we can't decide if we're going to make a so called "icon", we can just try to design stuff that won't become quickly obsolete.*

Kviseth (2021) also said that "there is no recipe for how to do it, for the technical part yes, but how to design to make people love something for 50 years is very difficult, there is no recipe for that.". Furthermore, she said that "designing something timeless is difficult, because timelessness for me can be something completely different for you." (Kviseth, 2021).

Grcic (2021) also talked about timelessness, but he said that

> *I don't think making sure that something will look good for a long time, the answer to that is not thinking about timelessness, I think always simplicity is the best answer to this, making sure things are simple and logical and well maybe even better than simple and logical is authentic and honest, straightforward.*

Furthermore, he said that products

> *have to be built in such a way that it guarantees this long lifecycle and use, but the other aspect and the more difficult one of course, it's the product looks or aesthetics or form because we all know that we follow fashions and something that you like today is not necessarily something that you still like in five years. (Grcic, 2021)*

Morrison (2021) also shared this view saying that "It's a two horned beast". He explained that "one is the physical durability of a product and the other is the visual longevity an object does or doesn't have. I try to design things that will look good and relevant for decades.".

Furthermore, Diez explained a third reason for why things become obsolete, and that needs to be taken into consideration to design to extend the life of products and influence product integrity.

I think there are several aspects that make a product wear out, one is that it breaks, then it has to be replaced, that's the worst. Then there is aesthetical wear out, or that things become obsolete because people are no longer interested in the use, that is the third thing. So, it's either aesthetic, the use case has changed, or the product is broken (Diez, 2021).

He explained the third point by saying that "you can as a designer design a product in such a way that it can adapt to different use cases" (Diez, 2021).

Diez said that designers can also design products to resist aesthetic wear out, which is especially important for plastic products, which are seen as disposable because of the cheap material. He explained that

it's difficult to make a good plastic chair that is valuable enough that people are willing to really keep them for a long time, because plastic has the image of something which is cheap and if you look at the prices of chairs it's also the case that plastic chairs are the cheaper chairs. (Diez, 2021)

Furthermore, he also explained that one can design for emotional durability, by designing products "in such a way that it enables the user to create a relation to the object". Diez (2021) said that "I really strongly believe that all the love and care that you invest as a designer in a product can be recognized in that product and can charge it emotionally". He also said that it is difficult to describe in detail how to do that, but that it is "the ingredient we designers are the ones that contribute the most to." (Diez, 2021). So, designing to prolong the life of products does not seem to be easy. There are some measures one can take as a designer, but there is not a one size fits all recipe for succeeding.

Design for end of life

Designing for end of life is also an important factor, as eventually, although one can extend the lifetime of products, all products become obsolete. The designers were therefore asked how they design for end of life of a piece of furniture. Lissoni said what he had already mentioned a couple of times, to not use composites and make it easy to disassemble different components. Kviseth and Morrison also pointed out the importance of designing for easy disassembly. Kviseth (2021) also mentioned that the designer should be “part of shaping and planning and proposing the end of life system so that the product is adapted to that”. Grcic (2021) also mentioned the importance of easy disassembly, and also said that “the best thing is if the product is a mono-material product, then the whole product can be thrown into a shredder and that’s it”. Diez said that it is difficult to control what happens to the product one designs at end of life, but that one could for instance encourage the manufacturer to implement a deposit refund scheme to bring the products back. So, it seems that easy disassembly was overall agreed upon as important for recycling at end of life. To use pure materials and to design end of life systems is also important to assure that once disassembled, the product can be recycled.

Change in approach to plastic

The designers that have been and still are designing furniture out of plastics materials were asked if their approach to or way of designing using plastic has changed in recent years, and almost all said yes. Grcic (2021) said “Yes, definitely, it has changed because when I started using plastics, I didn’t think at all about the precious resource and the problem of that and so that has definitely changed.”. He also said that the question now is “how can we avoid plastics by replacing it with adequate materials, different materials.” (Grcic, 2021). Morrison (2021) also had a similar experience, saying that

I think so, early on in my career, in the 80's and 90's there was not much discussion of plastic being a problem, the discussion has been growing and I have been looking for interesting recycled material for quite a while.

Diez (2021) also said his approach has changed

Yes, I think so, I think we are more careful, we use mono materials and even when we are making a product which has multiple components made from plastic, we try to make them all in the same color, preferably all black and from the same material, we always make them black and that you can always recycle.

He also mentioned that

I never designed a plastic chair because I was so against it, now I will design a plastic chair because it will be made from recycled plastic, which is an ocean plastic project, which I think makes sense for the moment. (Diez, 2021)

Lissoni on the other hand, replied that the approach has not changed particularly. So, it seems that designers have become more aware of the problem plastic can cause if not handled properly.

Designing with virgin vs recycled

The designers were also asked if using recycled plastics change the way they design in difference to when they use virgin plastic. Morrison (2021) answered ”Yes and no, there are somethings which you can’t do with recycled plastic because it’s less strong, but there are a lot of things you can do.”. Diez (2021) said that it does not change much because “a good recycled plastic has very similar qualities to virgin plastic”, he also said that “otherwise you probably need to make things a little bit thicker or have a bit more ribs”. Grcic (2021) said that the inferior quality of the material is the biggest difference, “so in the design process you have to either take that into consideration or it kind of prevents you from using it.”. Kviseth (2021) also shared this view, saying that you have to “think a bit differently to make it right in relation to the material.” Whereas Lissoni (2021) said, about PCR plastics, that “if you want to use them to create an aesthetic product, you’re going to crash into many problems and limits. Most of these materials are not aesthetically appealing”.

Interestingly, Grcic (2021) had another approach to the issue of aesthetics of recycled plastics saying that recycled plastics “comes with a certain aesthetic that determines maybe texture, also colors, maybe a kind of porosity and I think it’s interesting how all of this can be turned into a quality almost.”. Furthermore, he said that

> *this idea of a patina, of the traces of use and age on plastic has always been a problem, it’s always been an obstacle it seems, and I think now it has really turned around, now we see it as it brings life to this synthetic material and I think that’s big progress we’ve made in accepting this, I think this is a big breakthrough. (Grcic, 2021)*

Diez also shared this view, saying that designers should accept the downsides of using recycled plastics. Designers should *give up the idea of having a particular yellow or a particular red, it's OK to have a yellowish chair, a reddish chair and bluish chair and in a certain bandwidth we accept it and we're still accepting a kind of arbitrariness, a kind of coincidence. (Diez, 2021)*

He also said that if designers accept that aesthetic, that "We could reuse much more plastic than before." (Diez, 2021). In this regard, Diez also said designers should look more into using standard plastics, and less high-end plastics. So, it seems that there is a difference between designing with virgin and recycled plastic, and that one needs to approach using recycled plastic a bit differently, especially in terms of aesthetics.

The biggest challenges of designing with recycled plastics

The designers were also asked what they perceived to be the biggest challenges with designing for recycled plastics. Diez (2021) said that "To find a recycling process that is working, that is the biggest challenge.". Whereas Lissoni (2021) said that "You basically have to play with the look and production issues of the material / processing technology to create something appealing within the limits.". Similarly, Grcic (2021) said that "you have to adapt to the conditions of the material", but that he does not see any challenges. At last, Morrison (2021) said that "Strength and colour options" are the biggest challenges. Those two challenges have previously also been mentioned by the other designers. So, it seems that there are some challenges regarding limitations of recycled plastic, but that these challenges are not insurmountable. It is also worth mentioning that all designers were also asked if they liked working with recycled plastics despite the challenges, and they all said yes.

The biggest challenges of designing recyclable plastic products

To use recycled plastic does not necessarily guarantee that the product is recyclable, as many things can be done or added to the product to make it difficult to recycle. The designers were therefore asked what they see as the biggest challenges to designing recyclable plastic products. Morrison (2021) said "Nothing special, I think it just takes a bit off thought to find ways to use it that won't be a structural issue.". Grcic (2021) said that "the biggest challenge is determining that end of life", because

> *it's determined by users that start to not like the thing anymore and throw it out and of course failure or breakage could be a determining factor, but normally you wouldn't consciously build this into the product, and you can never determine it exactly.*

Lissoni, on the other hand, again mentioned disassembly, to build products so they can be disassembled, and composites. At last, Diez (2021) said that the biggest challenge to recyclability is "the aspect of color". He also mentioned another challenge, which is that "there are really not a lot of options in the plastic field yet, most of the plastics don't have closed loops.", which also poses a threat to that the products are actually recycled, although recyclable (Diez, 2021). So, it seems that the challenges are both related to the material in terms of additives that make recycling difficult, and to end of life in terms of how to assure that the product is actually recycled.

Additives and colors

The designers were asked how they relate to and work with additives and colors when designing plastic furniture, as additives and colors are a well-known issue regarding the recyclability of plastic furniture. Morrison (2021) said that "Yes, it's true. There are not always the ideal colours or finishes, and sometimes they seem a bit like they are trying to tell the world they're recycled materials.". Furthermore, Diez (2021) said that designers "should avoid specific additives", meaning additives that make it difficult to recycle the recyclable plastic material, such as glass fibers and certain colors. Grcic (2021) also agreed, saying that "First of all you try to avoid additives, softness or reinforcements, it's not as easy as it sounds, you can't simply say no additives or no reinforcing, you'd have to go up in material thickness or strength.". He also explained that

> *The nice thing when you are able to avoid reinforcement is that you get a much nicer quality of the plastic because glass fibers tend to kind of raise to the surface and you see markings of the fibers, it distorts the color. (Grcic, 2021)*

Kviseth mentioned the issue of colors and additives as one of the biggest obstacle to get plastics to circulate in the furniture industry. So, it seems that additives and colors are challenging because they compromise recyclability, and designers are aware of it, but that additives sometimes cannot be avoided.

To continue using virgin plastic or to not continue

Since all the designers like using recycled plastics, and the challenges seem somewhat manageable, the designers were asked if they will continue to design products with virgin plastics. They all said yes. Diez (2021) said that virgin plastic "for sure is necessary here and there, try to avoid it, but it will probably still be necessary.". Grcic (2021) also said "Yes, if necessary", and said that he would justify using virgin plastic by giving the product "an extended use cycle". Morrison (2021) also explained it similarly, saying that "I will when I have to because a well-designed chair that has a life of thirty years or so and which can later be recycled is in my opinion sustainable.". He also said that in cases where it is not possible to use recycled plastic, he tries to "design products which can be easily recycled to provide quality plastics for secondary use" (Morrison, 2021). Lissoni (2021) also said that "if there are no better options, yes.". So, they would all still use virgin plastic, because in some cases it does not seem to be possible to use recycled plastic. That in turn seems to pose a challenge to circularity, if one cannot move off the reliance on virgin plastic from fossil raw materials.

Designing more circular products

Morrison, Grcic and Diez were asked if they would do anything differently with the chairs they designed that are used in the case study to make them more circular. Diez (2021) said that he knows where the problems with Costume are and that he is working on the fabric cover "to make the cover somehow compostable or fully recyclable". He also said that "the rest is already I think on a really good way, even the polyurethane will be recyclable sooner or later" (Diez, 2021). Furthermore, Grcic (2021) said "certainly", that the Bell chair had not achieved everything that he thought it should be or wanted it to, but that given the conditions and time frame that it has come a very long way. At last, Morrison (2021) said that

> *There's one thing which might have been an improvement but it might also have shortened the life of the chair. The plastic shell can be easily disassembled from the legs, but there are inserts in the shell which are metal, and which need to be removed before the shell is broken up for recyclying. If these inserts were plastic the chair could be more easily recycled, but on the other hand the plastic inserts are weaker and the chairs might not have as long a life as they do with the metal ones.*

So, there seems to always be compromises one has to make when designing a product, and sometime the compromise is as difficult as choosing between easier recycling and longevity.

Circular design criteria for plastic furniture

The interviewees that have not developed a circular design guide were asked what they would say is the most important circular design criteria to create circular plastic furniture. Grcic said that it is important to design products for a long cycle, but that another interesting approach would be if manufacturers offered take back services and would take the plastic products back and recycle them before they are too degraded in quality. Lissoni (2021) said it is important that one can separate different materials and that products are repairable and parts are replaceable, “allowing people to change only a part instead of trashing the whole object”. At last, Morrison (2021) said that it is the most important that “the material be easily recyclable and that the message is communicated to the customer.”. So, it seems that longevity and recyclability are key.

Designing a circular design guide

Kviseth and Diez both have designed circular design guides for products, they were therefore asked about these guides as a means to learn about how they thought to develop them and what they find important to include in such a guide. Kviseth’s and Diez’s circular design guides can be found in the appendix.

For whom and what

Kviseth (2021) designed the circular design guide for product development and design internally in HÅG, so the type of products the guide is meant for are "seating solutions for the public". She did however point out that it is so general that it can be used for many products, for "all types of products that perhaps don't use energy" (Kviseth, 2021). Whereas Diez (2021) initially designed his guide to be used in his studio, but although initially meant for "the products that we are doing in our studio", he said that it is very general, and can actually be used for "everyday products, it can even apply to architecture." Although initially intended for his studio, Diez (2021) said that he "would be happy if more people would use it", and he wants designers to take these guidelines and develop them further. It would be his wish if the guidelines would "become opensource and it would become a shared discussion about what the values are that we would like to share as a kind of a common sense" amongst designers (Diez, 2021). He pointed out that "in the end it is really the designers that can start the projects and come up with a proposal", so designers are needed to make products, and that is why it is important that designers start a discussion about their values and how they want to design products (Diez, 2021). So, it seems that both Kviseth's and Diez's guides had a clear purpose but turned out to be quite general.

The goal

According to Diez, the circular design guide works as a checklist within the studio. It explains the designers what the studio's priorities are, and they have been constantly used in the studio for the last ten years. Diez (2021) also explained that he decided to make the guidelines public because

> *I wanted to also make it clear for myself and for my studio that there is absolutely no way back, if we are purposely disrespecting the guidelines, it would be a PR disaster and in order to somehow avoid that and to make it clear for everybody what the rules are that we are working with, I can already put them on my website and even in my contracts in the studio and say guys I'd really like to do a project with you but these are the rules we're working with.*

For Kviseth (2021), "The goal was to come up with some guidelines that we could always stick to". She also pointed out that

> *if you want to become good at sustainability and circular economy, you have to anchor yourself first and foremost in design or where design and product development is happening, I think that is the most important and best thing you can do, because it starts with the product. (Kviseth, 2021)*

So, it seems that circular design guidelines help navigate how to work to design a circular product.

How to develop a design guide

For Diez, the circular design guide has been developed based on his experience of designing products over the years, such as Papier, Chassis and New Order. The guidelines reflect the principles he works by and what his studio prioritizes. They have only recently been formulated in writing, as he explained that he started to rethink his own rules and figure out how to formulate them when he started teaching at die Angewandte.

Diez (2021) explained that

> *I was even thinking that we're still referring so much to Dieter Rams 10 theses of what good design is even though they are already 45 or almost 50 years old now, maybe it would be an idea to formulate 10 guidelines for circular design in order to make a point and say we should rethink our principle design rules that we're using as designers.*

The times were different when Kviseth developed her circular design guide. She tried to find inspiration from others that had thought about it before her and also worked a bit based on product, and there was not much to choose from. Most of all, Kviseth was inspired by cradle to cradle, and so to a large extent that is what underlies the Flokk guidelines. She also looked at Wilkhahn and Herman Miller who were quite progressive in terms of sustainability in the nineties. So, it seems that there are different approaches to designing a circular design guide, but it seems reasonable to look for sources of inspiration and to use one's own experience as well.

The most and least important points

To get an impression of what is the most and least important aspects of a circular design guide, the two designers were asked what they thought were the most and least important points in their guides. Kviseth (2021) said that point 4, long life span is the most important, so that

> *you don't have to replace and produce so much and make so many chairs, durability I think is the most important to reduce the consumption of*

> *resources. So, if you can do business on only making half as many products and continue to create value, I think that is the most important.*

Similarly, Diez (2021) said that "you should make sure that the object is long-lasting". Furthermore, he said that "the one that says make sure that you take materials either from biological cycles or from a closed material loop," is also more important and a central rule when it comes to circular economy (Diez, 2021).

In terms of the least important point, Kviseth said that point 1, low, weight, is less important today than it was back in the nineties when the guide was made. She said that she would "start with long life span as number 1, then right choice of materials as number 2, design for disassembly as number 3, fewer components and then low weight." (Kviseth, 2021). Whereas Diez (2021) said that

> *we are far away from being perfect, we're never able to achieve 100% on all the guidelines, so trying to do it as good as possible is somehow our situation in the moment I would say, more circular-ish, not yet circular, that's definitely the case.*

He also said that circularity is not the easy way of doing things, and that following these guidelines are an extra effort for the designer. So, it seems that longevity is very important, as is choosing materials that can be kept in a closed material loop.

End of life

Kviseth and Diez were asked how their circular design guides specifically contribute to designing for end of life of a product, since longevity is important, but eventually all products reach end of life. Kviseth (2021) said that all guidelines contribute, because it is easy to take apart, there are few different materials and not that many components, therefore it is "both economically efficient and also practical to sort in different containers the day when that system is in place and facilitated with labelling and things like that, so we're just missing the system that receives the furniture". Diez (2021) also said that "If the guidelines are respected, then the product is in the end easier to recycle". He however also stated that "it is difficult because you cannot so easily force someone to properly dispose of a product, it's always possible that someone dispose of it in the wrong way", but he believes that the right behavior can be triggered by the product, as he said "by the right semantics and by the way you communicate them" (Diez, 2021). So, it seems that both these circular design guides make products made for recycling systems, and that will be ready to circulate once systems are in place.

Changes to the guide

Both were also asked if they would change anything about the guide today. Diez (2021) said that the guide is changing constantly, such as improving the formulations, but all in all he said that "for the moment I think we are quite to the point.". Whereas Kviseth (2021) said the following

> *I think I would remove the point about low weight, but what would I add given the 25 years of experience I now have? I would probably not only say design for disassembly, because that is more at end of life. I always have one point that is design for repair, design for service, that comes before. So, I would focus more on that, so reuse and upgrade and those things today.*

She explained that HÅG did do those things, and it “was sort of part of these guidelines, but we never defined it as a separate criteria, but that is definitely something I would do now.” (Kviseth, 2021). Furthermore, Kviseth (2021) explained that

> *There’s one more thing that is very important to me, maybe that is also a criterion that should be in the guidelines, it’s what I always put first in my lists: is it nice to have or need to have? Meaning does the world need this product at all.*

So, all in all it seems that circular design guides are a constant work in progress, always open for improvement.

Adaptations for plastic furniture

Since no circular design guide made specifically for plastic furniture could be found, Diez and Kviseth were asked if they would have made any adaptations to their design guide if it were to apply specifically to plastic furniture. This question was asked as a means to see what they thought to be of importance in regard to creating a circular design guide for the use of plastic in furniture. Diez (2021) said that

> *You could maybe be a bit more specific, but the principles stay the same, you could give a bit more let’s say hints for specific additives, problems that you have specifically come across where plastic is used, but no, actually it doesn’t have to be that much of a change, I think.*

Whereas Kviseth (2021) said "Yes, I would at least put right choice of materials on top, but other than that no". She said that mono-materials are "very important in terms of the future material flows." (Kviseth, 2021). However, Kviseth (2021) also said "I think I would ask myself the significant question of whether we need so much plastics furniture.". She does not think it is a point in itself to make furniture from recycled plastics, she said that "it's not a goal to just make a chair because you have a lot of recycled plastic and then you use it for something." (Kviseth, 2021). Furthermore, Kviseth said that the system needs to be planned beforehand, that you know where the raw material is coming from and you know who can take it afterwards. She said that

> *we need bigger global systems, material hubs for instance, let say that PP could go back to national hubs in different countries with a material passport so that everyone has the same information about quality, content and age of the material and then you can use it and recycle it, because I don't think that you should get that chair back, we have to make it right so that it can become a new product somewhere else. (Kviseth, 2021)*

Furthermore, Kviseth (2021) said that one needs to think bigger and share the supply chain and recycling systems, "that you only lease the materials", as has already been mentioned previously in this thesis. So, it seems that there should be a more specific focus on the material in a circular design guide for the use of plastic in furniture, but that the general principles remain the same.

Simplicity

Both Diez and Kviseth pointed out the importance of keeping the circular design guide simple. Kviseth said that such guides often become very complex, and that it often is quite impossible to start using a design guide without any prior knowledge of the subject. Furthermore she said “that’s sort of the clue with those five guidelines, its only five so it’s clear, simple and manageable in a way.”, she also explained that it is something that everyone can read quickly, understand and remember (Kviseth, 2021). Similarly, Diez (2021) said that

> *I think these guidelines which I was formulating, the advantage is that everything fits on one page, that makes it somehow relatively accessible and compared to books, I mean there has been written so many books about circularity, but it feels complicated so that’s I think the benefit of these guidelines, that they’re simple.*

So, an important takeaway for the circular design guide is that it should be kept simple, understandable and not be too long.

