CATÓLICA LISBON
BUSINESS & ECONOMICS

Circular Economy Principles in Action: Insights from Mechanical Engineering Companies

Verena Hirschle

Dissertation written under the supervision of Laure Leglise

Dissertation submitted in partial fulfilment of requirements for the MSc in International Management, at the Universidade Católica Portuguesa, May 2023.

Abstract

Title: Circular Economy Principles in Action: Insights from Mechanical Engineering Companies

Author: Verena Hirschle

English:

Population growth leads to a greater resource demand, resulting in more waste and greenhouse gas emissions. The linear economic model used in the mechanical engineering (ME) industry is incapable of stopping this trend. The concept of circular economy (CE) offers an approach to solve this problem. This thesis examines how ME companies are implementing CE and identifies the barriers, drivers, and strategies faced by the companies during the implementation process. To examine five ME companies that have adopted CE, semi-structured interviews, supplemented by secondary data and direct observations, were conducted. The 10R framework and a classification of barriers, drivers, and strategies were used to guide the data analysis. The 10R framework helped to categorize the CE practices implemented by the company. This thesis found out that the implemented CE practices predominantly focus on extending the life span of machines. Internal and external barriers have hindered the successful implementation of these practices. These barriers include employees' rejection of CE and regulations differing nationally and internationally. However, drivers such as management and partnerships between companies significantly contribute to a successful CE implementation. The sustainability-oriented mindset of the management lays the foundation for adopting CE practices. Moreover, training on sustainability and CE of employees is essential for a successful CE implementation. Accordingly, companies should invest in employee training. The government should become aware of the importance of barriers for companies and should find solutions to minimize them.

Portuguese:

O crescimento da população leva a uma maior procura de recursos, resultando em mais resíduos e emissões de gases com efeito de estufa. O modelo económico linear utilizado na indústria da engenharia mecânica (EM) é incapaz de travar esta tendência. O conceito de economia circular (EC) oferece uma abordagem para resolver este problema. Esta tese examina a forma como as empresas de EM estão a implementar a EC e identifica os obstáculos, fatores de mudança e as estratégias enfrentadas pelas empresas durante o processo de implementação. Para examinar cinco empresas de EM que adotaram a EC, foram realizadas entrevistas semiestruturadas, complementadas por dados secundários e observações diretas. Para orientar a análise, foi utilizada a metodologia 10R que ajudou a categorizar as práticas de EC implementadas pelas empresas. Esta tese concluiu que as práticas de EC implementadas centram-se no prolongamento da vida útil das máquinas. O sucesso destas práticas tem sido dificultado por obstáculos internos e externos que incluem a rejeição da EC por parte dos funcionários e regulamentos diferentes a nível nacional e internacional. Fatores como a gestão e parcerias entre empresas contribuem para uma implementação bem-sucedida. A mentalidade orientada para a sustentabilidade da gestão estabelece as bases para a adoção de práticas de EC. Adicionalmente, a formação dos trabalhadores sobre sustentabilidade e EC é essencial para uma implementação bem-sucedida. Consequentemente, as empresas devem investir na formação dos trabalhadores. O governo deve conscientizar-se da importância dos obstáculos para as empresas e deve encontrar soluções para as minimizar.

Keywords: circular economy, mechanical engineering industry, barriers and driver for circular economy implementation

Acknowledgements

For years, I have been interested in the topic of sustainability and the impact of climate change on our planet. I became involved in a sustainability organization where I trained employees to behave more sustainably in the workplace. During my master's degree, I learned a lot about the strategic activities of companies. Alongside the more economic-focused topics, I examined Corporate Social Responsibility and Environmental, Social, and Governance. I knew the leverage to drive sustainability forward is greater if companies are convinced to act more sustainably. Through my commitment and interest in sustainability, I became familiar with the concept of CE. I realized how much I wanted to learn more about it and decided to write my thesis in this area. Through my bachelor's degree in industrial engineering, I gained a better understanding of the ME industry. During my research, I noticed that the topic of CE is rarely addressed in the academic literature in this industry, despite it being one of the largest industries in Europe and worldwide. Therefore, it was important for me to address this gap. I am proud to have contributed to this research topic that should inspire more ME companies to implement circular economy principles.