Kviseth’s circular design guide

Since her guide has been used for almost 30 years, it is possible to talk about what effect it has had. Kviseth was therefore asked if the guide has contributed to the changes she wanted it to, and she said yes. Kviseth said that one can see it by looking at the results Flokk shows about how much plastic the company has managed to recycle. The company has managed to recycle so much plastic because they have followed the guide, and that has led the company to become a frontrunner (Kviseth, 2021).

Furthermore, Kviseth was asked if it was a goal to create a circular design guide that would be relevant for so long. The answer was "no, I didn't think of that, that they should last, it had nothing to do with that, it was simply how I thought we should do it at HÅG" (Kviseth, 2021). Kviseth (2021) also explained that she thinks they have lasted so long because they are general, but the way to use them was that "the guidelines were translated into specific requirements in the design specifications for a new chair". So, the requirements for a chair could for example be that "it shouldn't have more than five screws and it should not be made with more than 3 different materials" (Kviseth, 2021). This was important because one can always come up with an argument that says one for example has designed for disassembly, but it is important with specific requirements, so it does not become too general, it must be a bit strict. So, for instance in terms of disassembly, the requirement could be that "it shouldn't take more than 10 minutes to disassemble this chair" (Kviseth, 2021). This is an important takeaway because to apply to a range of products, the guidelines need to be quite general, but different aspects apply to, and are more or less important, for the design of specific products.

Furthermore, Kviseth (2021) also mentioned an interesting discovery she has made over the years, that she thought would also be relevant for this thesis

> *something I think you should take with you as a little footnote is that it's much easier for privately owned or family-owned companies to do good work within circular economy and that type of thinking because it's much more value-driven than the large holding companies with stocks, stakeholders and quarterly reports that care about completely different things.*

That is an interesting observation that might also add up with some of the findings in the industry insight chapter.

Diez’s circular design guide

Although Diez’s guide has been in use for 10 years, it is quite new to the public. Nevertheless, based on the products the studio has designed over the last 10 years, Diez’s guide also seems to have had a positive effect. In difference to Kviseth’s guide for Flokk, Diez’s guide contains 5 more guidelines, 10 in total, and it also taps into other areas beyond product design. Some of the guidelines address whether a product can be complemented with or replaced by a service or system, Diez was therefore asked how he thinks a designer can contribute to incorporating more services or system as parts of products or even to integrating new business models in manufacturing companies. He said

> *I think designers can at a table, at a workshop, come up with these kinds of questions, hey guys do people really want kitchens or do they want food. It’s about rethinking the promise of a project. Is it really the car that is so cool or is the promise behind the car so cool, that I can be at any spot in our country or continent within a few hours and even that is not the promise, the promise is that there is something I can discover, I don’t know what it is, it’s a fantasy. (Diez, 2021)*

Furthermore, Diez (2021) said that “this way of thinking is actually typically part of the design thinking of a problem”, and that is why he put it inside the guide.

Some of the guidelines in Diez’s guide are not specific for product design, some might be said to apply more to for instance changing business models. When asked why he made the decision to include these guidelines, Diez (2021) replied that “Because I would be really restricted in mind if I would only formulate guidelines which are good for a product designer that wants to design products”. He also said that “our skills are not bound to physical objects, it’s a way of thinking, it’s a way of doing things” (Diez, 2021).

Furthermore, one of the guidelines in Diez's guide says that one should only use synthetic material "if products are covered by existing recycling systems" (Diez, 2021). Diez was therefore asked if he would define plastic as a material with an existing recycling system. He said that plastic recycling is starting to work much better, that 2020 in a way was the turning point when "the first packaging for consumer goods were made from 100% recycled plastic which came from objects of its kind, like a shampoo bottle is transformed into a shampoo bottle and another shampoo bottle and another shampoo bottle." (Diez, 2021). Diez (2021) summed it up by saying that "plastic can be recycled, it's working in some aspects, but it's still in the beginning.".

Favorite circular design guide

At last, all designers were asked if they had a favorite circular design guide that they use as an inspiration when they want to design circular products. This question was used as a means both to see if designers use circular design guides, and if yes to find out which guides that might be. All said that they do not really use any design guides. Kviseth and Diez use their own experience and their own circular design guides, that are based on their experience. Diez also pointed out that he does not know that many circular design guides, that there are more books written about circularity. Kviseth (2021) also said that "I think it's amazing that there are coming more circular design guides, because even though there are some common principles, some overriding principles, there is also a lot of industry adaptation or product adaptation". Furthermore, Grcic (2021) replied "Actually, no I don't, but the question is a good one, so I'll think about it.". At last, Morrison said

No, I don't think so, I try to keep up to date with technological improvements and new materials but I haven't seen a guide that might advise me on the subject. If you know of one please tell me about it?

With that remark, it is time to sum up the main takeaways for the circular design guide, and move onto the final chapter which introduces the circular design guide developed for this thesis, that hopefully can advise on the subject.

Key takeaways for the circular design guide for the use of plastic in furniture

Based on the circular design guide research and on the designer interviews, some key takeaways to incorporate in this thesis' circular design guide were found, both in terms of how to structure the guide and in terms of what content to include in it.

Structure

The review of different design guides most of all served as an inspiration on how to structure and write the guide. It served as an inspiration for what to name the different guidelines and what to combine together under each guideline in order to create a logical structure with an order that would be easy to follow. Furthermore, the importance of simplicity and to keep the guide short was identified to be of importance through the interviews with Kviseth and Diez, as well as through reading the different circular design guides, and is therefore a key takeaway. So, overall, the guide needs to be simple, understandable and not too long, yet specific and detailed enough to be of help to the designer. All in all, the guide should explain the complexity of the circularity of plastics in the furniture industry, but the guide itself should not be complicated.

Content

In terms of content, the research on the different design guides served to gain knowledge both about important specific guidelines for plastic as a material, especially in terms of recycling at end of life, and about strategies or design approaches for creating circular products that last and remain in use long. The circular design guide for plastic in the furniture industry needs to somehow combine the two.

Furthermore, the interviews with designers also resulted in some takeaways as to what is important to include in the guide in terms of content. One of these takeaways is to use mono-materials and avoid additives and colors that make it difficult to recycle the plastic material. Another takeaway is to make sure that there exist recycling systems to recycle the plastic material used in the furniture product, not to forget that designers should also design systems for the plastic furniture products or at least design the products so that they are ready to go into circular systems once those systems are up and running. In addition, the interviews with the designers served to highlight the importance of a different design approach when designing with recycled plastic, especially in terms of aesthetics. Furthermore, another takeaway from the designer interviews is that multiple design strategies are needed to extend life of plastic furniture, it is not enough to only make a product physically durable.

Overall, to put it quite simply, the key takeaways from the designer interviews were to focus on recyclability and longevity, both for the plastic material itself and for the furniture product made from it. So, the main takeaway in regard to content is that the guide should apply both to plastic as a material and furniture as a product, combined applying to plastic furniture products. The circular design guide should be both a guide on circularity at material and product level.

It should also be emphasized that all that has been learned from the interviews with manufacturer representatives and experts as well as from the case study served as the basis for what to include in the circular design guide in terms of content. The designer interviews were done in addition to ensure that designers' viewpoint were also considered given that the circular design guide is meant for designers.

Sum up of chapter 5

This chapter presented the overall most important findings from the industry insight and case study as well as a vision of an ideal future scenario for the circularity of plastics in the furniture industry, the future that the circular design guide is meant to help transition to. Furthermore, the chapter presented research conducted specifically to develop the circular design guide that is the final result of this thesis, by both studying existing circular design guides and by interviewing designers as a means to form a picture of circular design both in theory and practice. Altogether the research and interviews resulted in some key takeaways both in regard to how to structure the circular design guide and what to include in terms of content.

The chapter has explained that the overall greatest challenges facing the circularity of plastics in the furniture industry range from intangible definitions to the material specific issue of additives to addressing the complex systemic issue of reversed logistics. Describing a future where all these issues were resolved helped to form a picture of what change the circular design guide should facilitate to advance the transition to circularity. Furthermore, details around how exactly to convey that message to designers through the circular design guide were also made clear. The guide needs to be simple and understandable, and it needs to address both plastic as a material and furniture as a product.

To sum up, this chapter shed light on the needed transition the circular design guide for the use of plastic in furniture is designed for and showed what needs to be considered and included in the guide to facilitate that transition. So, in the next and final chapter, the circular design guide for the use of plastic in furniture is presented.

Chapter 6

The Circular Design Guide for the use of Plastic in Furniture

This chapter presents the result of this entire thesis in the shape of a circular design guide for the use of plastic in furniture. The circular design guide was created as a means to sum up all that was researched and learned throughout the interviews and case study into a concise circular design guide that could aid designers in designing circular plastic furniture.

This chapter introduces and explains the circular design guide in detail. It first presents the overall concept followed by the actual guide, and the thoughts behind the guide are explained, both in terms of structure, content and how to use the guide. At last, further work on the guide is discussed and the whole thesis is wrapped up with some concluding remarks.

The overall concept

As stated by EFIC, circular product design "provides the opportunity to prepare products for all opportunities of the circular economy - reuse, refurbishment, remanufacturing, and recycling, prolonging the life of products and materials." (EFIC, 2020). That is what this circular design guide for the use of plastic in furniture aims to do.

Who is the circular design guide for?

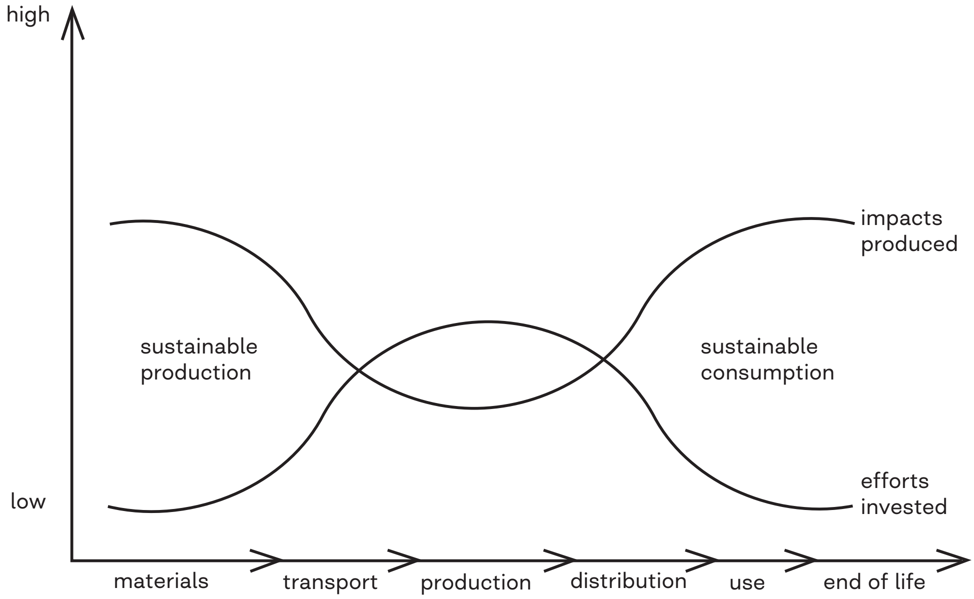
This is a circular product design guide, and not a business model guide. It is meant for designers designing plastic furniture for manufacturing companies. Since designers are in contact with practically everyone involved in production of a new product, they can not only influence how products are designed but with what and how they are made, and within what context a product should exist. So, the role of designers makes them key players when it comes to advancing the circular economy. Given this potential of the designer to drive circularity forward, it was deemed the most effective to create a guide for designers.

What is the purpose of the circular design guide?

The intention of the guide is to help designers design products that are made for the ideal future scenario of a circular economy for plastics in the furniture industry. It is meant to aid designers in preparing the products they design for a future where products will not be disposed of after one use cycle but will circulate at the highest value as long as possible. The intention of the guide is for designers to design products that will be ready to circulate once circular systems are established. So, it is a guide to ease the transition to a circular economy, and not a guide for when the circular economy is already in place. Therefore, this guide will contain some guidelines that might not be circular per definition, but aid in transitioning towards circularity.

What type of products is the circular design guide meant for?

The circular design guide is meant for plastic furniture. It does not need to be furniture consisting of 100% plastic, but furniture containing plastic parts. Furthermore,



Recreated after URBANREC

what is defined as furniture is a wide range of products, everything from furniture for sitting, sleeping, storing, working or eating. So, furniture can have a variety of functions. However, furniture are not necessarily products that require or consume energy during use. This guide focuses on furniture products that do not consume energy while in use, as energy consuming products require specific guidelines that address the use of energy. Furthermore, designers usually have little control over choice of energy source, but a longer lifespan has a positive effect on the accumulated energy consumption, as does the use of recycled materials (van den Berg & Bakker, 2015, p. 371; designaustria and IDRV, n.d., p. 10). Materials, use and end of life are the phases of a product's life cycle where one can impact the biggest change in terms of sustainability (URBANREC, n.d., p. 10). This circular design guide therefore mainly focuses on the use of recycled plastics in the furniture product and on extending product life, as well as of course making products recyclable, in order to help designers create sustainable and circular plastic furniture.

Why create another circular design guide?

One might ask the question of whether we need yet another circular design guide, that was also a central question in the development of this thesis' design guide. If this circular design guide is to be useful, it needs to offer something that no other circular design guide currently is offering. So, what separates this circular design guide from others is that it is based on knowledge derived from 19 interviews with product developers from manufacturing companies, practicing designers and plastic recycling experts, all part of what could be a circular value chain. So, to separate it from theoretical circular design guides, this guide is based on empirical research. The content of the guide is heavily based on what was learned through the interviews and case study, which hopefully makes this guide more tangible. Furthermore, this guide is not only meant for a specific material or a type of product, it is meant for a type of product made from a specific material. So, this guide is different from other circular design guides because it is specifically meant for the use of plastic in the furniture industry. It is based on unique insight into the industry it is meant for and is not yet another general circular design guide.

Inspiration

The circular design guide is based on and inspired by the circular design model developed in chapter 4 as a result of the case study. So, this circular design guide focuses on designing from recycling in production, designing for product integrity in the use phase and on designing for recycling at end of life. It should be noted that bioplastics is another option for a circular economy for plastics that could have been included in this guide, but based on the interviews in this thesis, using recycled plastics is currently the preferred option to accelerate the transition to a circular economy as it is an already available raw material. So, this guide therefore largely focuses on the use of recycled plastics and on longevity and recyclability of both the plastic material and furniture product.

The process

The development of these circular design guidelines has consisted of countless revisions, many of which were done in collaboration with Diez. Kviseth also read one of the latest versions of the guide and gave feedback as well. To discuss the guide with two designers who are experienced with developing circular design guides was very helpful and contributed greatly to refining the guide to the state it is currently in. The circular design guide has also been read by classmates at die Angewandte as a means to ensure that the guide was understandable, also for designers with no prior knowledge of the topic. The design guide is by no means a finished product, it should rather be seen as a work in progress that can be updated and adapted as the industry moves towards circularity.

So, without further ado, the next two pages show the circular design guide for the use of plastic that is the result of this thesis.

The Circular Design Guide for the Use of Plastic in Furniture

A product always exists in a
currently find ourselves in a
larity by designing products

Plastic is often used in furniture in ways that make it unfit for circularity. The following design guidelines therefore serve to help you find the right plastic material and to make sure that you use it in a way that makes it easy to recycle once the product finally reaches end of life.

1. Design services & systems
A product has a function it should fulfill, but it is not given that it needs to be a physical product to fulfill that functionality. It might be more effective to design a service or system instead. If a physical product does make sense, it is advisable to design a system or service for the product either before or alongside with the product to not only ensure product longevity, but to ensure that the product is looped back into circular systems at end of life.

2. Design with respect for the material
Plastic is a high-tech material, but it is often used for disposable low value products. So, strive to use plastic for long-lasting circular products in which the material can regain its value and showcase its unique abilities. Avoid using plastic materials that have their own closed loop recycling systems for a purpose that would result in downcycling of the plastic material, instead try to upcycle plastics.

3. Design out (of) waste
Choose plastics that can be recycled but have been labelled as waste and turn them into valuable products. The biggest environmental impact happens when you turn waste into a resource, creating a value chain that can clean the planet of waste. So, use plastic waste for which recycling systems exist, but that for some reason would be landfilled, incinerated or end up in nature and turn it into recycled plastic.

4. Design to close the loop
Use as much post-consumer recycled plastics as possible in the product. Post-industrial plastic is a resource but should not be defined as recycling. The percentage of recycled material in a new product is an indication of the actual rate of closed-loop recycling. The higher the recycled content the greater the environmental benefits. Increasing the use of recycled plastics also supports the secondary raw material market.

5. Design for recycling systems
Consider the recycling potential of the plastic used in the product by considering its use as a secondary raw material. The product is only recyclable if there is a system for the plastic material to go to and it is more likely to be recycled if there is a demand for it. So, consider what collection systems are available and use plastic materials that are economically recyclable and for which current recycling streams with effective technologies exist.

6. Design for recyclability
Design the product to be easily recyclable many times over and still retain material value by avoiding additives. Adding anything to a pure polymer makes recycling more difficult. Design for quality recycled plastics repeatedly by only using mono-materials, avoid additives that are potentially harmful for health and environment and could render the product unfit for recycling, and avoid colorants that compromise recyclability, the lighter the color the better.

context, and circular products are meant to exist within the context of a circular economy. However, we time of transition, in which you as a designer play a key role in moving the industry from linearity to circu- that will be ready to circulate at highest value for as long as possible once circular systems are in place.

7. Design with recycled plastics

Recycled plastics has different mechanical and aesthetic qualities than virgin plastics, embrace those qualities and start with the recycled plastic material as a prerequisite for your design. You might need to increase the wall thickness, construct a little differently and consider ways to turn signs of previous life into a quality that can bring life to the synthetic material. Be innovative, creative and work with the material instead of against it.

Plastics has an image of being cheap and disposable. The following design guidelines are meant to design plastic furniture products that counteract that impression and do not only turn plastics into long-lasting products, but into products people want to use for a long time.

8. Design for resilience

Design the product to resist obsolescence by making it physically durable, made to withstand wear and tear. Moreover, to prolong the use of a product, design it so that it is easy to clean and repair by users themselves in order to retain the product's functionality and appearance. If a product is easy to care for, it enables extended use and keeps the product in a working condition, prolonging its life by remaining functional and reliable.

9. Design for versatility

Design the product to be versatile both in appearance and usage to remain attractive. Obsolescence often occurs due to a change in taste or needs, and not due to physical wear out. Design the product to allow for a change in taste by enabling a change in appearance. Moreover, design the product to adapt to a change in needs, so that it can change with the user and fit into different living situations. Design the product to remain valuable to the user.

10. Design for emotional attachment

Design for emotional durability to create a long-term emotional bond between user and product. This might be the most difficult to design for, but the most rewarding in terms of resisting obsolescence, as emotional attachment increases the likelihood of valuing the product for a long time. Design with passion and consider how the product can be designed to bond with the user, for instance through circular activities such as repair or upgrading.

11. Design for multiple use cycles

Design the product in modules to enable circular activities such as reuse, repair or remaking. Modularity enables the replacement of obsolete components, avoiding that the entire product becomes obsolete. Use standardized parts to facilitate for modularity, by ensuring interchangeability and compatibility. Modularity also enables dis- and reassembly, making it easier to transport the product to its new home for reuse or to a manufacturer for remaking.

12. Design for dis- & reassembly

Design the product so that it is easy and quick to dis- and reassemble nondestructively multiple times for repair, remaking and eventually for recycling. Disassembly should be possible for nonprofessionals with basic manual tools. Use few big parts, fewer parts means quicker disassembly and bigger parts represent a greater recycling value. All plastic parts should be made from the same type of plastic for easier sorting for recycling.

The circular design guide explained

The process of summing up half a year of work into two pages with twelve circular design guidelines for the use of plastic in furniture has been challenging but rewarding. This section explains the thoughts behind the guide.

The structure of the guide

The first versions of this design guide were up to six pages long, which was too long. For this to be a guide that designers could easily read and use as a tool while working, it needed to be one to maximum two A4 pages long. Furthermore, it was a goal to not have more than 15 guidelines. The designer does not necessarily need to remember all guidelines by heart, but it was important that there were not so many guidelines that it would become complicated, that is also why there is only a heading with an explanation and not multiple layers of guidelines. However, since this is a guide both for a material and for products, it needed quite a few guidelines to cover all that was important without simplifying and merging guidelines to the point where it would become confusing. Therefore, these twelve points were decided on.

Furthermore, it was important that each guideline had a heading that could give a hint as to what the guideline was about, and that each guideline had an explanation of what to do in terms of design and why doing that is important. It was also important that the overall impression of the guide was tidy and structured. Therefore, all guidelines have the same number of lines of text, and all heading start with “Design” followed by what that guideline is meant to help design for. It was also important that the language in the guidelines did not have a negative tone, only stating all the things one should not do, but that it instead was rather positive and encouraging in order to motivate. To design for circularity is as Diez explained an extra effort for the designer, so it needs to look manageable. To not use illustrations and models in the circular design guide was also a conscious choice, as the guide should be able to speak for itself.

At last, another important point in developing these guidelines was the order of them. They needed to have a logical order that would be understandable to designers without any prior knowledge about the circularity of plastics in the furniture industry. It was therefore determined that the guide should be divided into two parts. The first part focuses on the plastic material. It made sense to start with design guidelines for the material, as the product cannot be circular if the material is not. For the second part the guidelines were expanded to apply to the overall product design, to assure that the plastic material is used in a circular product.

The plastic material guidelines

The circular design guide starts with a short introduction meant to set the scene and state the purpose of the guide. The introduction is followed by a short explanation of the guidelines for the use of plastic. These two sentences served to briefly explain why guidelines on the use of plastic are needed and what those guidelines will entail. This was written to give an indication of what to keep in mind overall in regard to designing with plastic. The following is an explanation of each of the guidelines in the plastic part of the design guide.

1. Design services & systems

This is not a guideline on the use of plastic per se, it was however placed first because of its importance. First of all, the designer should consider if a physical product is truly needed. Just because a new chair can be recycled does not mean that the world needs another chair. Recycling is not the answer to everything, less production and consumption is generally needed.

Secondly, one of the most important discoveries made throughout the work on this thesis is the importance of reversed logistics and of having services or systems in place for end of life. Furniture is usually first designed and put on the market, and then manufacturers start to consider how to recycle the products in hindsight, which is incredibly more challenging than to design a system or service before or alongside with the product. It is much easier to tackle the problem upfront, and with new products one has the opportunity to do so. Designing a service offered in connection with the product and systems for the product can be said to be as important as designing the product itself (European Environment Agency, 2017). As stated by the RSA, "if the system has not been designed to take account of the actual products, materials and behaviours that flow through it, there is very little point in merely changing the design of a single product" (RSA, 2015, p. 6). So, this guideline was placed as the first one to assure that even before thinking of designing the material product, the designer should consider how the product will be looped back into circular systems at end of life. This guideline highlights that designers have to anticipate and build the system the plastic will eventually go into, into the product. An example to illustrate this guideline is Vestre's Coast bench, which is only available for leasing, ensuring that the bench is recycled at end of life.

2. Design with respect for the material

This guideline was debated quite a lot, it was considered whether it should say to use other materials instead of plastic, meaning to avoid plastics as far as possible. However, it was determined that since this is a guide for the use of plastic in furniture, using plastic is so to speak a premise for the guide. The focus was therefore rather on using plastic the right way and with the right intentions, to use the material in a responsible manner, maybe even in a way that could restore the reputation of the material. Plastic itself is not inherently evil, it is how it is used and discarded that is problematic and that is what this guideline tries to emphasize. As Morrison also stated, furniture is in the first place by far not the worst application for plastic materials. Furthermore, what is meant with the last sentence in this guideline is to be aware of that one should not only use recycled plastic because one can, there should be a justifiable reason. So, to illustrate it with an example, a designer should not use PET bottles that can be recycled into PET bottles again and again in a closed loop for a chair that does not have a functioning recycling system. The designer should instead look for other sources that could be upcycled, since there as of today still is a lot of waste, even recyclable waste.

3. Design out (of) waste

This guideline represents a justifiable reason for using recycled plastic, to take waste and turn it into a valuable product. This guideline is based on what many of the interviewees mentioned as important to move towards circularity in the industry, which was to turn plastic waste into a resource in order to create a value chain that can clean the planet of waste, consequently resulting in a positive environmental impact. Furthermore, the guideline says to use plastic waste that can be recycled, so that one does not use waste material to design a new chair that is not recyclable at end of life, but that one takes waste materials that are recyclable and loop them into the recycling system so they can be used over and over again. Some examples to illustrate this guideline are the chairs from Flokk and NCP used in the case study. They use recyclable PP that if it had not been used for the chairs would be incinerated, and now the material can be recycled over again and be used for new products. At last, this guideline is one of those that would not apply to a circular economy, because in a circular economy waste would in theory not exist. However, we are first of all not there yet and there is so much waste that needs to be used before we will have managed to come close to designing out waste, so this is an important guideline for the transition. Furthermore, in the real world there will always be some leakage and waste, so although this guideline is likely to become less relevant, it will probably not become completely superfluous.

4. Design to close the loop

This is another guideline that would not apply to a circular economy, where loops are closed. However, as of today, they are not, so the purpose of this guideline is to help close them. This guideline is about using the type of plastic material that will have a real impact on the transition to a circular economy, which is not just any type of recycled plastic, but post-consumer waste. The importance of PCR plastic to accelerate the transition to circularity was also uncovered through interviews with manufacturers and experts. This guideline also serves to highlight and explain that only PCR plastic should be defined or referred to as recycled. Designers can also influence the manufacturer to use more PCR and to not advertise that a product is recycled if it is only made from PIR plastic. So, this guideline also serves to encourage designers to be stricter in their definition of recycled plastics.

Furthermore, this guideline is about using as much PCR plastic as possible, because as long as a product still uses virgin plastic from fossil raw material, it cannot be said to be circular. Moreover, increasing the use of PCR plastic will improve recycling infrastructure as well as cost and quality of the recycled plastic material. With an increased quality, more manufacturers are likely to start to apply PCR plastic because an issue as of today is that manufacturers do not trust in the quality of PCR plastic. So, this guideline is about moving off the reliance on virgin plastic, to increase recycling rates and eventually close the loop.

Guidelines 3 and 4 both aim to advance the transition to circularity by using recycled plastic in the front end, in production. Guideline 3 is about using and thereby reducing waste, whereas guideline 4 is about ceasing to use virgin plastic. In an ideal future circular economy, these two guidelines would in theory be rendered superfluous as there would be close to no waste and plastic would circulate in closed loop. However, for now they serve to reduce waste and increase the degree of circularity in products.

5. Design for recycling systems

This guideline is about making sure that the plastic material used will actually be recycled. It is based on what the expert interviews uncovered, that although many plastics are recyclable in theory, they are not necessarily recycled in the real world, for that to happen there needs to be recycling systems for the type of plastic used. Furthermore, to increase the likeliness of the plastic being recycled, there also needs to be a demand for the recycled plastic material, it is therefore better to use some of the most common plastic types, such as PE and PP which are big volume plastics with more or less functioning commercial recycling systems. This guideline is also about considering the economic viability of recycling the plastic used, by for example considering recycling rates, to use plastic materials that have a high anticipated future market demand or plastics that only need one recycling method to be recycled. So, this guideline is about designing for efficient recycling with existing recycling infrastructure. The guideline serves to encourage the designer to choose a plastic material for the product that is recyclable in the real world, which is of great importance to actually get plastics to circulate in the furniture industry.

6. Design for recyclability

This guideline serves to assure that the recyclable plastic material chosen for the design, remains recyclable throughout the design process. So, it is about the inherent recyclability of the plastic. That is of great importance, as additives are often added that make recyclable types of plastic difficult to recycle. This was a recurring theme throughout most interviews, whether with producers, experts or designers, and based on the case study it was made clear that many manufacturers try to make circular plastic products, but often add additives that render the plastic product difficult, if not even impossible, to recycle. All plastics are in theory recyclable, but this guideline is about making sure that the plastic material can be recycled many times over with existing recycling technology and can not only be used to produce the same plastic furniture product again, but that it can be used for multiple equal quality applications after recycling. That is important so that the product can be used where it is recycled for what is needed, so that it does not have to find its way back to the manufacturer to become another chair. For example in the case of S-1500, if fishing nets are more needed than chairs, the chair can be recycled into fishing nets instead.

Furthermore, this guideline is about not adding additives that make it difficult to recycle the plastic product, such as fibers. The more mono-material, the higher quality the plastic will have. The guideline also focuses on not adding colorants that have a limited aftermarket, such as dark or strong colors. At last, it is about considering the intrinsic safety of the material and to not use plastics containing chemicals that are potentially harmful and should not circulate in the future. So, this guideline is about retaining material value by not adding additives that either limit recycling or the secondary use of the recycled material, in order to keep the recycled plastic circulating at the highest value for as long as possible.

One could of course say that with chemical recycling, this guideline is not needed. However, this guide focuses on the use of existing recycling infrastructure, and that is largely mechanical recycling. Furthermore, chemical recycling is quite energy intensive, so to add additives and colorants to the material just because it can be chemically recycled is not deemed a good enough reason, because for a circular economy one should strive to keep the material integrity for as long as possible. So, chemical recycling should be used as a last resort when the mono-material plastic material is so degraded that it can no longer be mechanically recycled.

Guidelines 5 and 6 address recyclability of the plastic at end of life. They are essentially about design for recycling, because the product needs to be inherently recyclable and the outside factors that determine recycling needs to be taken into consideration as well, meaning that infrastructure for recycling the plastic material needs to be functioning. These two guidelines essentially tap into how easy it is to bring back the plastic to a material cycle and following these guidelines is meant to result in using a plastic material that is easy and efficient to recycle.

7. Design with recycled plastics

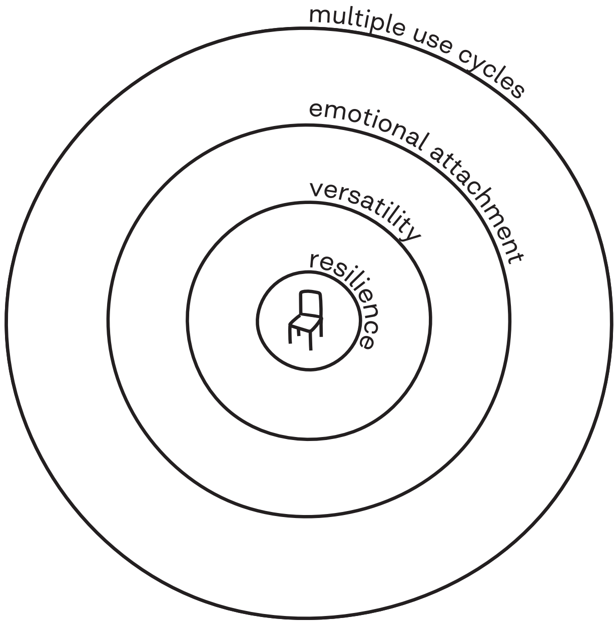
This guideline addresses the difference between virgin and recycled plastic to make the designer aware of it and design with the unique properties of recycled plastic in mind from the very beginning. This was a recurring topic in interviews with manufacturers and designers and is important to succeed at implementing high percentages of PCR plastic in the design. The importance of this guideline is to make designers aware that they cannot apply recycled plastic to a product as if it were virgin plastic, they need to approach it differently and embrace what that entails. It is about keeping an open mind and for instance accepting some variations in color or needing to use more material because the material is structurally different. This guideline is about changing the design approach to accept the span one gets with recycled plastic. An example that illustrates this guideline is S-1500 by NCP. The color the chair is available in is determined by what recycled plastic the company receives. N02 Recycle was also designed based on the properties of the recycled plastic material. The wall-thickness is for example greater than it would need to be with virgin plastic, to account for the recycled plastic span. This guideline was placed as the last one of the plastic guidelines as it goes more into design of the product, so it served well as a transition to the product guidelines that address design characteristics of the product.

The product guidelines

The plastic guidelines serve to lay the foundation for a plastic material of high value that is used correctly, so that it can be recycled over and over again. Following are the product guidelines that are meant to assure that the product made with the plastic material can live as long as possible and is recyclable at end of life. The two sentences introducing the product guidelines served to indicate the transition from material to product level and briefly explain what the focus is in terms of the overall plastic furniture product.

It was contemplated whether these guidelines should focus on circular strategies such as design for refurbishment and design for remanufacturing or if the guidelines should focus on design characteristics such as versatility and resilience. The latter was chosen as it was deemed more effective to guide the designer to equip the product with all qualities needed to be fit for circularity, than to have a guideline called design for remanufacture that the designer would likely disregard if the manufacturing company the designer is designing for does not offer remanufacturing. It therefore seemed advantageous to guide the designer to equip the product with all circular qualities needed to be ready for those circular strategies once they are in place in the future. Therefore, instead of for instance naming a guideline design for refurbishment, the focus was on design for versatility as a means to design the product in such a way that it can be refurbished. So, one could in a way say that the following guidelines serve as a checklist for the qualities a circular furniture product should inhabit to be prepared for different future circular strategies.

Before explaining each of the guidelines, it is necessary to explain the theory behind them and their order.



Theory

Based on the design guide research and interviews with designers, there are three reasons for why a product becomes obsolete. One is that it breaks. This is about the technical lifetime of the product, “which is part of the intrinsic properties of the product” (European Environment Agency, 2017, p. 40). The second reason is that the product becomes aesthetically obsolete, this is a matter of a change in taste, and is related to the aesthetic lifespan of the product. The third and last type of obsolescence is related to the functional lifetime of the product, “which is determined by the conditions that are created around it” (European Environment Agency, 2017, p. 40). This obsolescence occurs because the product no longer fulfills the needs of the user. Furthermore, in addition to physical durability, there is emotional durability, which especially can help counteract the last two reasons for obsolescence and is about extending the value life of the product. The value life is “a measure of the duration until the product value perceived by customers drop”, whereas the durable life of the product is “a measure of the duration until the product is non-functional” (CIRCit Norden, n.d., p. 22). So, a sketch was drawn that illustrates what qualities the product needs in order to prevent the three reasons for obsolescence, the guidelines explain this in detail.

8. Design for resilience

This guideline is the minimum requirement the product needs to fulfill to last long, it needs to be physically durable. It is about designing a product that is resilient against wear and tear. As explained by den Hollander et. al (2017, p. 520), a high physical durability can prolong a product’s use cycle, consequently extending its life. Furthermore, easy maintenance, such as cleaning, postpones obsolescence and repair reverses obsolescence (den Hollander et. al, 2017, p. 520). At last, a durable product is reliable, which is an important reason for people to use it instead of replacing it, even though it might be aesthetically outdated. So, this guideline is about designing the product so that it can remain functional. This is also what was mentioned most frequently by manufacturers in terms of circular product design, and it was mentioned by designers as well.

9. Design for versatility

This guideline is about designing the product to enable it to remain relevant to be used long. It is partly about preventing aesthetic obsolescence, meaning to prevent users from disposing of their product simply because they are visually tired of it. So, it is about designing the product so that the aesthetic lifetime of it matches the technical lifetime. Furthermore, it is partly about designing so that the functional lifetime of the product also matches its technical lifetime. So, it is about designing a product to adapt to different needs of the user, so that the product does not only fit into one context but can be reconfigured to fit in different scenarios and use cases. For example, Diez's Costume is a good example to illustrate this guideline. The cover can be changed if the reason for obsolescence is aesthetic, and the base unit can be reconfigured in different constellations to fit different needs. The product is designed so that the user can adapt the product to a change in taste or needs themselves, and it can be done without having to replace the entire product with a new one. This guideline was not mentioned much in the interviews other than by Diez, but is of importance for a circular product, because it does not matter if the product is physically durable and can last long if the user does not use it. So, this guideline encourages the designer to design the product in such a way that its life can be extended. In other words, this guideline is about designing the product to remain attractive to the user by offering the possibility of change.

10. Design for emotional attachment

This guideline is another level up from design for versatility, it is about designing the product to be loved by the user and therefore used for a long time. It is more difficult to design for, but even more effective in terms of longevity or product integrity. This is not about the physical, but about the emotional durability of a product. A user who is emotionally attached to a product will value it for a longer time and likely pass it on to another user rather than dispose if it. So, if people care about a product, they are also more likely to care for it accordingly. This guideline is about designing the value life of the product to match its durable life (CIRCit Norden, n.d.). In a way, it is also about designing a timeless product, because it is about designing a product that is appreciated by the user for a long time, without the user wanting to change anything about it. This type of durability could for instance be enabled through circular activities such as repair. People are for example more likely to feel more emotionally attached to products they have invested time and energy in repairing themselves. Emotional attachment was an aspect mentioned by some of the interviewed designers, but there is no clear recipe for exactly what a designer should do to succeed at designing for it. This guideline does therefore not say specifically what the designer needs to do to enable emotional attachment but rather aims to explain the importance of it and why it should be considered.

11. Design for multiple use cycles

This guideline is about designing the product for different circular activities and multiple lives. The product needs to be designed for multiple different future scenarios in order to live on. If a user, despite the product being designed using the three previous guidelines, decides to dispose of the product while still in a more or less working condition, it should be made to be reused, either by other users or by the manufacturer. It is difficult to predict what will happen to the product in the future, however, there are some measures that can be taken to prepare it for circularity and the many different lives that might entail. This guideline is about designing the product in a way that reflects reuse as a priority over recycling (RSA, 2015). It is about designing the product so that it can be reused directly, or that the product or its parts can be reused by the manufacturer in remaking many times over. Furthermore, what is meant by remaking are "all actions performed when a product returns back from the customer", such as refurbishment and remanufacturing (van den Berg & Bakker, 2015, p. 367). To ease reuse and remaking, modularity is important, and to ease the reuse of product parts in other products, standardization is important. Modularity was also mentioned by some designers as important for circular products.

One might say that this guideline could have been named "design for reuse and remaking", but this is one of those cases where it seemed more effective to name it design for multiple use cycles as to explain that the three previous guidelines are to extend a use cycle, whereas this one is to assure that the product is designed for more use cycles and users than only one. One could also say that this guideline could have been called "design for modularity", however it was not named that because modularity is also important for other guidelines in the guide, such as guidelines 8 and 9. The focus of this guideline is on enabling multiple use cycles before the product eventually is recycled. So, this guideline is about designing the product as a modular structure to enable multiple circular activities in order to retain product integrity for as long as possible.

12. Design for dis- & reassembly

This guideline is a must have as it assures that the entire product is recyclable, and not only the materials in it. Moreover, it is essential in order to enable circular activities and multiple use cycles. That is why it is important to design the product to enable non-destructive dis- and reassembly many times, to retain product integrity. Furthermore, to ensure that people actually disassemble the product, it needs to be easy to understand how to do it and easy to actually disassemble the product. That is why it should be possible to disassemble the product without any special training, and with tools everyone has at home, or at best without the need for any tools. It is also important that disassembly is not only easy, but quick. That applies if the user is to disassemble the product, but especially if the product is to be disassembled at a collection site, where if it would take too long to disassemble the product, “labour costs would be much higher than any value recoupled from the materials”, and that makes the product less likely to be recycled (RSA, 2015, p. 14). Another important thing is to mark the plastic parts with type of material. That was however not included in the design guide as it is more likely to be the manufacturers responsibility than the designers. The designer should nevertheless of course encourage the manufacturer to clearly mark all parts of the design with type of material.

So, this guideline is about not only designing the product to be disassembled, but to also be easy to reassemble to enable the product to live multiple lives, and at last to design it in such a way that disassembly is efficient to increase the likeliness of the product being recycled. This was also mentioned frequently, both by manufacturers and designers, and is almost a given, but is included in the guide because of its importance.

All in all, with all these layers of product guidelines, a furniture product should be able to last long, be used long and live multiple lives before it at last is recycled and looped back into the circular system.

Expanding the scope

After developing this guide, it became clear that it is so general that it could be used for plastic products in general. After reading the guide, Kviseth (2021) said "This applies to all types of plastic products. I would open up to a much wider scope and a larger audience!". The intention was to create a circular design guide for the use of plastic in furniture, so the development of this guide was focused on designing it specifically for plastic furniture. However, because the guide was meant to apply for all types of furniture products, and furniture products differ quite a lot both in usage and complexity, the guide consequently turned out to be quite general. The guide was consciously written as a guide on the use of plastic in furniture to answer the task of this thesis, but in hindsight, this guide can be said to be a guide for circular plastic products in general, and not only for furniture.

How to use the guide

First of all, for each guideline, specific requirements should be set for the product being designed in order to translate the more general guidelines into a set of requirements for the particular product that is to be designed. This guide is for all plastic furniture, so specific requirements are likely to differ for different types of furniture products and should be adapted accordingly. For certain products, the aspect of emotional attachment will for instance be more important than for others. Emotional attachment is for example probably more important for furniture in private homes than for an office chair in an office.

Secondly, as of today, it is not realistic that all guidelines can be fulfilled for every product. The designer should aim to fulfill as many as possible but choose the ones that are the most important to make the product being designed as circular as possible. If one guideline cannot be fulfilled, the whole guide should not be disregarded, but one needs a valid reason for not fulfilling a guideline. To for instance only use waste materials and design for resilience is not enough to design a circular product. One needs to, as explained with the design model in chapter 4, at least use recycled plastic to some extent, design the product for a long life and design it for recycling. So, not all guidelines need to be fulfilled, but one that applies to using recycled plastic, one that applies to longevity and one that applies to recyclability should be the minimum requirement to create a more circular, or circular-ish, product.

This circular design guide is not meant as a checklist one must follow to the letter, but as a tool to help designers to be aware of and consider all aspects needed to design a circular plastic furniture product. It is likely close to impossible to fulfill all guidelines, but it should serve as an overview to make an overall assessment of the circularity of the design and for the designer to gain an understanding of the consequences of not achieving some of the guidelines. Compromises will of course have to be made, but then it is important that the designer is aware of the consequences those compromises will have on the circularity potential of the product. All in all, this guide can hopefully raise awareness about what using plastics in furniture in a circular manner entails.

Future Work

This circular design guide is a work in progress that is likely to change as the industry moves towards circularity. Eventually, it will hopefully be turned into a circular design guide for when a circular economy is in place, and not for the transition to it.