I would like to express my gratitude to my supervisor, Laure Leglise, for her guidance, support, and encouragement during the conduct of this thesis. My time at Católica Lisbon ends with this master's thesis, and I cannot thank everyone enough for this challenging but incredibly educational experience. Studying at Católica Lisbon and my time in the exchange semester at the University of St. Gallen allowed me to move out of my comfort zone, grow, and above all, meet new people, some of whom have become friends.

Therefore, I would like to thank my fellow students and friends, without whom the past two years would not have been as memorable as they are. I also would like to thank my family for their unwavering support throughout my academic career and for always believing in me.

Contents

List of figures

List of tables

List of abbreviations

B2B	Business to business
Brückner	Brückner Group
CBM	Circular business model
CE	Circular economy
EU	European Union
EUR	Euro (€)
Heller	Gebr. Heller Maschinenfabrik
Kampf	Kampf Schneid- und Wickeltechnik
ME	Mechanical engineering

1. Introduction

> *"Transition to a circular economy requires all of us to team up and commit to doing things fundamentally different."*
>
> van Houten (2021), former CEO at Philips

It is projected that the number of people living on Earth will increase to 10.4 billion by 2100 (CGR, 2022), leading to more demand for resources, to mountains of waste and to emissions of climate gases. Over the past 50 years, global material consumption has nearly quadrupled. In 1972, the world consumed 28.6 billion tons of materials, whereas, in 2019, material consumption surpassed 100 billion tons. Today, over 90% of the 100 billion tons extracted and used materials go to waste. Alternatively, on the flip side, only 8.6% of resources are effectively recycled back into our economy. Moreover, 70% of all global greenhouse gas emissions are related to material handling and use (CGR, 2022). In the future, measures for more efficient raw material extraction or material processing will no longer be sufficient, but a fundamental change will be necessary. In order to ensure a complete change towards sustainability, mechanical engineering (ME) is indispensable (VDMA, 2021).

In the mechanical engineering industry, the traditional linear economic model of take, make and waste is still predominantly applied but is increasingly losing acceptance as it contributes to increased resource consumption instead of reducing it. One approach that offers a solution is the concept of circular economy (CE), which is becoming increasingly important and must become a fundamental prerequisite of economic activity (VDMA, 2021). The CE concept enables the reuse of resources and prevents disposal after use (Mhatre et al., 2021; Morseletto, 2020).

The ME industry plays a crucial role in the European Union (EU) economy due to its size, economic impact, and resource consumption (European Commission, 2012). According to the European Commission (2012), the industry employs over three million people in the EU and holds an estimated world market share of 36%. Additionally, the ME industry's economic influence extends to various other industries as it provides the necessary machinery and equipment for their functioning. However, due to its size and resource consumption, the ME industry faces significant challenges in terms of environmental sustainability. Substantial energy inputs and raw materials are required for ME processes, resulting in carbon emissions, and waste generation (European Commission, 2012). Therefore, it is crucial to focus on the

implementation of CE principles. Adopting CE principles can enable the ME industry to reduce its environmental footprint and contribute to a more sustainable world.

The literature already shows that companies face various barriers when implementing CE principles, while certain drivers are key success factors when implementing CE in the company. Several studies investigated barriers and drivers for the successful adoption of CE (Adams et al., 2017; De et al., 2022; Kirchherr et al., 2018; Oliveira et al., 2018; Ormazabal et al., 2018). This emerging body of literature generally addresses CE implementation and does not focus on an explicit industry. For example, the studies address barriers and drivers in the EU, as well as barriers and drivers in small and medium-sized companies. This means that the studies focused on a wide range of industries. Examining different industries prevents researchers from gaining a comprehensive understanding because the barriers and drivers to circular economy adoption vary across industries. By studying a specific industry, researchers can identify industry-specific barriers that impede the adoption of the CE and identify the factors that facilitate its implementation. This approach enables the formulation of tailored solutions that are more effective and relevant for the specific industry. However, only a few studies focus on a specific industry. For example, barriers have been studied for the construction, electronics, manufacturing, textiles & clothing, coffee, packaging, and wood industry (Adams et al., 2017; Bening et al., 2021; De et al., 2022; Kissling et al., 2013; Ritzén & Sandström, 2017; Todeschini et al., 2017; van Keulen & Kirchherr, 2021). Drivers have been analyzed in the manufacturing, service, wood, and construction industry (De et al., 2022; Lieder & Rashid, 2016; Smol et al., 2015; Tukker, 2015).

Despite being one of the largest industries in the EU (European Commission, 2012), there are few studies on how CE principles have been implemented and what barriers and drivers the companies face in the ME industry. To contribute to fill this gap, this thesis examines the implementation of the CE concept in the ME industry. In particular, the following research question is addressed:

> *"How do companies in the mechanical engineering industry implement circular economy principles?"*

To answer the research question, I adopted a qualitative approach and conducted a multiple-case study involving five notable companies in the ME industry: Brückner Group GmbH, Gebr. Heller Maschinenfabrik GmbH, Kampf Schneid- und Wickeltechnik GmbH & Co. KG,

Company A and Company B. The selected companies are worth studying due to their size and impact within the ME industry.

To access and categorize the already implemented CE practices by these companies, I utilized the 10R framework by Potting et al. (2017). The R frameworks, in general, have gained widespread acceptance to operationalize the concept of CE (Tserng et al., 2021). These frameworks vary solely in the number of Rs they encompass, with the 10R framework developed by Potting et al. (2017) being the most comprehensive. It includes the Rs refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover. Companies have widely adopted this framework as a guiding tool for developing CE oriented practices and identifying potential gaps (De et al., 2022). Additionally, the thesis also identified the primary internal and external barriers and key drivers the companies encountered and promising strategies the companies applied while implementing their CE practices.

This thesis is structured as follows: Section 2 reviews the existing literature on CE, and presents the state of CE in the ME industry, and the necessity to research of CE transformation in the ME industry. Further, it provides an understanding of CE practices using the 10R framework and previously studied barriers and drivers to the CE implementation. Section 3 then presents the methodology, including the research design, data collection, and data analysis. Section 4 introduces the empirical setting by providing an overview of the studied companies. Section 5 presents the results, which are further discussed in Section 6. The thesis concludes with the final remarks, encompassing the main findings, limitations of this thesis, and suggestions for further research, presented in Section 7.

2. Literature Review

Despite the significant increase in research on CE in recent years (Lieder & Rashid, 2016), a consensus on the topic remains elusive (Kirchherr et al., 2017). Moreover, it has been demonstrated that CE transformations encounter various barriers that must be overcome, and specific drivers play a crucial role in achieving successful implementation. Consequently, previous studies have investigated numerous barriers and drivers across different and within industries to address these barriers. However, a limited amount of academic research focuses on implementing CE principles in the ME industry and the barriers it faces during the implementation process. Similarly, information regarding the critical drivers for a successful transformation in the ME industry is scarce. The research findings that highlight the progress of CE in the ME industry can be found in subsection 2.2.

The literature review is structured in four subsections. The first subsection introduces the concept of CE, followed by the current state of CE in ME industry. The third subsection explains why research on the CE transformation in the ME industry is necessary. Finally, the fourth subsection introduces the implementation of CE principles, including the introduction of the 10R framework and barriers and drivers which occurred in various industries.

2.1 The concept of circular economy

There is still no unified consensus in the literature on the definition of CE. To address this issue, Kirchherr et al. (2017) collected 114 definitions of CE to create a comprehensive understanding of the concept of CE, which is described as "an economic system that replaces the "end-of-life" concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes" (p. 228). Geissdoerfer et al. (2017) provide another definition and describe the concept of CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (p. 759).

The concept of CE is a novel sustainable economic model that incorporates all social activities through the creation of cycles of material, energy, and waste flows (Bonciu, 2014). It represents a possible approach, as it involves the rational use of natural resources, which leads to the optimization of available resources and promotes the reuse of products, components, and materials over longer-lasting cycles (Morseletto, 2020). The main objective of the CE concept

is to maximize the value of resources by enabling the reuse of products and materials, resulting in greater benefits compared to disposal. Moreover, it aims to achieve sustainable development that simultaneously fosters environmental quality, economic prosperity, and social equity (Kirchherr et al., 2017). The CE concept offers a way to contribute to sustainability in today's production and consumption systems by prolonging the life of products, components, and materials, and minimizing waste, the use of new resources, and energy consumption (Nogueira et al., 2020; Stahel, 1998).