The design guide was read by classmates at die Angewandte without prior knowledge of plastic or circular economy, and it was read by Kviseth and multiple times by Diez. So, to some degree one can say that it has been user tested. However, it would have been interesting to user test this guide on practicing designers in the furniture industry, to have designers use this guide to design plastic furniture and compare those designs to other plastic furniture products that have been designed without this guide. In that regard one should also monitor products designed with this guide throughout their lives and compare to other products designed without this guide to see if it has any effect on the circularity of those plastic furniture products. That would be very interesting but will be an entire study of its own that would take years to complete. Nonetheless, it could be important research to determine what is needed to turn circularity from theory into practice.

All in all, this circular design guide is an example of a tool that can aid designers in designing for integrity and recyclability both at material and product level, to overall design a circular product. However, this guide is just the beginning, the concept can be expanded further to apply to multiple materials and product categories. There should be a database with circular design guides available to designers. For instance, if a designer is to design wooden furniture, the first part of these guidelines would be for wood instead of plastic, whereas the second part would remain the same. Or if a product requires energy during use, the second part of the guidelines would be adapted to take that into account. It would be really interesting if such a resource for designers existed, where they could choose type of material and product category and get a set of guidelines on how to design such a product in a circular manner, both at material and product level. So, the natural next step would be to continue to build on this guide and extend it to apply to other materials and product categories. In that regard, this circular design guide can be seen as an invitation to other designers to contribute to building a collection of circular design guidelines for the use of different material in a variety of products.

Closing remarks

To work on this thesis has been both challenging and rewarding. I have been in contact with so many people that I would normally only dream of talking to, and this thesis made it possible, and has given me a unique behind the curtain look into the furniture industry.

The starting point for the thesis was the task description, which has guided me in what do to throughout this project. Interviews with manufacturers and the case study were done and the circular design guide was developed. Furthermore, experts and designers were also interviewed, although not in the task description. The decision to do those interviews as well proved to be very helpful as it served to not only hear from the companies that produce plastic furniture, but from those who know what would potentially happen to the furniture at end of life, and those who design the products in the first place. These interviews made me see the issue from multiple angles to help me gain a more comprehensive understanding of it. Furthermore, through all these interviews it was made clear that the designer plays an important role in accelerating the transition to circularity, and I therefore decided to develop the circular design guide as a guide for designers.

My motivation was to do this as a theoretical thesis in order to delve into the subject, and I do not regret it. At times it was challenging, and I really missed the creative work of designing a product, but all in all it gave me the time to do all the interviews and research I have done. If I were to also design a product, I would not have had time for all this research, and I believe that this research was more important work, and more needed, than to design a new piece of plastic furniture that would have then only been based on a fraction of the research I have managed to do with this being a full-on theoretical project.

My personal goal for this project was to learn a lot, and I have. I have learned so much about circularity, plastics, the furniture industry and about designing for all three of those topics combined. I have learned about how design works in the real world, in the industry, beyond what we are taught at university. The real world is complex, and compromises will have to be made, which is also why the use of plastic in the furniture industry is not yet circular, but only circular-ish at best. Although compromising is inevitable in the industry, I do think designers can make a stand and set stricter demands, such as for instance only designing with PCR plastic and not virgin plastic. However, for it to have an effect designers need to come together and make a collective decision to take a stand, otherwise there will always be someone else waiting to take the job if the first designer says no. Designers have more influence and power than they think, and they should use that influencing power to help the industry move in the right direction. The time has passed when the designer was only occupied with how a product looks, today it is necessary that designers consider the context in which the products they design are meant to exist in, all the infrastructure, systems and services the product affects and is affected by. The role of the designer has expanded to be more complex. Today, designers need to occupy themselves with chemistry, sourcing and whatnot if they are to design a truly circular product. Moreover, with this new expanded role, comes a greater responsibility and a bigger potential for the designer to be the key enabler to implement the needed changes to move the furniture industry towards circularity.

The end result

The decision to design a circular design guide as the final product of this thesis is also a decision I do not regret. Circularity is much talked about as a theoretical concept, and this guide is an attempt at getting circularity from theory to practice, and to help the furniture industry in doing so by offering designers a tool on how to design for circularity in the furniture industry.

All in all, I think this guide can be said to offer something special that separates it from other design guides. The developed design guide is different because it consists of two parts, one focused on material level and one focused on the product level. This seemed like a clever approach to assure cyclability and longevity both on material and product level, as one through the case study could see that both rarely were present in current plastic furniture. Furthermore, it is a guide based on challenges described by manufacturers and designers themselves, as well as challenges detected through analyzing their products. So, the guide is not only based on what the furniture industry thinks it needs to achieve circularity, but moreover on what the products produced by the industry reflect is needed in order to achieve circularity.

In a way, the circular design guide is a summary and the conclusion of this master's thesis. It is not a physical product, but it is a tool for practicing designers to use to design circular products. I do hope it can contribute to the circularity of plastics in the furniture industry by shedding some light on the challenges to overcome for the furniture industry to become circular. Furthermore, I hope that designers start to use this guide and implement the guidelines when they design new plastic products and that they use this guide as a starting point for developing more circular design guidelines for other materials and types of products.

The result of this master's thesis is the circular design guide, which given the timeframe of the master's thesis looks as presented in this chapter. This guide is based on the current state and knowledge of circularity in the furniture industry. So, as learned through this thesis, I do not consider the guide to be finished. A circular design guide, especially one that is meant for a state of transition in which things will change constantly should be continuously improved upon in accordance with the furniture industry moving towards circularity.

Thoughts around the process

Conducting 19 interviews has been a rich and insightful learning experience. I learned how to conduct interviews with different people, to adapt the interview to what information I wanted to extract and within the time limits that were sometimes given by the interviewees. Furthermore, I learned how time-consuming it is to process and analyze the comprehensive amount of information, so the interviews combined with other research resulted in less time to write the thesis than originally planned although I have been working almost every day for the past six months, including weekends. What I learned from this experience is that at some point one has to trust in the work that has been done and start to write to comprehend the amount of work that has actually been done. There will always be one more source that could have been read or one more person that could have been interviewed, however what is the biggest takeaway here is to be able to make choices and set boundaries and to trust in and argument for those decisions.

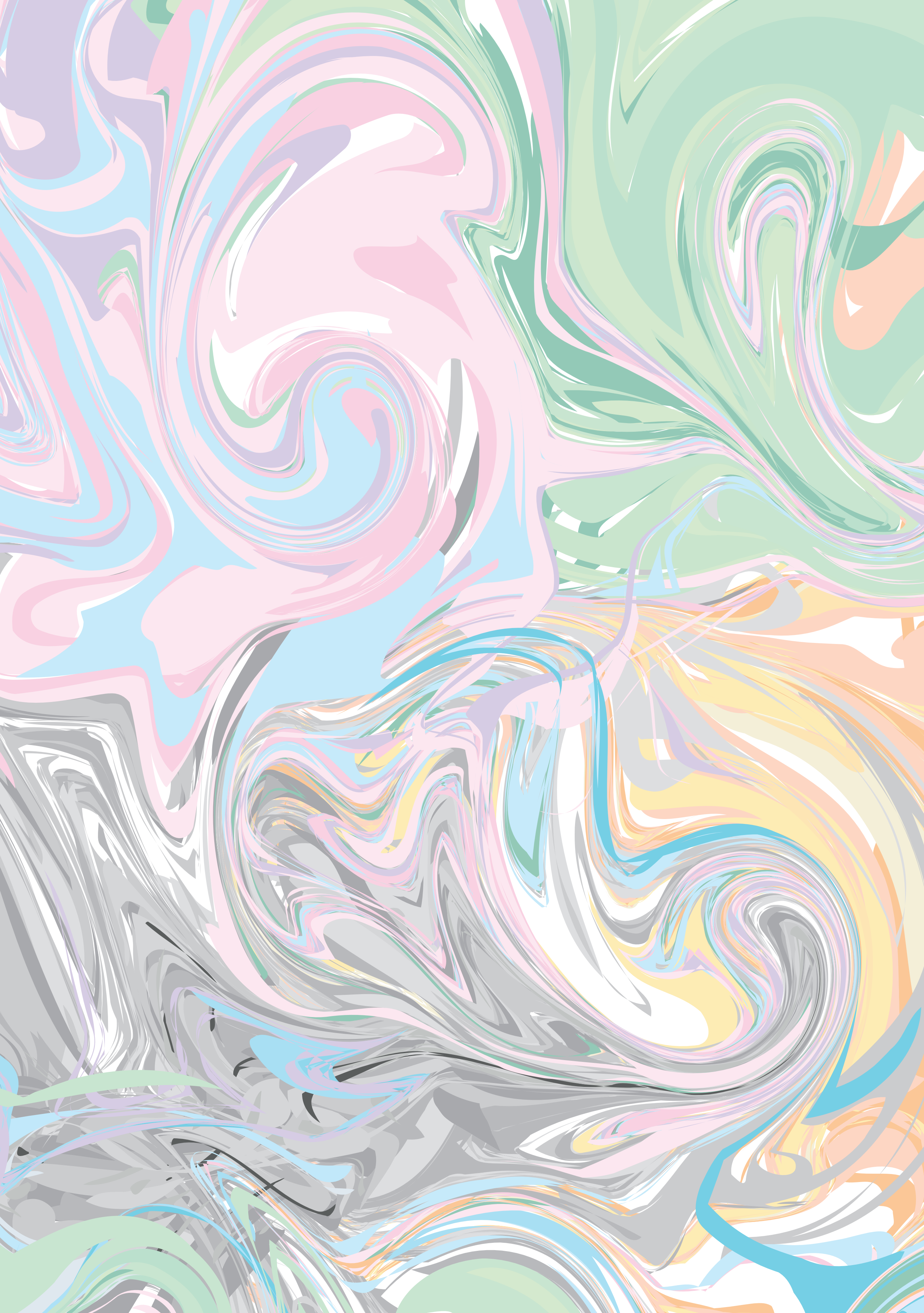
So, this thesis is the result of the selection made of whom to interview and what chairs to analyze. Interviews with other designers or representatives of other manufacturing companies or selecting other chairs for this case study would most likely not have significantly changed the result of this master's thesis, since there was a trend amongst the interviewees revealing that the individual players in the furniture industry in general are facing many of the same challenges. Therefore, my selection of interviewees for this case study can be said to reflect a realistic picture of the furniture industry.

Had it not been for the lockdown and travel restrictions, I would have studied and examined each chair used in this case study in real before analyzing them for this thesis. Furthermore, I would have conducted a workshop in Munich with Diez Office, that could have been very useful for my thesis, as it would amongst others have given me the chance to get all the designers working in the studio to read, discuss and give feedback on my design guide. Nevertheless, a circular design guide is a living document, so there is still time to have more designers give feedback on the guide, just not within the time-frame set for this thesis.

Something which I perceived as a challenge, especially in the beginning, in regard to this thesis was that I had been on an exchange for the last 1.5 years, so I could not take the classes at NTNU that are meant to prepare you for writing a master's thesis. I did however complete a class called "Seminar für Masterstudierende und DiplomandInnen" at die Angewandte, led by the Alison J. Clarke, professor and head of the department of design history and theory and director of the Victor J. Papanek Foundation. I took that class in an effort to prepare myself as best possible for writing the master's thesis. So, I might not have had the same preparing path leading up to writing a master's thesis as other students at NTNU, but in hindsight I do not necessarily see it as a bad thing. In the beginning I did not know what to expect or what was expected of me in terms of writing a master's thesis and in one way that was very challenging, as I would question whether what I was doing was right in terms of a master's thesis. On the other hand, I think it has been positive as I was not bound by any rules or preconceived notions of how I had to do this master's thesis, and that also gave me more freedom to have a more open, creative and investigative approach, like Diez also wanted.

The collaboration & road ahead

To collaborate with Diez has been an amazing opportunity that I greatly appreciate. No matter how busy he may have been, he always took time to discuss the thesis with me and guide me in the right direction. So, I also do hope that this thesis is useful to Diez Office and that it has contributed to get a better understanding of the practical problems of implementing a circular economy, at least it has done so for me. Diez wanted me to take on an investigative role, like that of a journalist, for this thesis in order to critically review what the furniture industry is doing. So, the focus of this thesis was not to write an academically correct paper, but to explore and investigate the world of plastics in the furniture industry. Diez also wants to help me publish the work of this thesis for a larger audience, because the topic, as he said, is so important and relevant at the moment. So, the overall next step is to figure out how to present the thesis in a popular science-based format and publish it in a magazine, most likely in an online design magazine. All in all, the journey I embarked on in the beginning of January is far from over, but with this thesis, a chapter of it is coming to an end.



References

Acaroglu, L. (2019). *What is Greenwashing? How to Spot It and Stop it.*
Available at: https://medium.com/disruptive-design/what-is-greenwashing-how-to-spot-it-and-stop-it-c44f3d130d5
(Accessed 12 June 2021).

Arbeitsgemeinschaft Verpackung + Umwelt, n.d. *Polypropylen (PP).*
Available at: https://www.agvu.de/de/polypropylen-pp-147/
(Accessed 30 May 2021).

Barrett, A. (2018). *Bioplastic Feedstock 1st, 2nd and 3rd Generations.*
Available at: https://bioplasticsnews.com/2018/09/12/bioplastic-feedstock-1st-2nd-and-3rd-generations/
(Accessed 29 May 2021).

Bjørnbet, M. M., Skaar, C., Fet, A. M. & Schulte, K. Ø. (2021). Circular economy in manufacturing companies: A review of case study literature. *Journal of Cleaner Production*, 294.

Brea, R. M., 2021. [Interview] (22 March 2021).

Breyer, M. (2020). *The Big Awful Truth About Biodegradable Plastics.*
Available at: https://www.treehugger.com/great-awful-truth-about-biodegradable-plastics-4858235
(Accessed 29 May 2021).

Buchbinder, J. (2021). [Interview] (2 March 2021).

CIRCit Norden (n.d). *Guidelines for circular product design and development.*
Available at: https://circitnord.com/wp-content/uploads/2020/04/Guidelines-for-circular-product-design-and-development.pdf
(Accessed 26 April 2021).

Circle Economy (n.d). *The Circular Product Design Framework.*
Available at: https://www.circle-economy.com/resources/circular-product-design-framework
(Accessed 27 April 2021).

Daae, J. (2021). [Interview] (23 March 2021).

De Decker, K. (2018). *How circular is the circular economy?.*
Available at: https://unevenearth.org/2018/11/how-circular-is-the-circular-economy/
(Accessed 15 May 2021).

Delva, L. et al. (2019). *An introductory review mechanical recycling of polymers for dummies.* Available at: https://www.researchgate.net/publication/333390524_AN_INTRODUCTORY_REVIEW_MECHANICAL_RECYCLING_OF_POLYMERS_FOR_DUMMIES.

den Hollander, M., Bakker, C. A. & Hultink, E. J. (2017). Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. *Journal of Industrial Ecology,* 21(3), pp. 517-525.

den Hollander, M. (2021). *Six strategies for longer lasting products.*
Available at: https://ocw.tudelft.nl/course-lectures/3-4-2/
(Accessed 7 May 2021).

designaustria and IDRV (n.d.) *Qualitätsstandards für Circular Design.*
Available at: http://www.idrv.org/wp-content/uploads/circulardesign.pdf
(Accessed 26 April 2021).

Diez, S. (2021). [Interview] (14 May 2021).

Diez, S., (n.d.) *Circular Design Guidelines*. [Online]
Available at: https://www.diezoffice.com/circular-design-guidelines/
(Accessed 20 May 2021).

Du Bois, E. et al. (2018). *Design from Recycling Manual.* Available at: https://www.researchgate.net/publication/324220953_DESIGN_FROM_RECYCLING_MANUAL

ECOS (2019). *For better not worse: Applying ecodesign principles to plastics in the circular economy*. Available at: https://ecostandard.org/wp-content/uploads/2019/06/APPLYING-ECODESIGN-PRINCIPLES-TO-PLASTICS.pdf
(Accessed 29 May 2021).

EEB (2017). *Circular economy opportunities in the furniture sector.* Available at: https://eeb.org/library/circular-economy-opportunities-in-the-furniture-sector/
(Accessed 2 June)

EFIC (2020). *The Furniture Sector and Circular Economy 2.0.*
Available at: https://circulareconomy.europa.eu/platform/en/knowledge/furniture-sector-and-circular-economy-20-european-furniture-industries-confederation-shares-its-views
(Accessed 2 June 2021).

Emeco (n.d.) *Our story.*
Available at: https://www.emeco.net/about
(Accessed June 8 2020).

EU Ecolabel (n.d.) *EU Ecolabel.*
Available at: https://ec.europa.eu/environment/ecolabel/
(Accessed 24 June 2021).

EuRIC (2020). *Plastic Recycling Factsheet.*
Available at: https://www.euric-aisbl.eu/position-papers/item/381-euric-plastic-recycling-fact-sheet
(Accessed 29 May 2021).

European Comission (2020). *A new Circular Economy Action Plan For a Cleaner and more competitive Europe.*
Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0017.02/DOC_1&format=PDF
(Accessed 15 May 2021).

European Commission (2018). *A European Strategy for Plastics in a Circular Economy.*
Available at: https://eur-lex.europa.eu/resource.html?uri=cellar:2df5d1d2-fac7-11e7-b8f5-01aa75ed71a1.0001.02/DOC_1&format=PDF
(Accessed 15 May 2021).

European Environment Agency (2017). *Circular by design: Products in the circular economy.* (EEA Report No 6/2017). Available at: https://www.eea.europa.eu/publications/circular-by-design
(Accessed 2 June 2021)

Fairs, M. (2019). *"To end plastic pollution, we first need to eliminate language pollution".*
Available at: https://www.dezeen.com/2019/10/15/climate-change-greenwashing-opinion/
(Accessed 12 June 2021).

FH Campus Wien (2020). *Circular Packaging Design Guideline: Design Recommendations for Recyclable Packaging.*
Available at: https://www.ara.at/fileadmin/user_upload/Downloads/Guideline/FH-Campus-Wien_Circular-Packaging-Design-Guideline_FIN_ENG_Web.pdf
(Accessed 7 May 2021).

Flokk (n.d.) *Our Company.*
Available at: https://www.flokk.com/global/about-us/our-company
(Accessed 8 June 2021).

Flokk, (n.d.) *Sustainability.*
Available at: https://www.flokk.com/global/about-us/sustainability
(Accessed 12 June 2021).

Fortum (2019). *Plastics recycling in a circular economy.*
Available at: https://www.fortum.no/sites/default/files/documents/fortum_plastics_review_2019_final.pdf
(Accessed 29 May 2021)

Fraunhofer CCPE (2020). *Thanks to pyrolysis, even problematic plastics can be recycled.*
Available at: https://ccpe.fraunhofer.de/index.php/2020/09/13/thanks-to-pyrolysis-even-problematic-plastics-can-be-recycled/
(Accessed 31 May 2021).

Fraunhofer (n.d.) *Profile / Structure.*
Available at: https://www.fraunhofer.de/en/about-fraunhofer/profile-structure.html
(Accessed 9 July 2021).

Fritz Hansen (n.d.) *Our heritage.*
Available at: https://www.fritzhansen.com/en/Company/Our-Story/Our-Heritage
(Accessed 7 June 2021).

Fritz, S. (2012). *Plastic - the mouldable material of modern chairs.*
Available at: https://www.architonic.com/en/story/susanne-fritz-plastic-the-mouldable-material-of-modern-chairs/7000634
(Accessed 3 June 2021).

Frosch (n.d.) *The company behind Frosch.*
Available at: https://frosch.de/Unternehmen/index-2.html
(Accessed 27 June 2021).

Geyer, R., Jamback, J. R. & Law, K. L. (2017). Production, use and fate of all plastics ever made. *Science Advances*, 3(7).

Grønt Punkt Norge (2017). *Basic Facts Report on Design for Plastic Packaging Recyclability.*
Available at: https://www.grontpunkt.no/media/2777/report-gpn-design-for-recycling-0704174.pdf
(Accessed 23 April 2021).

Grønt Punkt Norge (n.d. -a). *Lær mer om resirkulert plast.*
Available at: https://www.grontpunkt.no/snarveier/nyheter-innsikt/resirkulert-plast/
(Accessed 30 May 2021).

Grønt Punkt Norge (n.d.) *Grønt Punkt Norge - recycling used packaging in Norway.*
Available at: https://www.grontpunkt.no/english
(Accessed 9 July 2021).

Grcic, K. (2021). [Interview] (11 May 2021).

Gregson, N., Holmes, H. & Crang, M. (2015). *Interrogating the Circular Economy: The Moral Economy of Resource Recovery in the EU.*
Available at: https://www.researchgate.net/publication/275353098_Interrogating_the_Circular_Economy_The_Moral_Economy_of_Resource_Recovery_in_the_EU/references
(Accessed 15 May 2021).

Hahn, J. (2021). *Space Available and Peggy Gou create furniture from "heartbreaking" plastic waste.*
Available at: https://www.dezeen.com/2021/06/21/peggy-gou-space-available-trash-chair/
(Accessed 21 June 2021).

Haug, A. (2016). *Design of resilient consumer products*. Brighton, UK, Design Research Society.