In light of the ME industry's significant role as a dominant manufacturing industry and its consumption of raw materials, there is mounting pressure for companies to support the transition towards a CE and make sustainable improvements.

2.2 Circular economy in the mechanical engineering industry

The ME industry is assigned to the manufacturing industry and is one of the dominant industries worldwide (Rais, 2018). In a smaller context, the ME industry is one of the largest industrial industries in the EU, as it is responsible for 9.5% of all the production in EU manufacturing industries (European Commission, 2012). Through its size, the industry is one of the world's largest consumers of raw materials (European Commission, 2012). It even uses many raw materials beyond base metals and petroleum-based plastics (Umwelt Bundesamt, 2021). As it is common in other industries, the ME industry traditionally used a linear economic model, where materials are disposed after their use.

In order to reduce the disposal of materials and drive the economy towards CE, the European Commission is countering the current practices with its CE based legislation. With this legislation, the European Commission aims to minimize the environmental impact caused by economic activities and to ensure that the natural resources involved in economic activities reach a maximum lifetime (Sartal et al., 2020). The consequence for the ME industry is an intense pressure to support the transition towards CE. Therefore, it is clear that ME companies and companies in the manufacturing industry must make improvements towards sustainability in line with the CE to remain competitive in the long term (Johansen & Rönnbäck, 2021). Accordingly, ME companies must redesign their machines to enable the production of reusable and recyclable products (Geng et al., 2019). The goal must be to maintain the functionality and value of the machine and the manufactured final product for as long as possible within the overall product cycle (Gregson et al., 2015). It is worth highlighting that the ME industry is an

essential driver for the overall societal change towards the minimization of the extraction of natural resources (Geissdoerfer et al., 2017; Sauvé et al., 2016). The machines manufactured by the ME industry provide the tools with the help of which corporate sustainability measures can be applied (VDMA & McKinsey, 2022). Due to the long life span of machines, their future viability in terms of sustainability is closely linked to the solutions they support for more sustainable manufacturing. For example, packaging machines can save resources by efficiently using film webs or processing thin films or films made from recycled material, thus helping to conserve resources. At the same time, the amount of waste generated by packaging is reduced. Nevertheless, this is only possible if the machines that produce packaging materials have the necessary functionalities (VDMA & McKinsey, 2022). Hence, the ME industry plays an essential role in the societal transformation towards a CE (Lindahl et al., 2023).

2.3 The necessity to research circular economy in mechanical engineering

Many studies shed light on the barriers encountered in implementing CE and drivers that enable CE transformation in different industries. Previous studies chose different foci to examine barriers to CE. Some studies took a geographic approach (e.g., China (Geng & Doberstein, 2008), the Netherlands (Kok et al., 2013), Sweden (Whalen et al., 2018), Spain (Ormazabal et al., 2018), the EU (Kirchherr et al., 2018)). Others focused on specific industries (e.g., construction (Adams et al., 2017), electronics (Kissling et al., 2013), manufacturing (Ritzén & Sandström, 2017), textiles and clothing (Todeschini et al., 2017), coffee (van Keulen & Kirchherr, 2021), wood (De et al., 2022), and packaging (Bening et al., 2021)). Shahbazi et al. (2016) examined barriers related to material efficiency in manufacturing, and Zhu & Geng (2013) examined barriers to supply chain advancement for energy conservation and emissions reduction.

Drivers have also been investigated and identified in various studies. For a geographic approach, the Ellen MacArthur Foundation (2015) identified drivers for India, and Moktadir et al. (2018) looked at drivers in Bangladesh. Researchers who focused on specific industries are Lieder & Rashid (2016), who examined drivers that occur in the manufacturing industry, Tukker (2015) identified drivers in the service industry, De et al. (2022) analyzed drivers for the wood industry, and Smol et al. (2015) examined drivers for the construction industry.

Although previous studies examine barriers and drivers from various perspectives, more attention should be given to the implementation of CE practices in the ME industry, as most

studies focusing on the manufacturing industry rather than explicitly on the ME industry. Therefore, this thesis aims to address this gap by investigating the following question:

> *"How do companies in the mechanical engineering industry implement circular economy principles?"*

Three main aspects are essential to determine how companies implement CE principles. Firstly, finding out which CE practices are already implemented is crucial. This is demonstrated using the 10Rs. Second, what barriers have been and are still being encountered and third, what drivers are decisive for the implementation of CE practices.

2.4 Implementing circular economy principles

The introduction of CE in companies is very complex. For this reason, various frameworks have been proposed to facilitate the practical implementation of CE. One such framework is the 10R framework developed by Potting et al. **(**2017). This framework provides companies with a structured approach to implement CE practices and drive sustainable change.

Due to the complexity involved in implementing CE, multiple barriers arise that need to be overcome. These barriers exhibit industry-specific variations, necessitating tailored strategies for their resolution. A comprehensive understanding of these barriers is crucial for developing targeted approaches. Additionally, identifying the drivers essential for successful CE adoption is of paramount importance.

In the following subsections, the 10R framework will be presented in more detail and barriers and drivers from various industries that have already been investigated will be highlighted.

2.4.1 Understanding circular economy implementation using the R frameworks

The R frameworks have become a common conceptual tool for implementing CE (Kirchherr et al., 2017), and were developed by academics to reduce resource and material consumption and design CE (Potting et al., 2017). Initially, the R framework comprised the 3Rs reuse, recycle, reduce. Subsequently, several additional R frameworks have been introduced in the literature, including 4R, 5R, 6R, 9R, and 10R (Sohal & De Vass, 2022). All R frameworks are very similar and differ mainly in the number of Rs. Each R stand for an individual CE strategy.

R0 and R1 are CE strategies that reduce the consumption of natural resources and materials. This is achieved by requiring fewer products for the same consumption. Although these CE

strategies do not include the reuse of products and components or the reuse of recycled materials, they are also generally considered CE strategies (Potting et al., 2017). Unlike the R0 and R1 CE strategies, the remaining CE strategies (R2-R9) include the reuse of products, components, or recycled materials. Regardless of the number of Rs, ultimately, all R frameworks provide a common framework for adopting CE practices (De et al., 2022). To provide a comprehensive and systematic understanding of all ten CE strategies, this thesis uses the 10R framework proposed by Potting et al. (2017) (Figure 1).

The CE strategies exist to reduce the consumption of raw materials and minimize the production of waste. The 10R framework is ordered by priority according to their levels of circularity. The different Rs typically range from Rs with a low number achieving high circularity to Rs with a high number achieving low circularity (Potting et al., 2017). According to the degree of circularity, Rs are divided into three groups:

(i) Smarter product use and manufacture
(ii) Extend life span of product and its parts
(iii) Useful application of materials

Accordingly, smarter product use and manufacture (R0-R2) like product sharing is preferable overextend a product's life (R3-R7) because the product is used for the same product function or more users can be served by one product. Recycling materials and recovering energy (R8-R9) have the lowest priority, as the materials are no longer available to be applied in other products (Potting et al., 2017). These circular strategies require different social-institutional changes. To achieve a successful CE transition, policies need to cover the entire product chain, from resource extraction and processing to material production, product manufacturing and use, as well as the collection and processing of discarded products (Potting et al., 2017).

Figure 1. The 10R framework

Circular Economy	Circularity level	CE strategies	Definitions
	Smarter product use and manufacture	R0 Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product.
		R1 Rethink	Make product use more intensive (e.g., through sharing products, or by putting multi-functional products on the market).
		R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials.
	Extend lifespan of product and its parts	R3 Reuse	Reuse by another consumer of discarded product which is still in good condition and fulfils its original function.
		R4 Repair	Repair and maintenance of defective product so it can be used with its original function.
		R5 Refurbish	Restore an old product and bring it up to date.
		R6 Remanufacture	Use parts of discarded product in a new product with the same function.
		R7 Repurpose	Use parts of discarded product in a new product with a different function.
	Useful application of materials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality.
		R9 Recover	Incineration of materials with energy recovery.
Linear Economy			

Source: Adapted from Potting et al. (2017, p.5)

However, the implementation of CE practices in companies is progressing slowly (De et al., 2022; Ghisellini et al., 2016; Guerra et al., 2021; Hazen et al., 2020; Kirchherr et al., 2018; Oliveira et al., 2018). The mix of barriers and drivers can be cited as a reason for slow adoption (De et al., 2022).