Hawkins, G., Giles, D. B., Phillips, C. & Zahara, A. (2019). *Myths of the Circular Economy.* Available at: https://discardstudies.com/2019/11/18/myths-of-the-circular-economy/ (Accessed 15 May 2021).

HAY (n.d.) *Sustainability Manifesto.*
Available at: https://assets.presscloud.com/file/24/245205816276374/HAY_Sustainability_manifesto.pdf
(Accessed 7 June 2021).

Heinrich Böll Stiftung (2019). *Plastikatlas: Daten und Fakten über eine Welt voller Kunststoff.* Available at: https://www.boell.de/de/2019/05/14/plastikatlas?dimension1=ds_plastikatlas
(Accessed 29 May 2021).

IKEA (n.d.) *Circular Product Design Guide.*
Available at: https://gbl-sc9u2-prd-cdn.azureedge.net/-/media/aboutikea/newsroom/documents/512088_
v2.pdf?rev=cd1d03b6b74c4544b1705c7a73df31f2&hash=49420E99AFDD82C3F7C6BC0CB52AFD8B
(Accessed 26 April 2021).

Infinitum (n.d.) *Infinitum.*
Available at: https://infinitum.no
(Accessed 27 June 2021).

Initiative Frosch (n.d.) *Kleine Kunststoffkunde.*
Available at: https://initiative-frosch.de/kleine-kunststoffkunde/
(Accessed 30 May 2021).

Initiative Frosch (n.d.) *Richtiges Recycling, falsches Recycling.*
Available at: https://initiative-frosch.de/richtiges-recycling-falsches-recycling/
(Accessed 27 June 2021).

International Organization for Standardization (2016) ISO 14021:2016 Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling). Available at: https://www.standard.no/no/Nettbutikk/produktkatalogen/Produktpresentasjon/?ProductID=809742
(Accessed 7 May 2021)

International Organization for Standardization (2010). *ISO 14025:2010.* Available at: https://www.standard.no/no/Nettbutikk/produktkatalogen/Produktpresentasjon/?ProductID=438649
(Accessed 7 May 2021)

International Organization for Standardization (2018). *ISO 14024:2018*. Available at: https://www.standard.no/no/Nettbutikk/produktkatalogen/Produktpresentasjon/?ProductID=964618
(Accessed 7 May 2021)

Isaac, G. (2020). Plastic chairs: Addressing the environmental emergency. *Fusion Journal*, pp. 18-29. Available at: https://www.researchgate.net/publication/343219247_Plastic_chairs_Addressing_the_environmental_emergency
(Accessed 3 June 2021)

Jahren, S. (2021). [Interview] (14 April 2021).

Karrer, B. (2021). [Interview] (3 March 2021).

Kviseth, K. (2021). [Interview] (30 April 2021).

Langballe, J. T. (2021). [Interview] (16 February 2021).

Lazell, J., Magrizos, S. & Carrigan, M. (2018) Over-claiming the circular economy: The missing dimensions. *Social Business*, 8(1), pp. 103-114.

Lietsch, F. (2021). [Interview] (24 March 2021).

Lindholm, G. (2021). [Interview] (15 February 2021).

Lodgaard, C. (2021). [Interview] (5 March 2021).

Magis (n.d.) *Responsibilty.*
Available at: https://www.magisdesign.com/profil/responsibility/
(Accessed 8 June 2021).

Martinko, K. (2021). *Australia Is Smart to Ban Biodegradable Plastics*.
Available at: https://www.treehugger.com/australia-smart-ban-biodegradable-plastics-5116196
(Accessed 31 May 2021).

Mestre, A. & Cooper, T. (2017). Circular Product Design. A Multiple Loops Life Cycle Design Approach for the Circular Economy. *The Design Journal*, 20, pp. 1620-1635.

Miniwiz (2021). *Can Plastic Furniture Be Sustainable?*.
Available at: https://miniwiz.medium.com/can-plastic-furniture-be-sustain-able-eee981d454ce
(Accessed 4 July 2021).

Morrison, J. (2021). [Interview] (15 June 2021).

Netværk for cirkulær plastemballage (2019). *Design Guide: Reuse and recycling of plastic packaging for private consumers.*
Available at: https://plast.dk/wp-content/uploads/2019/12/Design-Guide-Re-use-and-recycling-of-plastic-packaging-for-private-consumers-english-version-1.pdf
(Accessed 30 May 2021).

NIKE (n.d.) *10 Principles of Circular Design.*
Available at: https://www.nikecirculardesign.com/guides/MiniGuide.pdf
(Accessed 27 April 2021).

Norwegian Trash (2021). *Åtte designprinsipper for en mer sirkulær verden.*
Available at: https://norwegiantrashtalk.medium.com/ni-prinsipper-for-å-designe-en-mer-sirkulær-verden-c7e62189ffa2
(Accessed 7 May 2021).

Ogoori (n.d.) *About Ogoori.*
Available at: https://www.ogoori.eco/about
(Accessed 27 June 2021).

Ogoori (n.d.) *Ogoori.*
Available at: https://www.ogoori.eco/copy-of-home
(Accessed 28 June 2021).

Oliart, M. (2021). [Interview] (25 February 2021).

Perin, E. (2021). [Interview] (19 February 2021).

Politowicz, K. & Earley, R. (n.d.) *The TEN.*
Available at: http://www.tedresearch.net/teds-ten/
(Accessed 7 May 2021).

Precious Plastic (2020). *Safety and Fumes.*
Available at: https://community.preciousplastic.com/academy/plastic/safety
(Accessed 10 June 2021).

Precious Plastic (2020). *The Basics of Plastic.*
Available at: https://community.preciousplastic.com/academy/plastic/basics
(Accessed 30 May 2021).

Rams, D. (n.d.) *10 principles for good design - by Dieter Rams.*
Available at: https://ifworlddesignguide.com/design-specials/dieter-rams-10-principles-for-good-design
(Accessed 7 May 2021).

Rashid, K. (2017). *A brief history of the humble plastic chair (and its oil-free future).*
Available at: https://edition.cnn.com/style/article/history-of-plastic-chairs-karim-rashid/index.html
(Accessed 3 June 2021).

Rieger, T. (2021). [Interview] (6 April 2021).

Rollinson, A. N. & Oladejo, J. (2020). *Chemical Recycling: Status, Sustainability, and Environmental Impact,* Available at: https://www.researchgate.net/publication/346018224_Chemical_Recycling_Status_Sustainability_and_Environmental_Impacts
(Accessed 31 May 2021)

Rossi, S. A. E. (2021). [Interview] (18 February 2021).

RSA (2015). *Rearranging the Furniture: An RSA Great Recovery Design Residency in collaboration with SUEZ Recycling and Recovery UK.* Available at: https://www.thersa.org/reports/the-great-recovery-rearranging-the-furniture
(Accessed 2 June 2021)

Schaart, E. (2020). *The problem with recycling? One word: Plastics.*
Available at: https://www.politico.eu/article/the-problem-with-recycling-one-word-plastics/
(Accessed 15 May 2021).

Schreiner, M. (2017). *Der Monobloc: Ein Stuhl für alle und überall.*
Available at: https://www.augsburger-allgemeine.de/kultur/Journal/Design-Der-Monobloc-Ein-Stuhl-fuer-alle-und-ueberall-id41568591.html
(Accessed 3 June 2021).

Selvefors, A., Rexfelt, O., Renström, S. & Strömberg , H. (2019). Use to use – A user perspective on product circularity. *Journal of cleaner production,* 223, pp. 1014-1028.

Shahbazi, S. & Jönbrink, A. K. (2020). Design Guidelines to Develop Circular Products: Action Research on Nordic Industry. *Sustainability*, 12(9).

SINTEF (n.d.) *Applied research, technology and innovation.*
Available at: https://www.sintef.no/en/sintef-group/this-is-sintef/
(Accessed 9 July 2021).

Snøhetta (n.d.) *Plast.*
Available at: https://snohetta.com/projects/403-plast
(Accessed 7 June 2021).

Stahel, W. R. (2016). *The circular economy.*
Available at: https://www.nature.com/news/the-circular-economy-1.19594
(Accessed 15 May 2021).

The Ellen MacArthur Foundation (2012). *Towards the Circular Economy Vol. 1: an economic and business rationale for an accelerated transition.* Available at: https://www.ellenmacarthurfoundation.org/publications/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an-accelerated-transition
(Accessed 15 May 2021)

The Ellen MacArthur Foundation (2016). *The New Plastics Economy: Rethinking the Future of Plastics.*
Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf
(Accessed 29 May 2021).

The Ellen MacArthur Foundation (2017). *The New Plastics Economy: Rethinking the Future of Plastics & Catalyzing Action.*
Available at: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/NPEC-Hybrid_English_22-11-17_Digital.pdf
(Accessed 29 May 2021).

The Ellen MacArthur Foundation (2021). *Circular-ish: the messy reality of circular design.* Available at: https://the-circular-economy-podcast.simplecast.com/episodes/circular-ish-the-messy-reality-of-circular-design-episode-25-Dh2hYq_B
(Accessed 27 June 2021)

The Ellen MacArthur Foundation (n.d.) *Circular Design.*
Available at: https://www.ellenmacarthurfoundation.org/explore/circular-design
(Accessed 31 May 2021).

The European Commission (2016). COMMISSION DECISION (EU) 2016/1332 of 28 July 2016 establishing the ecological criteria for the award of the EU Ecolabel for furniture. *Official Journal of the European Union.* Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.210.01.0100.01.ENG
(Accessed 24 June 2021)

The European Commission (n.d.) *Criteria in a nutshell.* Available at: https://ec.europa.eu/environment/ecolabel/documents/factsheet_furniture.pdf
(Accessed 24 June 2021)

The International EPD System (n.d.) *Environmental Product Declarations.*
Available at: https://epdweb3.azurewebsites.net/all-about-epds/the-epd
(Accessed 24 June 2021)

The Nordic Swan Ecolabel (n.d. -a). *The official ecolabel of the Nordic countries.*
Available at: https://www.nordic-ecolabel.org/the-nordic-swan-ecolabel/
(Accessed 24 June 2021)

The Nordic Swan Ecolabel (n.d. -b.) *The Nordic Swan Ecolabel promotes circular economy.*
Available at: https://www.nordic-ecolabel.org/contentassets/b8ceb100e3184ee88ae1b3f632f9238e/fact-sheet_circular-economy_nordic-ecolabelling_nov2018.pdf
(Accessed 24 June 2021).

The Nordic Swan Ecolabel (n.d. -c.) *Nordic Ecolabelling for Furniture and fitments.*
Available at: https://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=031
(Accessed 24 June 2021)

The Nordic Swan Ecolabel (n.d. -d). *About Nordic Swan Ecolabelled Furniture and fitments.* Available at: https://www.nordic-ecolabel.org/product-groups/group/?productGroupCode=031
(Accessed 24 June 2021)

Thiel, J. (2010). Monobloc – On the World Chair. *Tabloid Design Miami*, 17.
Available at: http://signal2noise.de/wp-content/uploads/2015/09/Jens-Thiel-Monobloc-Design-Miami.pdf
(Accessed 3 June 2021)

Tonkinwise, C. (2015). Design for Transitions – from and to what?. *Design Philosophy Papers*, 13(1). Available at: https://www.researchgate.net/publication/290472543_Design_for_Transitions_-_from_and_to_what
(Accessed 27 June 2021)

Tonkinwise, C. (2017). Transitions in Sociotechnical Conditions that Afford Ownership: Sustainable Who? in Chapman, J.. In: *Routledge Handbook of Sustainable Product Design*. London: Taylor & Francis Group, pp. 349-358.

URBANREC (2020). *URBANREC GUIDELINES: 'New approaches for the valorisation of URBAN bulky waste into high added value RECycled products.*
Available at: https://urbanrec-project.eu/ficheros/URBANREC_D6.1__Guidelines_3.pdf
(Accessed 2 June 2021).

URBANREC (n.d). *Ecodesign guideline.*
Available at: https://urbanrec-project.eu/ficheros/URBANREC_D6.2_Guidelines.pdf
(Accessed 6 May 2021).

van den Berg, M. R. & Bakker, C. A. (2015). *A product design framework for a circular economy.* Nottingham UK, PLATE Conference. Available at: https://www.plateconference.org/product-design-framework-circular-economy/
(Accessed 26 April 2021)

Veelaert, L., Du Bois, E., Hubo, S., Van Kets, K. & Ragaert, K. (2017) Design from Recycling, *EKSIG 2017: Alive. Active. Adaptive*. Rotterdam, June 19-20, 2017. pp. 129-143.

Vestre, J. C. (2021). [Interview] (10 March 2021).

Vestre (n.d. -a) *How do you build the world's most environmentally friendly furniture factory?.*
Available at: https://vestre.com/news/how-do-you-build-the-worlds-most-environmentally-friendly-furniture-factory
(Accessed 8 June 2021).

Vestre (n.d. -b) *The growing importance of EPDs. Why it matters and how you use them.*
Available at: https://vestre.com/news/the-growing-importance-of-epds-why-it-matters-and-how-you-use-them
(Accessed 24 June 2021)

Vitra Design Museum (2017). *Monobloc – A Chair for the World.*
Available at: https://www.design-museum.de/en/exhibitions/detailpages/monobloc-a-chair-for-the-world.html
(Accessed 3 June 2021).

Wilkhahn (n.d). *Sustainability Report 2020 – 2022.*
Available at: https://www.wilkhahn.com/fileadmin/user_upload/Wilkhahn-Environmental-Statement.pdf
(Accessed 6 May 2021).

Zero Waste Europe (2020). *Understanding the Environmental Impacts of Chemical Recycling.*
Available at: https://zerowasteeurope.eu/library/understanding-the-environmental-impacts-of-chemical-recycling-ten-concerns-with-existing-life-cycle-assessments/
(Accessed 31 May 2021).

Image references

p. 49: Eames's plastic chair, https://www.vitra.com/de-at/magazine/details/the-story-of-an-icon

p. 49: Joe Colombo's Universale, https://homeunionnyc.com/products/1972-abs-plastic-universale-chair-by-joe-colombo-for-kartell

p. 49: Panton chair, https://www.bukowskis.com/en/lots/1279916-six-panton-chair-classic-by-verner-panton-for-vitra

p. 51: Fauteuil 300, https://www.swiss-architects.com/de/architecture-news/gefunden/monobloc-ein-stuhl-fur-die-welt

p. 51: Grosfillex Resin Garden Chair, https://www.amazon.com/Grosfillex-Pacific-Fanback-Armchair-49092066/dp/B00QMQIYWW

p. 109: MagicPp, n.d. *Background with different plastic chairs for separate garbage collection outdoors*. [digital image] Available at:
https://www.shutterstock.com/nb/image-photo/background-different-plastic-chairs-separate-garbage-1822995209 (Accessed: 15.07.21)

p. 111: Fritz Lietsch, http://www.eco-world.de/scripts/shop.prg?shop=presse&wg=referenten

p. 123, 169, 185, 208, 209, 213, 215, 217, 219, 220, 222: HAY. *AAC ECO 12*.
Available at: https://hay.presscloud.com/digitalshowroom/#/gallery/AAC-12-Eco

p. 124, 127, 169, 186, 206, 209, 213, 214, 216, 219, 223: HAY. *Revolt.*
Available at: https://hay.presscloud.com/digitalshowroom/#/gallery/Revolt

p. 128, 169, 188, 206, 209, 213, 215, 216, 218, 220, 224, 235: Fritz Hansen. *N02 Recycle*.
Available at: https://downloads.fritzhansen.com/asset-bank/action/browseItems?categoryId=1722&categoryTypeId=1&cachedCriteria=1

p. 131: Nendo. Nov. 2019. *N02 Recycle*. Available at:
https://nendo.jp/en/works/n02-recycle/

p. 132, 169, 189, 206, 209, 212, 215, 216, 219, 220, 225, 235: S-1500, https://senseon.no/shop/s-1500-stol-i-resirkulert-plast/

p. 137: Stephen Citrone. *S-1500*. Available at:
https://snohetta.com/projects/423-s-1500-revamping-an-icon-by-rethinking-industrial-recycling

p. 138, 169, 190, 205, 208, 209, 212, 215, 217, 218, 220: Alfi, https://www.madeindesign.co.uk/prod-alfi-chair-ash-legs-by-emeco-refalfi18ahgreen.html

p. 141: Alfi, https://www.architonic.com/de/product/emeco-alfi-chair-high-back/1306523#&gid=1&pid=2

p. 142, 169, 192, 204, 205, 212, 214, 216, 218, 227, 218: Emeco, *On & On.* Available at: https://emeco.centracdn.net/client/dynamic/articles/original-14emecoononcollection_stackingchair_rpetseat_greenblue_9683.jpg

p. 145: Emeco, *On & On.* Available at: https://emeco.centracdn.net/client/dynamic/articles/original-1emeco_ononcollection_chairs_1_9255.jpg

p. 147, 149, 169, 194, 210, 214, 217, 218, 220, 235: Magis. *Costume.* Available at: https://www.magisdesign.com/product/costume/

p. 148: Diez Office, 2021. *Costume.* Available at:
https://www.diezoffice.com/stories/costume-for-magis/

p. 147, 149, 169, 195, 204, 205, 215, 217, 218, 220, 230: Magis. *Bell chair.*
Available at: https://www.magisdesign.com/product/bell-chair/

p. 154, 156, 169, 196, 210, 215, 216, 219, 220, 231, 235: Flokk. *Capisco Puls made from recycled sow plough markers.*
Available at: https://www.flokk.com/global/hag/limited-edition-hag-capisco-puls-reserve-today

p. 158, 163, 169, 232, 235: The Coast Bench, https://www.architonic.com/de/product/vestre-coast-bench/20188398

p. 164: The FS Stool, https://cobaltniche.files.wordpress.com/2013/11/fs_stool1_0.jpg

p. 166: https://www.fluidsolids.com/loesungen/

p. 187: HAY, n.d. *Product fact sheet Revolt.*

p. 188: Fritz Hansen, n.d. *Product fact sheet N02 Recycle.*

p. 189: NCP, n.d. *Product sheet S-1500.*

p. 191: Emeco, n.d. *Product brochure Alfi.*

p. 193: Emeco, n.d. *Product brochure On & On.*

p. 194: Magis, n.d. *Costume catalogue.*

p. 195: Magis, n.d. *Bell catalogue.*

p. 245: Capisco, https://www.stylepark.com/de/flokk/hag-capisco#

p. 266: Frosch packaging, https://initiative-frosch.de/verpackungen/

p. 268: https://www.oa.no/panting/

p. 288: Kjersti Kviseth, https://renas.no/forbruk-med-omtanke/

p. 289: Dirk Bruniecki, n.d. *Konstantin Grcic.*
Available at: https://www.dirkbruniecki.de/konstantin-grcic/konstantin-grcic-munich-5/

p. 289: Francesco Canesi Lissoni, image received via email

p. 289: Robert Brembeck. n.d. *Stefan Diez*. Available at: https://www.robbreport.de/autos/galerie/der-neue-bmw-ix#page1

p. 289: Jasper Morrison, available at: https://www.gessato.com/creative/jasper-morrison/

Appendix

The interview guides in the appendix reflect the actual interviews, therefore some questions have been removed or added based on the interviewees answers

Appendix A - Interview guide HAY

Interviewee: Gustav Lindholm, Senior Product Developer - Furniture

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is HAY's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are HAY's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does HAY wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consum er's?

Questions regarding the use of plastic:
Q7) Has HAY's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is HAY using plastic?
Q9) What types of plastic do you use?
Q10) For what products does HAY use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those made from virgin plastics?

Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?
Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is HAY doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding specific projects:
About A Eco:
Q24) Could you tell me about the plastic material used?
Q24a) What does it consist of?
Q24b) How much of it is recycled? Why?
Q24c) How is it made?
Q24d) Do you make the material in house, or do you use a subcontractor
Q25) I read that you use recycled waste material from your own production lines, so you use industrial waste and not post-consumer waste for this chair?
If yes: Why?
Q26) Why do you only make it in black?
Q27) I noticed that for the About a chair series you use different bases, some are wooden, and others are made from steel, why did you choose the wooden base for the Eco series? (instead of for instance steel?)
Q28) Why do you not offer it with different bases?
Q29) What would happen to the chair at its end of life?

Q30) How would the chair be recycled?
Q31) How much does the chair cost?
Revolt:
Q32) Could you tell me about the plastic material used?
Q32a) What does it consist of?
Q32b) How big part of the material is recycled? Why?
Q32c) How is it made?
Q32d) Do you make the material in house, or do you use a subcontractor?
Q33) Why do you use ABS for this chair?
Q34a) Why is the plastic made from white goods?
Q34) How do you make the different colors?
Q35) Why do you make 9 colors?
If the black version is 100% recycled ABS, then why not just make that one?
Q36) What would happen to the chair at its end of life?
Q37) How would the chair be recycled?
Q38) How much does the chair cost?

Questions regarding the two projects Revolt chair and About A Eco:
Q39) If you could, is there anything you would have done differently to make them even more sustainable?
Q40) Why have you chosen to recreate already existing chairs with a recycled plastic content, instead of creating new designs?
Q41) Why is the recycled content in these chairs only 30%?
Q42) Do you also use recycled plastic in other furniture that we have not talked about?
Q42a) If yes, could you tell me about them?
Q43) What is the estimated life span of the two chairs?
Q44) Why is the recycled plastic content 30 % in the two chairs?

Questions regarding Arbour Eco:
Q45) I noticed that the About A Eco chair is not the only furniture piece with an Ecolabel, the Arbour Eco sofa also has one (The Nordic Swan Ecolabel), is it a goal of HAY to create products that get such labels?
Q45a) If yes: Why?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix B - Interview guide Fritz Hansen

Interviewee: Jesper Thimes Langballe, Product Development Manager

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Fritz Hansen's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Fritz Hansen's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Fritz Hansen wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?

Questions regarding the use of plastic:
Q7) Has Fritz Hansen's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is Fritz Hansen using plastic?
Q9) What types of plastic do you use?
Q10) For what products does Fritz Hansen use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those made from virgin plastics?

Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?
Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is Fritz Hansen doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding specific projects:
N02 Recycle:
Q24) Could you tell me about the plastic material used?
Q24a) What does it consist of?
Q24b) How is it made?
Q24c) Do you make the material in house, or do you use a subcontractor?
Q25) I read that the seat shell is made from minimum 95% recycled plastics, what are the other remaining percentages?
Q26) Where does the household waste come from?
Q27) Why do you use household waste?
Q28) How do you make the 7 colors?
Q29) Why do you make 7 different colors?
Q30) Why have you chosen to make 5 different models?
Q31) How is the seat shell attached to the different bases? Let's say the basic version with the 4 steel legs, how is the seat shell attached to the base?

Q32) Do all models have the EU Ecolabel?
Q32a) If no: Why not?
Q33) Was it a goal to create a chair that would get the EU Ecolabel?
Q33a) If yes: Why?
Q34) What would happen to the chair at its end of life?
Q35) How would the chair (the different models) be recycled?
Q36) What is the estimated lifespan of the chair?
Q37) How much does it cost?
Q8) If you could, is there anything you would have done differently to make the chair even more sustainable?
Q39) Do you also use recycled plastic in other furniture that we have not talked about?
Q40) Is there a reason why you are using post-consumer waste and not industrial waste, which you said is also sort of easier to control?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix C - Interview guide Snøhetta

Interviewee: Stian Alessandro Ekkernes Rossi, Architect

General questions about the furniture industry:
Q1) What's your take on plastic as a material?
Q2) What do you think about the way plastic is used in the furniture industry?
Q3) Do you think there has been any changes in the last few years in regard to the furniture industry's approach to plastic?
Q4) What changes do you wish to see in the furniture industry?
Q5) What do you think the furniture industry has to do to be able to implement these changes?

General questions about the Plast research project:
Q6) What made you start the research project Plast?
Q7) Why did you choose to focus on plastic?
Q8) What was the purpose of the project?
Q9) How did you work on this project?
Q10) Did you have any partners for this project?
Q10a) If yes: Who?
Q10b) What did that material investigation entail?
Q11) I read that it was a research project, so what researchers did you collaborate with and how did that work?
Q12) How did it go from research to actual product development?
Q12a) What were the challenges in this transition?
Q13) What have you learned from this project?
Q14) What is the most surprising or important thing you learned about plastic?
Q15) What do you think the furniture industry can learn from this project?

Questions about S-1500 for NCP:
Q16) How did you discover that you could get plastic from (the aquaculture players) Nova Sea and Kvarøy Fiskeoppdrett?
Q17) What type of plastic is the chair made of?
Q18) I read that fishing nets, ropes and pipes are used, is there any other plastic waste also used?
Q19) Does the plastic, since it comes from aquaculture, differ to plastic retrieved on land?
Q20) Are there any additives in the recycled plastic material?
Q20a) If no: Why not?
Q21) How is it possible to make 8 different colors without adding any color pigments?
Q22) Can you take me through the process from waste to finished product?
Q22a) So, it is mechanical recycling?

Q23) How did you develop the marbling that makes the chair so special?
Q24) How is that marbling made in mass production?
Q25) Why do you offer thee chair with 2 different bases?
Q26) Why is the base made from steel?
Q26a) Could you tell be a bit more about that?
Q27) How is the seat shell attached to the base?
Q28) I read that the project contributes to building a local circular economy, as it employs plastic waste from the local industry to produce chairs in the same area. I also read that the chair has an expected lifetime of at least 100 years. In that regard, I was wondering, what happens to the chair at its end of life?
Q29) How will the chair be recycled?
Q30) I have looked at a number of different chairs made from recycled plastics, and several of them, with much lower recycled content, advertise that they have an Ecolabel. So, why does this chair not have an Ecolabel?
Q31) Why does this chair have a significantly lower carbon footprint than similar products made from virgin plastics?
Q32) How much does the chair cost?
Q32a) If you could, is there anything you would have done differently to make it even more sustainable?
Q32b) What is the warranty and how long are spare parts offered?

Questions regarding design for recycling and design of products consisting of recycled plastic:
Q33) What has this project taught you about what is important to keep in mind when designing for recycling.
Q34) What are the challenges connected to designing for recyclability?
Q35) What are the challenges connected to designing a product made from recycled plastics?
Q36) In general, what is important in order to design sustainable plastic furniture?
Q37) Is Snøhetta working on any other relevant projects related to plastics and circular economy?
Q37a) If yes, could you tell me about them?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix D - Interview guide Magis

Interviewee: Enrico Perin, Designer

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Emeco's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Emeco's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Emeco wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?

Questions regarding the use of plastic:
Q7) Has Emeco's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is Emeco using plastic?
Q9) What types of plastic do you use?
Q10) For what products does Emeco use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those made from virgin plastics?
Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?

Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is Emeco doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding design of future products:
Q24) Do the new products you design mostly consist of virgin or recycled plastic?
Q24a) How is the distribution between virgin and recycled plastic?
Q24a-i) If mostly virgin plastic: Why?
Q24a-ii) If mostly recycled plastic: Why?
Q24) What is important in order to design sustainable plastic furniture?
Q25) What is Magis doing in order to design for recyclability?
Q26) What are the challenges connected to designing for recyclability?
Q27) What are the challenges connected to designing a product made from recycled plastics?
Q24) Do you have any new, upcoming sustainable plastic projects?
Q24a) If yes: could you tell me about them?

Questions regarding specific projects:
Bell chair:
Q24) Could you tell me about the material used?
Q24a) What does it consist of?
Q24b) How is it made?

Q24c) Do you make the material in house, or do you use a subcontractor?
Q25) As I understood, the material is fiberglass reinforced. Why?
Q26) How do you make the 3 colors?
Q27) Why do you make 3 colors?
Q28) What are the "dots" that you can see in the color? What do they come from?
Q29) What would happen to the Bell Chair at its end of life?
Q30) How would the chair be recycled?

Costume:

Q24) Could you tell me about the material used?
Q25) Is it the same material as used for the Bell Chair?
Q25a) If not:
Q25a-i) What does it consist of?
Q25b) How is it made?
Q25b-i) Do you make the material in house, or do you use a subcontractor?
Q26) Why do you use industrial and not municipal waste when the color of the plastic does not matter (since it is covered with fabrics)?
Q27) Are the smaller plastic parts used for the attachment mechanisms also recyclable?
Q27a) What type of plastic are they made from?
Q28) What material does the fabric cover consist of?
Q29) What would happen to the product at its end of life?
Q30) How would the product be recycled?
Q31) Regarding the two projects Bell Chair and Costume: if you could, is there anything you would have done differently to make them even more sustainable?
Q32) What is the expected life span of the Bell Chair and Costume?
Q33) What is the warranty on them?
Q34) How much does the Bell chair cost? and how much does Costume cost (one unit)?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix E - Interview guide Emeco

Interviewee: Jaye Buchbinder, Product Development Engineer & Head of Sustainability

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Emeco's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Emeco's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Emeco wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?

Questions regarding the use of plastic:
Q7) Has Emeco's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is Emeco using plastic?
Q9) What types of plastic do you use?
Q10) For what products does Emeco use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those made from virgin plastics?

Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?
Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is Emeco doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding specific projects:
Alfi:
Q24) Could you tell me about the plastic material used?
Q24a) This chair is made with 92.5% PP combined with 7.5% wood fiber, whereas the 1 inch reclaimed is made with 88% PP and 2% wood fiber, so I was wondering why is there a difference here?
Q24b) That's the wood fiber or is there anything else in there?
Q24c) What does it consist of?
Q24d) How big part of the material is recycled? Why?
Q24e) How is it made?
Q24f) Do you make the material in house, or do you use a subcontractor?
Q24g) Why do you mix recycled PP with waste wood fiber?
Q25) Why do you use industrial waste and not post-consumer waste for this chair?
Q25a) Is the PP post-industrial or post-consumer?
Q25b) In general, why do you use industrial waste for some products, and post-con-

sumer waste for others?
Q25c) Where do you get the post-consumer PP from?
Q27) How do you make the 6 different colors?
Q28) Why do you make 6 colors?
Q29) How do you attach the seat shell to the base?
Q30) Why do you offer it with 2 different bases?
Q31) What is the estimated life span of the chair?
Q32) What would happen to the chair at its end of life?
Q33) How would the chair be recycled?
Q33a) and then when you recycle it, does it become PP with wood fibers again or do you separate those in a way?
Q33b) and can it only be made into the same chair again or can you make other products with that material when you recycle it?
Q33c) and can it be recycled in other recycling facilities or just in house?
Q34) How much does the chair cost?
On & on:
Q35) Could you tell me about the plastic material used?
Q35a) What does it consist of?
Q35b) How much of it is recycled? Why?
Q35c) How is it made?
Q35d) Do you make the material in house, or do you use a subcontractor?
Q35e) Why is the material fiberglass reinforced?
Q35f) How do you work to improve the materials or increase the recycled plastic content?
Q35g) Is it a goal to make those materials into 100% recycled plastic?
Q36) Is the material used for the on & on chair the same as for the 111 Navy chair, only that the composition is improved (increased recycled plastic content of the material)?
Q36a) If yes: How do you work to improve materials/ increase the recycled plastic content?
Q37) The name on & on indicates that the chair can be endlessly recycled, and I also read that the polymer does not downgrade. How did you develop a material that can be endlessly recycled without downgrading?
Q38) How big is the carbon footprint of this chair?
Q39) How do you make the 6 different colors?
Q39a) Could you tell me more about the non-toxic pigments used?
Q40) Why do you make 6 colors?
Q41) Why do you also offer the chair with plywood seats and upholstered seats?
Q41a) For the upholstered seat, do you use PU foam?
Q42) How is the seat attached to the frame?
Q43) What is the estimated life span of the on & on chair?

Q44) What would happen to the chair at its end of life?
Q45) How would the chair be recycled?
Q45a) Can that also be recycled in other recycling facilities?
Q45b) so that means that it could also be recycled into other products?
Q46) How much does the on & on chair cost?

Questions regarding the two projects On & On and Alfi:

Q47) If you could, is there anything you would have done differently to make them even more sustainable?
Q49) Do you also use other types of recycled plastic that we have not talked about?
Q49a) If yes, could you tell me about those recycled plastics?
Q50) Are you developing any new plastic materials?
Q50a) If yes: Could you tell me about them?
Q51) How do you work to develop new environmental materials?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix F - Interview guide FluidSolids

Interviewee: Beat Karrer, Founder & CEO

Questions regarding FluidSolids:
Q1) With a background coming from design, why did you choose to create a new bio-plastic?
Q2) Why do you focus on bioplastic instead of recycled plastic?
Q3) How did you work to turn the idea of a circular economy into an actual business that creates a closed loop system?
Q4) Is it bioplastic, biodegradable or both?
Q5) What does the material consist of?
Q5a) How much of it is post-industrial waste? Why?
Q5b) Why do you use post-industrial waste and not post-consumer waste?
Q6) How is the material made?
Q7) How do you make different colors?
Q8) Is there a difference in quality, strength or other physical properties between your material and virgin plastics?
If yes: Why?
Q9) Is there a difference in the life span of your material versus virgin plastics?
If yes: Why?
Q10) Do you have a take back system for your material?
Q11) Can the material be recycled in normal recycling facilities or does it have to be re-cycled by the producer of the material?
How is it recycled?
Q12) Is the material suited or furniture?
If yes: Why and how?
Q13) Do you have any upcoming projects where the material is used for furniture? If yes: could you tell me about those projects?

Questions regarding the FS stool:
Q14) How is the seat attached to the wooden legs?
Q15) What is the estimated life span of the stool?
Q16) What happens to the stool at its end of life?
Q16a) Can you dissemble the stool?
Q17) How much does the stool cost?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix G - Interview guide Ecoalf

Interviewee: Mónica Oliart, PR & Collaborations Manager

Questions regarding sustainability and circular economy in your company and in the furniture industry:
Q1) What is Ecoalf's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Ecoalf's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Ecoalf wish to see in the furniture industry?
Q6) What do you consider to be the furniture industry's responsibility and what is the consumer's?
Q7) What do you think the furniture industry can learn from your company? (In regard to sustainability, recycling and circular economy?)
Q8) Do you notice any difference in working with the furniture industry in difference to the fashion industry when it comes to sustainability?
Q8a) If yes: What are the differences?
Q8b) Why do you think it is more present in the fashion industry?
Q9) Do you notice any difference in working with the furniture industry in difference to the fashion industry regarding the use of plastic?
If yes: What are the differences?

Questions regarding materials and production:
Q10) Do your materials mostly consist of industrial waste or post-consumer waste?
Q11) How is the distribution between industrial and post-consumer waste?
Q12) Can you take me through the process from retrieving scrap material to finished fabrics made from plastic?
Q13) How do you recycle plastic waste (what technologies do you use)?
Q14) How does plastic waste retrieved from the ocean differ from plastic waste retrieved on land?
Q15) Is there a difference in quality, strength or other physical properties?
If yes: Why?
Q16) Is there a difference in the life span of recycled ocean plastic and recycled plastic from land?
If yes: Why?
Q17) What colors can you make with recycled ocean plastic?

Questions regarding Viccarbe x Ecoalf:
Generally about the project:
Q18) Why did you decide to do a collaboration with Viccarbe?
Q19) What is Ecoalf's role in the collaboration?
Q20) What is the goal of the collaboration?
About the first phase of the project:
Q21) Why have you chosen to use an already existing fabric that you use for clothes for the sofa and chair?
About the second phase of the project:
Q22) Can you describe the R & D project you are doing together with Viccarbe?

Q23) Is it possible to fully make the chair from recycled ocean plastic?
If no: Why not?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix H - Interview guide Viccarbe

Interviewee: Rubén Mateos Brea, Product Manager

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Viccarbe's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Viccarbe's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Viccarbe wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?

Questions regarding the use of plastic:
Q7) Has Viccarbe's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is Viccarbe using plastic?
Q9) What types of plastic do you use?
Q10) For what products does Viccarbe use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those made from virgin plastics?

Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?
Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is Viccarbe doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding Viccarbe x Ecoalf:
Generally about the project:
Q24) Why did you decide to do a collaboration with Ecoalf?
Q25) What is Viccarbe's role in the collaboration?
Q26) What is the goal of the collaboration?
About the first phase of the project:
Q27) How is the Ecoalf fabric different than the originally used fabrics?
Q28) Are you going to replace all fabrics used for your products with Ecoalf's fabric?
Q26a) If yes: Why?
Q26b) If no: Why not?
About the second phase of the project:
Q29) Can you describe the R & D project you are doing together with Ecoalf?
Q30) As I have understood it, the chair that Stefan is designing is part of the second phase of the Viccarbe x Ecoalf project. Is this chair the first new design that you will make for the Viccarbe x Ecoalf project?

Q30a) If yes: Why did you decide to make a chair?
Q30b) If no:
Q30b-i) What will the first furniture piece be?
Q30b-ii) Why?
Q31) Could you give me the design brief for the chair you are making together with Stefan?
Q33) Can you tell me about the material you will use for the seat shell?
Q34) How do you make that material?
Q35) I read about the collaborative project with Ecoalf and it said you are working on a new line of furniture. Are you planning to make more recycled plastic furniture or plastic furniture made for recycling?
Q35a) If yes: Could you tell me about the furniture pieces you are planning to create?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix I - Interview guide Flokk

Interviewee: Christian Lodgaard, Senior Vice President, Products & Brands

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Flokk's take on a circular economy?
Q2) Is your company working towards a circular economy?
Q2a) If yes: What are you doing specifically?
Q2b) If no: Why not?
Q3) What are Flokk's sustainability goals?
Q4) How are you working to achieve your sustainability goals?
Q5) What change does Flokk wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?

Questions regarding the use of plastic:
Q7) Has Flokk's approach to plastic changed over the last few years?
Q7a) If yes:
Q7a-i) Why?
Q7a-ii) How?
Q7b) If no: Why not?
Q8) Why is Flokk using plastic?
Q9) What types of plastic do you use?
Q10) For what products does Flokk use plastics?
Q11) Do you use different types of plastics for different purposes?
Q11a) If yes: Why? (please explain why the specific types of plastics have different usage)
Q12) Do you produce products using virgin plastics?
Q12a) If yes: Why?
Q12b) If no: Why not?
Q13) Do you also use recycled plastics in your products?
Q13a) If yes:
Q13a-i) In your experience, how is producing a product from recycled plastic different than making it from virgin plastic?
Q13a-ii) For what purposes do you use recycled plastics?
Q13b) If no: Why not?
Q14) Is there a difference in quality, strength or other physical properties between your recycled plastic products and virgin plastic products?
Q14a) If yes: Why?
Q15) Is there a difference in the life span of your recycled plastic products versus those

made from virgin plastics?
Q15a) If yes: Why?
Q16) What happens to the products you produce at their end of life?
Q16a) Specifically, what happens to the plastic products at their end of life?
Q17) Do you have a system for the takeback of your plastic products?
Q17a) If yes:
Q17a-i) How does it work?
Q17a-ii) What happens to the plastic (dismantling, reuse, recycling etc.)?
Q17b) If no:
Q17b-i) Why not?
Q17b-ii) Are you planning to create one?

Questions regarding design of future products:
Q18) Do the new products you design mostly consist of virgin or recycled plastic?
Q18a) How is the distribution between virgin and recycled plastic?
Q18a-i) If mostly virgin plastic: Why?
Q18a-ii) If mostly recycled plastic: Why?
Q19) What is important in order to design sustainable plastic furniture?
Q20) What is Flokk doing in order to design for recyclability?
Q21) What are the challenges connected to designing for recyclability?
Q22) What are the challenges connected to designing a product made from recycled plastics?
Q23) Do you have any new, upcoming sustainable plastic projects?
Q23a) If yes: could you tell me about them?

Questions regarding specific projects:
HÅG Capisco Puls Snow Plough Markers:
Q25) Could you tell me about the plastic material used?
Q25a) What does it consist of?
Q25b) How much of it is recycled? Why?
Q25c) How is it made?
Q25d) Do you make the material in house, or do you use a subcontractor
Q26) How do you make the color?
Q27) Is this limited edition chair the same as a standard Capisco Puls 8010, except that the recycled plastic source is different?
Q28) What percentage of the other materials that the chair consists of are recycled (such as steel and aluminum)?
Q29) I read that the discovery of snow plough markers as a resource was part of a research project you did together with SINTEF, could you tell me about that research project?

Q30) What would happen to the chair at its end of life? Q31) How would the chair be recycled?
Q32) What is the life span of the chair?
Q33) How much does it cost?
Q34) If you could, is there anything you would have done differently to make it even more sustainable?
Questions regarding other models/chairs and recycled plastic:
Q35) Why is the recycled content in Capisco Puls lower than in Capisco?
Q36) Both Capisco and Capisco Puls consist of post-consumer and post-industrial waste, how much of the recycled plastic is post-consumer?
Q37) I also heard in one of your talks that you said that post-consumer plastic is the most sustainable plastic you can use, why is that?
Q38) Where does that post-consumer plastic waste that you use come from?
Q39) Where does the post-industrial plastic waste that you use come from?
Q40) Why does only Capisco have the Nordic Swan Label, and not Capsico Puls as well?
Q41) Why is certification important to Flokk?
Q42) What type of certification do you think is the most important/ says the most about the sustainability of a product?
Q43) Why do your chairs have one of the lowest carbon emissions in the industry?
Q44) You were recently placed as nr 4 in a sustainable report by Dodds and Shute, congratulations, that is impressive! I noticed that you didn't score maximum on materials and production, why is that?
Q45) Is recycled PP the only type of recycled plastic you use, or do you also use other types of recycled plastic in other furniture that we have not talked about?
If yes, could you tell me about them?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix J - Interview guide Vestre

Interviewee: Jan Christian Vestre, CEO
with some supplementary answers by Ope

Questions regarding sustainability and circular economy in your company and generally in the furniture industry:
Q1) What is Vestre's take on a circular economy?
Q2) What are you doing, specifically, to work towards a circular economy?
Q3) What are Vestre's sustainability goals?
Q4) How are you working to achieve your sustainability goals (to become the most sustainable furniture brand in the world)?
Q5) What change does Vestre wish to see in the furniture industry?
Q6) What do you consider to be the industry's responsibility and what is the consumer's?
Q8) Vestre is the first company in the world to put EPDs on all your products, congratulations on that! Why do you think EPDs are important?
Q8a) Do you think that they are more important than sustainability certifications/ecolabels? Why?
Q9) You have a Vision Zero, that you will not produce a single product which cannot last forever. What is important in order to design a piece of furniture that truly can last forever?
Q9a) and design them in such a way that they don't go out of date?
Q10) What is important in order to design sustainable plastic furniture?
Q11) What is Vestre doing in order to design for recyclability?
Q12) What are the challenges connected to designing for recyclability?
Q13) Do you have a takeback system for your furniture?
If yes: How does it work?