2.4.2 Barriers to the implementation of circular economy principles

In the process of the transition towards CE, the literature shows that companies are repeatedly confronted with various barriers. A first barrier is the consumers' preference for new products based on their aesthetics and appearance, which hinders the acceptance and demand for remanufactured products (Kumar et al., 2019). For instance, this lack of demand and acceptance can negatively affect the implementation of CE practices (Kumar et al., 2019; Mittal & Sangwan, 2014). Thus, there is little pressure on the manufacturing industry to produce more sustainably. Consequently, there is no pressure on the ME industry to shift towards more sustainable production, either. A second barrier is the lack of knowledge about CE. For example, companies do not know or consider the by-products of their production during the

development phase. This limits the possibility of implementing CE practices (Oliveira et al., 2018). A third barrier often mentioned to the implementation of CE practices is the perceived risks, costs and the lack of capital (Cristoni & Tonelli, 2018; Kirchherr et al., 2018; Rizos et al., 2016). Due to the lack of collected data, companies often remain unaware of the value of waste they generate (Daian & Ozarska, 2009). This reduces their willingness to invest in waste collection and recycling. Lastly, a fourth barrier is the political emphasis on recycling as a barrier to further CE practices, such as reuse or remanufacturing, can also be mentioned here.

2.4.3 Drivers to the implementation of circular economy principles

Drivers are important factors that facilitate the adoption of CE, as they help companies overcome their reluctance to implement CE practices (Kirchherr et al., 2018). Accordingly, several drivers encourage companies to implement CE and make the implementation possible in the first place.

A first driver is the government, as it sets laws and rules that companies must comply with. It can impose measures such as reuse, upgrading, and recycling of materials on companies (Kazancoglu et al., 2021; Moktadir et al., 2018). A second driver is partnerships with other companies outside and along the value chain are another key driver (Liu et al., 2022). A third driver critical to CE transformation is environmentally conscious top management leadership (Moktadir et al., 2018; Rizos et al., 2016; Siemieniuch et al., 2015; Sohal & De Vass, 2022). In addition, narrowing the communication gap between management and employees to achieve CE goals is critical for success (Trisyulianti et al., 2022). Moreover, strategic and innovative leadership plays a significant role in adopting CE practices. A fourth driver is the long-term competitive advantage, which shows that companies with a circular business model (CBM) are more effective and efficient in the long run (Rizos et al., 2016). Shifting from a linear to a CBM has been found to lead to cost benefits (Christmann, 2000; Ranta et al., 2018) and help companies gain a competitive advantage (Simpson et al., 2004; Stewart & Gapp, 2014). Lastly, a fifth driver is that companies must comprehend and incorporate CE as part of their corporate strategy, as this approach enables the successful execution of individual CE practices (Sohal & De Vass, 2022).

3. Methodology

This section is divided into three subsections. The first subsection presents the reasons why a qualitative approach is the most appropriate method to answer the research question. It also explains the benefits of conducting a multiple-case study. In the second subsection, the conducted process of data collection is described. This includes the reasons for selecting interviewees as the primary data source. Finally, the third subsection provides an overview of the data analysis process.

3.1 The research design

The research question relates to CE practices implemented by companies in the ME industry, and the barriers that must be overcome during the implementation process. Therefore, I intend to gain a deep understanding of what CE practices companies in the ME industry are already implementing and what barriers they face. Besides, the research question requires an understanding of which drivers are important for CE implementation. Therefore, a qualitative approach is best suited for answering this research question. As a qualitative approach allows for an in-depth understanding of a complex organizational phenomenon (Creswell & Poth, 2016) and helps to gain insights that would be difficult to obtain using quantitative methods (Mays & Pope, 2020).

I chose a multiple-case study to explore how companies adopt CE principles and to identify barriers and drivers faced by the ME industries. It allows for comparing and contrasting data from different sources (Stake, 2013). In addition, a multiple-case study can provide extensive and detailed data that allow for an in-depth understanding of the phenomenon under study (Merriam, 1998; Yin, 2017). Moreover, a multiple-case study offers the advantage of confirming findings by noting the same patterns in different cases, leading to more robust results (Zainal, 2007).