Questions regarding specific projects:
The Coast bench:
Q14) As far as I could tell, plastic isn't really a material that you typically use in your furniture, so why did you decide to design a new bench made of plastic?
Q15) What were the challenges connected to designing a product made from recycled plastic, and in particular from post-consumer ocean plastic waste?
Q16) Could you tell me about the plastic material used?
Q16a) What does the plastic material consist of?
Q16b) How is it made?
Q16c) Could you take me through the entire journey from waste picked up by volunteers to finished product?
Q16d) How do you make different colors?
Q17) What is the estimated life span of the bench?

Q18) What would happen to the bench at its end of life, how would it be recycled?
Q19) I also read that the plastic will be recycled and turned into new products, what exactly is the plastic recycled into?
Q20) I read that the plastic panels would have to be regularly replaced, do you know how often? and why?
Q21) I read that you will have a deposit system or lease the bench, could you explain why? and how it works?
Q22) How do you trace the plastic material?
Q23) Could you explain how the cooperation with Oogori works?
Q24) How much does it cost?
Q25) Do you have any new, upcoming sustainable plastic projects?
If yes: could you tell me about them?

The Plus:
Q26) It is said to be the first circular furniture factory in the world, I feel like circular economy is a lot of theory, not that much practice, so how do you turn it into actual production?

At last, is there anything you want to add? Or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix K - Interview guide Fritz Lietsch

The furniture industry in general
Q1) What change do you wish to see in the furniture industry? Especially regarding the use of plastic?

Responsibility
When it comes to taking responsibility, there were different opinions, some think the industry should lead the way and guide the consumer, whereas others think the responsibility lies with both as the consumer should also make demands, one also mentioned that politicians have responsibility.
Q2) What would you say is the furniture industry's responsibility and what is the consumer's? (maybe also politicians)
Q3) Would you say it's the furniture manufacturers responsibility to take back their products at end of life? Why/ why not?

Circular economy efforts
Q4) A majority of the ones that I've interviewed focus on designing for disassembly and recycling, whereas a few have more focus on design for longevity. Those who focus on extending life have also implemented circular business models such as buy back and refurbishment systems. Would you say that design for recycling and disassembly is the only thing needed to create a circular furniture industry?
Q5) What do you think is the most important things furniture manufacturer should to do to contribute to a circular economy and to closing loops?
Q6) Do you think furniture as a service or systems for instance such as buy back, and refurbishment are important? Why?
Q7) Speaking of design for longevity, what do you think the warranty of plastic furniture should be? One mentioned an interesting thing which is that you should ban warranties below 15 years, so far most have a warranty of only 5 years.

Susttainability efforts
Q10) Where would you say the biggest room for improvement in the furniture industry is in regard to sustainability?
Q11) How would you measure the environmental impact of a furniture company?
Q12) Do you think furniture companies should have a publicly accessible sustainability report?
Q13) I have noticed that those who have close to nothing online are vaguer in the interviews as well, their goals are vaguer and they don't have any specific actions to show to, whereas those who have corporate sustainability reports on their websites with numbers and detailed information about the effect of their actions are much more transparent about and specific on what they do in terms of sustainability in the interview as well. What does that tell you? / How would you interpret that?

Q14) Another trend I've noticed from these interviews is that many only have sustainability goals for their own production, and none on how they can contribute to reach other sustainable development goals. Do you think it is right to only focus on what they can do themselves within the company or should they also contribute in other ways, especially the social dimension of sustainability (because they seem to only focus on the economic and environmental)? Why/ why not?

Certification

There were a lot of different opinions about this, some favored EPDs, some favored Ecolabels and others think Ecolabels are irrelevant, whereas others wanted both and some were more focused on ISO standards.

Q15) Do you think certification is important? Why?

Q16) What type of certification would you say is the most important for furniture to truly say something about the environmental impact/footprint of a product?

Q17) Would you say EPDs, Ecolabels or both side by side?

Q18) Based on the divided opinions from the interviews, it seems that no type of certification exists at the moment that can truly inform the customer on the environmental impact of a product, what do you think would be a better solution?

Plastics & greenwashing

Q19) From these interviews, I noticed that many were reluctant to say what percentage of their products are made from virgin and recycled plastics, why do you think that is? (could it be a sign of greenwashing?)

Q20) Some were also reluctant to say why they don't have a take back system and why they don't plan to make one, how would you interpret that?

Q21) Those who were reluctant to answer these questions are also the same who don't have sustainability reports online. What do you say to that connection?

Q22) What do you think of furniture manufacturers who use recycled plastic waste to make their own plastic materials that aren't recyclable at the tail end?

Q23) Is there any typical sign of greenwashing in the furniture industry?

Q23a) What is the most common greenwashing in the furniture industry in your experience?

Q24) Would you call it greenwashing to use post-industrial waste and call it recycled plastic? Why/ why not?

At last is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix L - Interview guide Grønt Punkt Norge

Interviewee: Johannes Daae, Head of Development
Everything Johannes says in this interview is based on how it works for packaging.

I'm doing a case study where I'm comparing different chairs made from plastic waste. In these interviews I will be asking questions both regarding that these chairs are made from recycled plastic and their potential for recycling at end of life.

General questions about recycling:
Q1) A tendency that I have noticed during these interviews is that many say that they do not take back their products or take responsibility for them being recycled because there is no system for it, would you say that is true?
Q2) Are there some types of plastic that are easier to recycle than others? I've noticed that the majority of recycled plastic furniture is made from PP, but there is also some PE, PET and ABS.

Questions About The Challenges Of Recycled Plastics/ Established Truths
Q3) Many challenges connected to using recycled plastics were mentioned, which makes it more difficult to use than virgin plastic. Especially the quality of the material is a problem. Is recycled plastic really worse than virgin? If yes, what qualities make it worse?
Q4) Another challenge was to actually find recycled plastic, is sourcing really a problem?
Q5) Price was also an issue, that recycled plastic costs more than virgin, is that right?
Q6) Many say that they therefore rather use post-industrial waste (because they have control of the quality as opposed to post-consumer). Would you define using post-industrial waste as recycling? Why/ why not?
Q7) Some also focus on bioplastics in the future, while others think that it doesn't have the potential to even get close to being as good for the environment as recycling plastic. Would you say that recycling plastic is better than going with bioplastics? Why/ why not?
Q8) Would you say that there are some myths/ established truths about recycled plastic that aren't true? If yes, what?

Questions regarding specific chairs:
BELL CHAIR:
Q9) Magis said that those dots you see in the color represent the "impurities" in the recycled nature of the material, but they use post-industrial waste, and the others who use post-industrial waste don't have dots in the color. So, what I'm wondering is: do you think the dots in the color are completely natural or do you think it's something they do

on purpose?
Q10) Potential for recycling: Can the material be recycled?
Q10a) Why/ why not?
Q10b) If yes: What can it become? Downgrading, upcycling or same quality?
Q11) Magis says that this chair can be recycled 1:1 and become a new Bell chair, but can that happen when Magis does not have a system to take the chair back? What do you think most likely will happen to this chair at end of life?
Q12) Q10 What do you think of furniture manufacturers who develop their own recycled plastics materials that they claim are recyclable? Is it a good or bad solution? Why? (What is needed to make it a good solution?)
Q13) Composite materials were in general something the interviewees disagreed on, so can plastic composite materials be recycled? Is it harder to recycle than pure plastics?

ALFI:
Q14) Potential for recycling: Can the material be recycled?
Q14a) Why/ why not?
Q14b) If yes: What can it become? Downgrading, upcycling or same quality?
Q15) What do you think most likely will happen to this chair at end of life?
Q16) A lot of these chairs come in many different colors. Generally speaking, are there any limitations to what colors you can get with recycled plastics made from post-consumer waste?

ON & ON:
Q17) Potential for recycling: Can the material be recycled?
Q17a) Why/ why not? (colors?)
Q17b) If yes: What can it become? Downgrading, upcycling or same quality?
Q18) What do you think most likely will happen to this chair at end of life?

N02 RECYCLE:
Q19) Potential for recycling: Can the material be recycled?
Q19a) Why/ why not? (colors?)
Q19b) If yes: What can it become? Downgrading, upcycling or same quality?
Q19c) Speaking of chemical recycling, do you think that it is a good solution? Because I've read a lot about how energy intensive it is.
Q20) What do you think most likely will happen to this chair at end of life?

REVOLT:
Q21) HAY said that it is necessary with 70% virgin plastic to get the different colors, do you think that is right?

Q21a) I don’t get it to match with Fritz Hansen, does it make sense to you/ do you have any explanation for it?
Q22) Is it problematic to recycle ABS in terms of toxins? Many manufacturers don’t use it because of toxins, whereas HAY has introduced a new chair in ABS that has received the EU flower.
Q23) Potential for recycling: Can the material be recycled?
Q23a) Why/ why not? (colors?)
Q23b) If yes: What can it become? Downgrading, upcycling or same quality?

AAC 12:
Q24) Why do you think it’s only 30% post-industrial waste in this chair, especially since the color is black?
Q25) Potential for recycling: Can the material be recycled?
Q25a) Why/ why not?
Q25b) If yes: What can it become? Downgrading, upcycling or same quality?

COSTUME:
Q26) Potential for recycling: Can the material be recycled?
Q26a) Why/ why not?
Q26b) If yes: What can it become? Downgrading, upcycling or same quality?

CAPISCO PULS SNOW PLOUGH MARKERS:
Q27) Potential for recycling: Can the material be recycled?
Q27a) Why/ why not? (color?)
Q27b) If yes: What can it become? Downgrading, upcycling or same quality?

S-1500:
Q28) Potential for recycling: Can the material be recycled?
Q28a) Why/ why not? (color?)
Q28b) If yes: What can it become? Downgrading, upcycling or same quality?

Appendix M - Interview guide Fraunhofer

Interviewee: Tobias Rieger, research assistant

I have interviewed 8 furniture manufacturers and these questions are based on the findings of those interviews.
I'm doing a case study where I'm comparing different chairs made from plastic waste. In these interviews I will be asking questions both regarding that these chairs are made from recycled plastic and their potential for recycling at end of life.

General questions about recycling:
Q1) A tendency that I have noticed during these interviews is that many say that they do not take back their products or take responsibility for them being recycled because there is no system for it, would you say that is true?
Q2) Are there some types of plastic that are easier to recycle than others? I've noticed that the majority of recycled plastic furniture is made from PP, but there is also some PE, PET and ABS.

Questions About The Challenges Of Recycled Plastics/ Established Truths
Q3) Many challenges connected to using recycled plastics were mentioned, which makes it more difficult to use than virgin plastic. Especially the quality of the material is a problem. Is recycled plastic really worse than virgin? If yes, what qualities make it worse?
Q4) Another challenge was to actually find recycled plastic, is sourcing really a problem?
Q5) Price was also an issue, that recycled plastic costs more than virgin, is that right?
Q6) Many say that they therefore rather use post-industrial waste (because they have control of the quality as opposed to post-consumer). Would you define using post-industrial waste as recycling? Why/ why not?
Q7) Some also focus on bioplastics in the future, while others think that it doesn't have the potential to even get close to being as good for the environment as recycling plastic. Would you say that recycling plastic is better than going with bioplastics? Why/ why not?
Q8) Would you say that there are some myths/ established truths about recycled plastic that aren't true? If yes, what?

ABS
Q9) Is it problematic to recycle ABS in terms of toxins? ABS is also something the interviewees disagreed on, several don't use it at all because of toxins, whereas for instance HAY recently introduced a new chair in ABS that has received the EU flower.
Q9a) So, they don't affect the recycling?

COLOR

Q10) Are there any limitations to what colors you can get with recycled plastics made from post-consumer waste? There were different opinions about this, especially regarding white color. (Some said that it is not possible to make white post-consumer plastic, whereas others claim that they do)

Q11) Are all colors suitable for recycling?

Q11a) Are some colors preferred more than others when it comes to recycling?

Q11b) What colors can be recycled and retain the color, and to which do you have to add pigment?

COMPOSITES

Q12) Composite materials were in general something the interviewees disagreed on. Some say it's necessary and recyclable and others avoid it like the plague because they say it's not recyclable. Can plastic composite materials be recycled? Is it harder to recycle than pure plastics?

Q13) Can you recycle glass fiber reinforced plastic? Why/ why not?

Q13a) One manufacturer has a chair made from 77% PP (pre-consumer) + 20% glass fiber + 3% color master. Do you think that is recyclable?

Q13a-i) If yes: what can it be recycled into? (downgrading, recycling or upcycling)

Q13a-ii) Do you separate the glass fibers and plastic material?

Q13a-iii) Can you also reuse the glass fibers or only the plastic?

Q13a-iv) So, both the chair examples that I have here are recyclable then?

Q13a-v) And what happens to the color pigment?

Q13b) Another manufacturer has a chair made from 70% PET (post-consumer) + 20% glass fiber + 10 % color pigment. Do you think that is recyclable?

Q13b-i) If yes: What can it be recycled into? (downcycling, recycling or upcycling)

Q14) Can you recycle wood fiber reinforced plastic? Why/ why not?

Q14a) One manufacturer has a chair made from 92.5% PP (post-consumer) + 7.5% wood fiber. Do you think that is recyclable?

Q14a-i) If yes: What can it be recycled into? (downcycling, recycling or upcycling?)

Q15) If you manage to recycle composites, how do you do it?

Q15a) What technologies do you use?

Q16) And how energy intensive is this process in difference to mechanical recycling?

Q17) What is the end result of the recycling process?

Q18) When do you think it will be possible to recycle such composites on an industrial scale?

Q18a) And with the wood fibers, when do you think that will be possible on an industrial scale?

CHEMICAL RECYCLING:

Q19) Why are you investing in chemical recycling?

Q20) Do you think chemical recycling is suitable for recycling furniture? Why? / Why not?

Q21) In comparison to mechanical recycling, what is chemical recycling suited for (in terms of furniture)?

Q22) Do you think chemical recycling is better than mechanical recycling? Why/ why not?

Q22a) And when do you think that will be possible, that it becomes normal to combine those two?

At last is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix N - Interview guide SINTEF

Interviewee: Susie Jahren, Senior business developer & Polymer Chemist

I'm doing a case study where I'm comparing different chairs made from plastic waste. In this interview I will be asking questions both regarding the fact that these chairs are made from plastic waste and their potential for recycling at end of life.

Q1) Many use post-industrial waste instead of post-consumer plastic, would you define using post-industrial waste as recycling? Why/ why not?

ALFI:
Q2) Potential for recycling: Can the material be recycled?
Q2a) Why/ why not?
Q2b) If yes: What can it become? Downgrading, upcycling or same quality?
Q3) What do you think most likely will happen to this chair at end of life?
Q4) A lot of these chairs come in many different colors. Generally speaking, are there any limitations to what colors you can get with recycled plastics made from post-consumer waste?
There were different opinions about this, especially regarding white color. (Some said that it is not possible to make white post-consumer plastic, whereas others claim that they do)

ON & ON:
Q5) Potential for recycling: Can the material be recycled?
Q5a) Why/ why not? (colors?)
Q5b) If yes: What can it become? Downgrading, upcycling or same quality?
Q6) What do you think most likely will happen to this chair at end of life?

BELL CHAIR:
Q7) Magis said that those dots you see in the color represent the "impurities" in the recycled nature of the material, but they use post-industrial waste, and the others who use post-industrial waste don't have dots in the color. So, what I'm wondering is: do you think the dots in the color are completely natural or do you think it's something they do on purpose?
Q8) Potential for recycling: Can the material be recycled?
Q8a) Why/ why not?
Q8b) If yes: What can it become? Downgrading, upcycling or same quality?
Q9) Magis says that this chair can be recycled 1:1 and become a new Bell chair, but can that happen when Magis does not have a system to take the chair back? What do you think most likely will happen to this chair at end of life?
Q10) Q10 What do you think of furniture manufacturers who develop their own recy-

cled plastics materials that they claim are recyclable? Is it a good or bad solution? Why? (What is needed to make it a good solution?)
Q11) Composite materials were in general something the interviewees disagreed on, so can plastic composite materials be recycled? Is it harder to recycle than pure plastics?

N02 RECYCLE
Q12) Potential for recycling: Can the material be recycled?
Q12a) Why/ why not? (colors?)
Q12b) If yes: What can it become? Downgrading, upcycling or same quality?
Q12c) Speaking of chemical recycling, do you think that it is a good solution? Because I've read a lot about how energy intensive it is.
Q13) What do you think most likely will happen to this chair at end of life?

REVOLT
Q14) HAY said that it is necessary with 70% virgin plastic to get the different colors, do you think that is right?
Q14a) I don't get it to match with Fritz Hansen, does it make sense to you/ do you have any explanation for it?
Q15) Is it problematic to recycle ABS in terms of toxins? Many manufacturers don't use it because of toxins, whereas HAY has introduced a new chair in ABS that has received the EU flower.
Q16) Potential for recycling: Can the material be recycled?
Q16a) Why/ why not? (colors?)
Q16b) If yes: What can it become? Downgrading, upcycling or same quality?

AAC 12:
Q17) Why do you think it's only 30% post-industrial waste in this chair, especially since the color is black?
Q18) Potential for recycling: Can the material be recycled?
Q18a) Why/ why not?
Q18b) If yes: What can it become? Downgrading, upcycling or same quality?

COSTUME:
Q19) Potential for recycling: Can the material be recycled?
Q19a) Why/ why not?
Q19b) If yes: What can it become? Downgrading, upcycling or same quality?

CAPISCO PULS SNOW PLOUGH MARKERS:
Q20) Potential for recycling: Can the material be recycled?

Q20a) Why/ why not? (color?)
Q20b) If yes: What can it become? Downgrading, upcycling or same quality?

S-1500:
Q21) Potential for recycling: Can the material be recycled?
Q21a) Why/ why not? (color?)
Q21b) If yes: What can it become? Downgrading, upcycling or same quality?

At last is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix O - Questions to evaluate the circularity of a furniture product made from plastic waste materials

Some of the questions apply to more than one phase but have been placed under the life phase that seemed to be the most relevant for the question.

Production: Design from Recycling
Production entails a lot of factors, most of them which are not disclosed by manufacturers, such as where a product is made, with what energy source and so on. What however is known to this thesis is that all chairs in this case study are made using plastic waste materials, and that was the focus of the production phase. So, in terms of designing for circularity for the first phase of a product's life cycle, the focus was on designing from recycling. These questions served to see what type of plastic materials were used, how they were applied, and consequently how the design of the product was affected by it.

1) How close to being actual waste is the waste material used in the product?
The biggest environmental impact happens when you put a price tag on waste and make it a resource, when you create a value chain that can contribute to cleaning the planet of waste. For instance, when you use waste that would otherwise be landfilled or incinerated. Therefore, post-consumer waste is better than post-industrial waste.

2) How much of the plastic material is recycled?
The higher the recycled content, the greater environmental impact.

Use: Design for product integrity
For the use phase, the focus was on finding any clues as to how long-lasting the product is and if there were any circular initiatives in place to extend the lifetime of the product and keep it in use. Warranty and maintenance guides are usually the only information the manufacturer gives that to any degree can indicate life expectancy of the product, besides that, one has to look at the product design and whether the manufacturer offers any circular services or systems for the product. So, in terms of designing for circularity for the use phase of a product's life cycle, the focus was on designing for product integrity, and these questions served to help determine if the chair has in fact been designed for product integrity beyond physical durability.

3) How long is the warranty period and access to spare parts?
The warranty can say something about how durable the product is, and therefore in turn something about how long-lasting it is and to what extent it resists obsolescence. During the warranty period you usually have access to spare parts, so broken parts can be replaced, that is if the product is modular, which is especially important for more complex products consisting of multiple materials. Therefore, the longer the warranty, the bigger the chances are of the product being brought back to a working condition, reversing obsolescence.

4) What is the estimated product lifetime?
The warranty is typically shorter than the expected lifetime of the product. Life expectancy can therefore say something about the actual durability and therefore about product integrity of the product.

5) How versatile is the product?
For a product to be circular and to be designed for product integrity, it needs to be versatile, so that it will be used longer. Often it is more of a style issue than a durability issue and changing the appearance of the product would prevent people from disposing of the product simply because they are visually tired of it. The product should also be versatile in usage, that it can be changed to fit different scenarios in life so that the product can grow with the user, and not just fit in one setting. Either the consumer should be able to adapt the product to a change in need or taste themselves or services can be offered by the manufacturer.

End of life: Design for recycling
For the end-of-life phase, the focus was on assessing not only if the product is recyclable, but that it is easy, efficient and effective to recycle. These questions reflect whether a product is simply labelled as recyclable by the manufacturer or if the product is in fact recyclable in the real world, and if recyclable, how much effort it requires to actually recycle the product. So, in terms of designing for circularity for the last phase of a product's life cycle, the focus was on designing for recycling.

6) Is the product recyclable?
It is a step in the right direction if the product is made from recycled material, but as long as it is not recyclable at the tail end, the environmental impact and contribution to a circular economy will be limited. For a product to be circular and contribute to keep plastics circulating in closed loops it needs to be made from recycled materials and be recyclable at the tail end too, preferable recycled into products of the same quality or even upcycling Downcycling is better than landfill and incineration, but not preferred because the product will become waste again faster than with recycling or upcycling.

7) What is the end-of-life potential of the product?
It does not help if the manufacturer claims that the product can be recycled, if it can only be recycled theoretically or in a lab. What matters if it can be recycled in the real world, and for that to happen there needs to be a system for it to go to. Preferably, the product can be recycled in local mechanical recycling facilities that are easy to access for the last user without much of an effort to increase the chances of the product actually being recycled.

8) How easy is it to recycle the product?
Almost every material is recyclable, especially with chemical recycling or a combination of chemical and mechanical recycling. However, recycling requires resources, so it is preferable if the product can be recycled with as little consumption of resources such as energy in the recycling process. Therefore, mechanical recycling is usually to be preferred, and if the product can only be chemically recycled, which is very energy intensive, it needs a justifiable reason.

9) How pure is the material?
The purer material, the better. If you add fibers to the recycled plastic, it is very difficult, if not impossible, to recycle mechanically. Mono-material constructions are preferable because they can be recycled in most standard recycling facilities without much of an issue and the material can be used for other products as well, not just for the same piece of furniture it was before.

10) What colorants are added to the plastic material?
The lighter the color, the better for application after recycling. The darker or stronger colors, the more difficult it is to color and to find an application after recycling.

11) How easy is it to disassemble the product?
The fewer and bigger parts the better for recycling. The bigger the part, the greater value it represents for recycling and fewer parts usually means quicker disassembly. The product should be easy to disassemble by people without training and with tools everyone has at home, and the parts should be clearly marked with type of material.

12) Is recycling a last resort for the product?
Just because one user wants to get rid of the product does not mean that it should be recycled, especially if a product is still in a good working condition. It is important to not reduce the circularity of plastic in the furniture industry to only be about using recycled materials in production and recyclability at end of life, the product needs to avoid going to the grave for as long as possible because recycling and production also requires resources such as energy.

13) Does the manufacturer offer any services or systems that contribute to the circularity of plastics in the furniture industry?
This can be systems that prolong the product's useful life, such as repair, refurbishment, remanufacturing and/or reselling for reuse. It can also be circular business models such as take-back, buy back or rent schemes that ensure that the manufacturer takes responsibility for the product's end of life.

14)Does the product have any certification? If yes, what can that certification say about the production, use and recycling of the product?

If the product has some type of certification, it might say something about the circularity of the product. It can be anything from a carbon footprint or energy use in production to a requirement for recycled content, additives, a minimum warranty and spare part access or that the product is designed for disassembly and recycling.

Appendix P - Interview guide designer

Interviewee: Kjersti Kviseth

General questions about design for circularity (for all designers):
Q1) Do you think the circular economy is the future? Why?
Q2) What is the designer's role in bringing about a circular economy?
Q3) How do you think designers can contribute to building a functioning circular economy for plastics in the furniture industry?
Q4) What would you say is the biggest obstacle to get plastics to circulate in closed loop in the furniture industry?
Q5) What is important when designing for circularity? (recyclable/recycled materials, product integrity, services/systems?)
Q6) Do you have a favorite circular design guide that you use as an inspiration when you want to design circular products?
Q7) Do you like working with recycled plastics? Why/ why not?
Q7a) If yes: Why?
Q7b) If no:
Q7b-i) Why not?
Q7b-ii) What would it take for recycled plastics to become a material that you would like to work with?
Q8) Would you define using post-industrial plastic waste as recycling?

Design guide:
Q9) What was the goal of creating these guidelines?
Q10) Was it a goal to create a guide that would be relevant for a long time (almost 30 years now)? How did you think to make that happen?
Q11) Who is the guide meant for?
Q12) What type of products is the guide meant for?
Q13) How did you work to formulate a design guide?
Q14) What would you say is the most important point in the design guide? Why?
Q15) What would you say is the least important point in the design guide? Why?
Q15a) Why is the right choice of material important?
Q16) Would you change anything about the guide today? Would you remove or add any criteria?
Q17) Would you say that the design guide you created has contributed to bring about the change you wanted it to?
Q17a) If yes: Why and how?
Q17b) Have some criteria not yet been fulfilled?
Q18) Has there been any unforeseen consequences of following this guide? (positive or negative?)
Q19) These guidelines were made for furniture, but would you make any adaptations

to them if they were to apply specifically for plastics furniture?
Q20) Do you have any tips for how a designer can think to predict and control the environmental impact of a product he or she designs?
Q21) The long life span point, I find that interesting, it's very important, but it's maybe the most difficult to design for because it's hard to design for instance emotional attachment. What is important in order to design a product people want to keep for as long as possible? / How do you design to prolong the lifetime of a product?
Q22) When you designed these guidelines, it was pretty forward thinking and not standard for furniture manufactures to have circular design guides, the issue now is to design for a future system that does not yet exist, a functioning recycling system for plastic furniture. Do you have any tips for defining guidelines that can help transition into that future where systems are in place?
Q23) This guide has relatively few guidelines in difference to other design guides I've looked at, why did you only make 5 guidelines?
Q24) How do these guidelines contribute to designing for end of life of a product?
Q25) Do you have any tips for how designers can contribute to controlling what happens to the products they design at end of life?

At last, is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix Q - Interview guide designer

Interviewee: Konstantin Grcic

General questions about design for circularity regarding plastics in the furniture industry:

Q1) How do you think designers can contribute to building a functioning circular economy for plastics in the furniture industry?

Q2) What would you say is the biggest obstacle to get plastics to circulate in closed loop in the furniture industry?

Q3) What do you think are the most important circular design criteria to create circular plastics furniture?

Q4) Has your approach to or way of designing using plastics changed over the last years?

Q4a) If yes: Is it related to designing for a circular economy?

Q4a-i) If yes: How?

Q5) Do you like working with recycled plastics?

Q5a) If yes: Why?

Q5b) If no: What would it take for recycled plastics to become a material that you would like to work with?

Questions about your experience with recycled plastics:

Q6) Does using recycled plastic change the way you design in difference to when using virgin plastic?

Q6a) If yes: Why and how?

Q6b) If no: Why not?

Q7) In your experience, what would you say are the biggest challenges with designing for recycled plastics?

Q8) In your experience, what would you say are the biggest challenges with designing a plastics product that is recyclable?

Q9) A well-known issue regarding the recyclability of plastics furniture is additives and colors. How do you relate to and work with additives and colors when designing plastics furniture?

Questions about design of circular products:

Q10) In the future, will you continue to design products with virgin plastics?

Q10a) If yes: Why?

Q10b) If no: Why not?

Q11) How do you design to prolong the lifetime of the furniture you design?

Q12) How do you design for end of life of a piece of furniture?

Q13) To design for a circular economy is in a way to design for a future we don't yet know exactly how will look. The systems for recycling plastics furniture are not yet established. So, what would be your advice for designing products for a system that does not yet exist?

Q14) If you could, would you have done anything different with *CHAIR* to make it more circular?

Q15) Do you have a favorite circular design guide that you use as an inspiration when you want to design circular products?

At last, is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix R - Interview guide designer

Interviewee: Stefan Diez

General questions about design for circularity (regarding plastics in the furniture industry):
Q1) How do you think designers can contribute to building a functioning circular economy for plastics in the furniture industry?
Q2) What would you say is the biggest obstacle to get plastics to circulate in closed loop in the furniture industry?
Q3) Do you have a favorite circular design guide that you use as an inspiration when you want to design circular products?
Q4) Has your approach to or way of designing using plastics changed over the last years?
Q4a) If yes: Is it related to designing for a circular economy?
Q4a-i) If yes: How?
Q5) Q7 Do you like working with recycled plastics? Why/ why not?
Q5a) If yes: Why?
Q5b) If no:
Q5b-i) Why not?
Q5b-ii) What would it take for recycled plastics to become a material that you would like to work with?

Questions regarding the design guide:
Q6) What was the goal of creating these guidelines?
Q7) Who is the guide meant for?
Q8) What type of products is the guide meant for?
Q9) What would you say is the most important point in the design guide? Why?
Q10) What would you say is the least important point in the design guide? Why?
Q11) Would you change anything about the guide today? Would you remove or add any criteria?
Q12) Would you make any adaptations to the design guidelines if they were to apply specifically for plastics furniture?
Q13) How do these guidelines contribute to designing for end of life of a product?

Specific questions about the 10 guidelines:
Q14) I have some questions regarding point 1, about designing for long life:
Q15) In general, what is important in order to design a product that remains relevant to the user for as long as possible?
Q16) How exactly do you design for “high levels of emotional durability”?
Q17) Point 4 says to only use materials that come from functioning material cycles, would you define plastics as “a functioning material cycle”? Or to put it differently, what types of plastics would you say have functioning material cycles?
Q18) Point 4 also says that «a return station should be accessible to the last user with little effort”, what do you mean by return station? Is that like a local facility or more like a

take back system from the manufacturer?
Q19) In point 5, it says that "in case of products for daily use, a high cost of production may be offset by daily savings", would you say that that applies to plastics furniture? Why?
Q20) Some of these points address whether a product can be complemented or replaced by a service or a system, how do you think a designer can contribute to incorporating more services or systems as part of products or even contribute to integrating new business models in manufacturing companies?
Q21) Some of these guidelines aren't specific for product design, why have you chosen to also include guidelines that might apply more to changing business models or production? (Point nr 5, 6 & 9)
Q22) Point 9 doesn't really have that much to do with designing a product, so why did you choose to define that as a design guideline?

Questions regarding experience with recycled plastics:
Q23) Does using recycled plastic change the way you design in difference to when using virgin plastic?
Q23a) If yes: Why and how?
Q23b) If no: Why not?
Q24) In your experience, what would you say are the biggest challenges with designing for recycled plastics?
Q25) In your experience, what would you say are the biggest challenges with designing a plastics product that is recyclable?

Questions regarding design of circular products:
Q26) In the future, will you continue to design products with virgin plastics?
Q26a) If yes: Why?
Q26b) If no: Why not?
Q27) How do you design to prolong the lifetime of the furniture you design?
Q28) Do you have any tips for how designers can contribute to controlling what happens to the products they design at end of life?
Q29) To design for a circular economy is in a way to design for a future we don't yet know exactly how will look. The systems for recycling plastics furniture are not yet established. So, what would be your advice for designing products for a system that does not yet exist?
Q30) If you could, would you have done anything different with *CHAIR* to make it more circular?

At last, is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix S - Interview guide designer

Interviewee: Francesco Canesi Lissoni

General questions about design for circularity regarding plastics in the furniture industry:
Q1) How do you think designers can contribute to building a functioning circular economy for plastics in the furniture industry?
Q2) What would you say is the biggest obstacle to get plastics to circulate in closed loop in the furniture industry?
Q3) What do you think are the most important circular design criteria to create circular plastics furniture?
Q4) Has your approach to or way of designing using plastics changed over the last years?
Q4a) If yes: Is it related to designing for a circular economy?
Q4a-i) If yes: How?
Q5) Do you like working with recycled plastics? Why/ why not?

Questions about your experience with recycled plastics:
Q6) Does using recycled plastic change the way you design in difference to when using virgin plastic?
Q7) In your experience, what would you say are the biggest challenges with designing for recycled plastics?
Q8) In your experience, what would you say are the biggest challenges with designing a plastics product that is recyclable?
Q9) A well-known issue regarding the recyclability of plastics furniture is additives and colors. How do you relate to and work with additives and colors when designing plastics furniture?

Questions about design of circular products:
Q10) In the future, will you continue to design products with virgin plastics?
Q11) How do you design to prolong the lifetime of the furniture you design?
Q12) How do you design for end of life of a piece of furniture?
Q13) To design for a circular economy is in a way to design for a future we don't yet know exactly how will look. The systems for recycling plastics furniture are not yet established. So, what would be your advice for designing products for a system that does not yet exist?
Q14) Do you have a favorite circular design guide that you use as an inspiration when you want to design circular products?

At last, is there anything you want to add or anything you want to ask me?
Thank you so much for taking the time to answer my questions!

Appendix T - Interview guide designer

Interviewee: Jasper Morrison

General questions about design for circularity regarding plastics in the furniture industry:
Q1) How do you think designers can contribute to building a functioning circular economy for plastics in the furniture industry?
Q2) What would you say is the biggest obstacle to get plastics to circulate in closed loop in the furniture industry?
Q3) What do you think are the most important circular design criteria to create circular plastics furniture?
Q4) Has your approach to or way of designing using plastics changed over the last years?
Q4a) If yes: Is it related to designing for a circular economy?
Q4a-i) If yes: How?
Q5) Do you like working with recycled plastics?
Q5a) If yes: Why?
Q5b) If no: What would it take for recycled plastics to become a material that you would like to work with?

Questions about your experience with recycled plastics:
Q6) Does using recycled plastic change the way you design in difference to when using virgin plastic?
Q6a) If yes: Why and how?
Q6b) If no: Why not?
Q7) In your experience, what would you say are the biggest challenges with designing for recycled plastics?
Q8) In your experience, what would you say are the biggest challenges with designing a plastics product that is recyclable?
Q9) A well-known issue regarding the recyclability of plastics furniture is additives and colors. How do you relate to and work with additives and colors when designing plastics furniture?

Questions about design of circular products:
Q10) In the future, will you continue to design products with virgin plastics?
Q10a) If yes: Why?
Q10b) If no: Why not?
Q11) How do you design to prolong the lifetime of the furniture you design?
Q12) How do you design for end of life of a piece of furniture?
Q13) To design for a circular economy is in a way to design for a future we don't yet know exactly how will look. The systems for recycling plastics furniture are not yet es-

tablished. So, what would be your advice for designing products for a system that does not yet exist?

Q14) If you could, would you have done anything different with *CHAIR* to make it more circular?

Q15) Do you have a favorite circular design guide that you use as an inspiration when you want to design circular products?

Appendix U

Circular Design Guidelines by Stefan Diez

In the currently practised system of a linear economy, value is created based on the consumption of materials, which, against the backdrop of limited resources, will inevitably lead to the loss of one's own economic basis and livelihood. In the circular economy, value creation is decoupled from material consumption by keeping materials in a material cycle. Although the shift to a circular economy is widely believed to have no alternative, its implementation poses major challenges for society, as well as unique opportunities. Shaping this process will remain the major challenge of our generation, with designers playing one of the key roles. The Circular Design Guidelines summarise how designers can contribute to transforming the global economic system into a circular economy.

1. A circular product remains useful for a long time.

Good design adapts to changing requirements to ensure prolonged usage. This longevity is not only about durability, but also about ensuring that a product can remain useful throughout its lifespan. People's lives and situations change constantly; product design needs to accept this reality by embracing flexibility and modularity as much as possible.

2. A circular product can be repaired.

Products are made from different parts and materials that wear out at different speeds. Designers need to understand this variability and design around it, such that all components can be repaired or replaced by either the user or local repair shops. Signs of wear are inevitable, and designers should select materials whose ageing does not reduce their value.

3. A circular product can be updated.

All products are imperfect and contain elements that can be further developed and refined. Design should accept and work with this imperfection, creating products in which individual elements can be improved and reincorporated, extending their lifespan on the market. Good design is essentially pragmatic – it recognises its limits and remains open to improvement.

4. A circular product is produced from renewable or recyclable materials.

A product's end of life is as important as its usage, and materials should be selected with respect to the material cycles of which they are a part. Synthetic materials should only be used if products are capable of easy disassembly and covered by existing recycling systems. Natural materials must be harvested sustainably and processed such that they remain compostable.

5. A circular product uses as little energy as possible over its entire lifespan.

Energy consumption should be limited, with this applied over a product's entire lifetime, not solely during its manufacture. A high energy usage during production may be justified by a longer lifespan, or else by future savings on recycling. Aluminium is energy intensive to produce, for instance, but subsequently efficient to recycle and retain within the material cycle.

6. A circular product can be transported efficiently.

A product's distribution should be factored into the design process. Designing products to occupy as little space as possible when being shipped can improve the environmental impact of their transport; reduce packaging; and ultimately lower the overall cost for the customer. A product's initial distribution is as important a part of its lifespan as its usage or afterlife.

7. A circular product is more than just circular.

All manufacture comes with an environmental cost, so any product's existence must be justified by more than circularity alone. A good product offers a tangible advantage to the user, and represents something that they can become meaningfully attached to and want to preserve. Circularity is not puritanical – to fulfil its aims, it must also be innovative, elegant and joyful.

8. A circular product can be used by many.

Long-lasting products can be used by multiple people, particularly in the case of designs that are only required for a short period of time. An object such as a child's chair should be rented rather than purchased, and these considerations should affect the business model behind design. Responsible cycles of rental, repair and reuse can benefit both the user and seller.

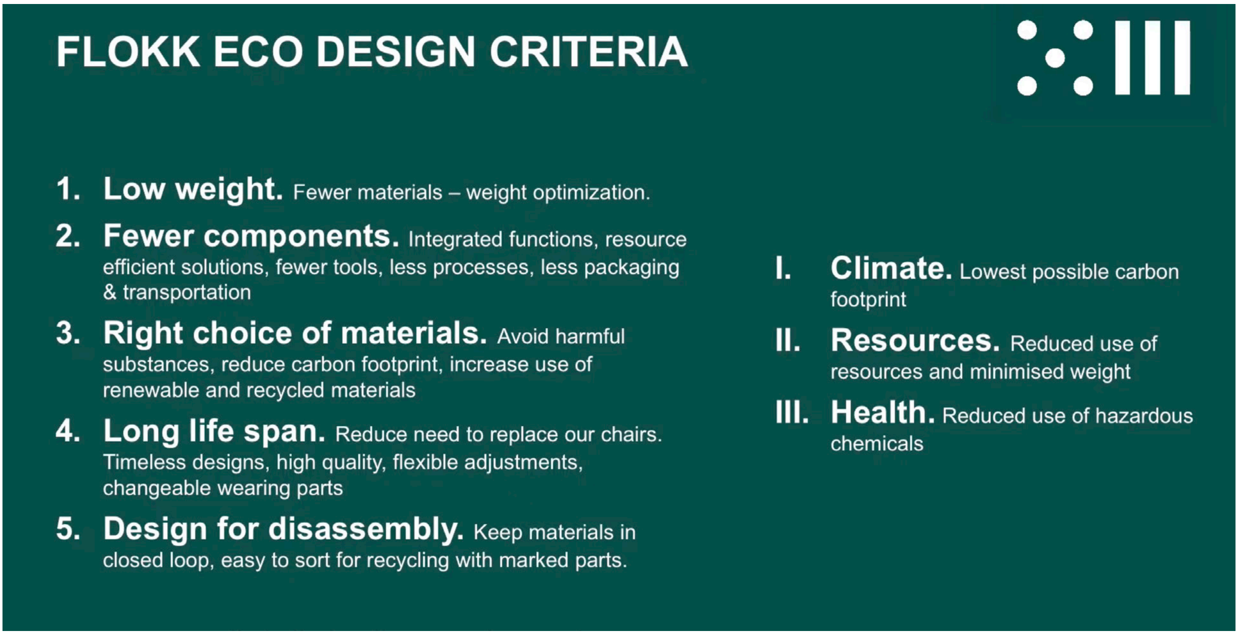
9. A circular product considers those who manufacture, maintain and recycle it.

A design is only sustainable if its production, maintenance and recycling treat people equitably. Good products are produced in countries that respect human rights, and in factories and workshops that pay and treat workers fairly – a good design is one that doesn't only consider the end user, but which also provide satisfaction and professional fulfilment to those who produce it.

10. A circular product is as little product as necessary.

Not every design needs to be a product. Physical objects are vehicles for a function or service, but there are other ways of delivering these. Digital platforms, service design and interface design all have lighter footprints than objects, but can often meet the same needs. Good product design always considers whether there are ways to render the material object superfluous.

Appendix V


FLOKK ECO DESIGN CRITERIA
1. Low weight. Fewer materials – weight optimization.
2. Fewer components. Integrated functions, resource efficient solutions, fewer tools, less processes, less packaging & transportation
3. Right choice of materials. Avoid harmful substances, reduce carbon footprint, increase use of renewable and recycled materials
4. Long life span. Reduce need to replace our chairs. Timeless designs, high quality, flexible adjustments, changeable wearing parts
5. Design for disassembly. Keep materials in closed loop, easy to sort for recycling with marked parts.
I. Climate. Lowest possible carbon footprint
II. Resources. Reduced use of resources and minimised weight
III. Health. Reduced use of hazardous chemicals

Madeleine Kristin Wieser

Circular Design Guide for the Use of Plastic in Furniture

NTNU
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Science and Technology