When case research is applied, samples are often built up by selecting cases based on various criteria rather than choosing a stratified or random sample (Eisenhardt, 1989). In this thesis, I purposively selected the companies based on the following criteria:

(i) The companies under study are German companies in the ME industry.
(ii) The companies are solely engaged in business to business (B2B) activities, meaning they sell their machines and services to other companies rather than to end consumers.

(iii) The companies have already implemented CE principles and are no longer in the pilot phase.

On the one hand, the focus on German ME companies is due to the facilitated data access. On the other hand, the ME industry is one of Germany's most important and largest industries. With sales of 271 billion euros, ME is the second most important revenue driver in the German economy. In an international comparison, Germany is among the most significant ME countries globally, with only China and the USA achieving higher sales (Statista, 2023).

I contacted a total of twenty companies, including the five that are the subject of this thesis. Of the fifteen companies that are not part of this thesis thirteen companies did not respond despite multiple contact attempts. Further, I interviewed two of the fifteen companies but subsequently excluded them as they did not meet the selection criteria described above. The first excluded company claimed in advance to have already implemented CE principles. However, after two 60 minute interviews, it became apparent that the company focused on sustainability but had not yet implemented any of the 10Rs mentioned above. The second excluded company had already implemented a variety of CE principles but mainly as a part of their business to consumer business. The resulting five companies selected and examined in this thesis meet the criteria. Since these companies had already implemented CE practices, they could provide insights of the barriers they encountered during the implementation and present drivers that were decisive for the implementation process. Two of the five companies ask to remain anonymous, which from now on will be referred to as Company A and Company B. The other three companies are the Brückner Group GmbH (Brückner), Gebr. Heller Maschinenfabrik GmbH (Heller) and Kampf Schneid- und Wickeltechnik GmbH & Co. KG (Kampf).

3.2 Data collection

I relied on methodological triangulation to guide my data collection, which involves the use of multiple data collection methods such as interviews and documents (Fusch et al., 2018). Triangulation involved combining primary data from semi-structured interviews and secondary data from various documents. From March to April 2023, I conducted semi-structured interviews with twelve company representatives. These included CEOs, senior executives, employees who assisted during the implementation, sustainability managers, or representatives from partner companies or subsidiaries (Table 1). All interviewees clearly understood the concept of CE and how individual CE principles were implemented in their respective

companies. I conducted ten interviews via the video conference software Zoom or Microsoft Teams and two in person. Each interview lasted between 30-60 minutes, during which I asked the respondents the following three main questions:

(i) What CE principles have been implemented in their company?
(ii) Which barriers did they encounter during implementation?
(iii) What was the decisive factor in overcoming these barriers?

The two in-person interviews also included a factory tour. I documented the tour and recorded the observations with the interviewees' consent. On-site observations provided a firsthand insight into the manufacturing process, such as designing and constructing various components and assemblies, touring the entire production line, and reviewing each implemented CE practice. I conducted eleven out of twelve interviews in German and one in English. I recorded and transcribed all interviews. I provided translations where necessary.

Table 1. Primary Data

Cases	Type of data	Name of the interviewee	Position in the organization	Date	Length
Brückner	Interview	Weidacher Quirin	Sustainability Manager	16/03/2023	40 minutes
	Interview	Winklhofer Bernhard	Head of Process Technology Upgrading & Service	06/04/2023	35 minutes
Heller	Interview & direct observation	Georg Preu	Occupational Safety Specialist, Environmental Protection & Environmental Management Officer	17/03/2023	60 minutes
	Interview & direct observation	Stefan Wölffing	Management System Officer	17/03/2023	60 minutes
Kampf	Interview	Kemper Tim	Quality and Sustainability Manager	15/03/2023	45 minutes
	Interview	Maik Krüger	Head of Business Development	31/03/2023	30 minutes
	Interview	Fabian Held	CEO *(Maschinen Ritter, a subsidiary of Kampf)*	30/03/2023	60 minutes
Company A	Interview	Person A1	Sustainability Manager	17/03/2023	60 minutes
	Interview	Person A2	Head of Sales at Wipf *(packaging manufacturer and partner of company A)*	06/04/2023	45 minutes
Company B	Interview	Person B1	Corporate Sustainability Manager	15/03/2023	30 minutes
	Interview	Person B2	Sales Engineer, North America	31/03/2023	30 minutes
	Interview	Person B3	Sales Manager Rebuild Packaging Systems	19/04/2023	30 minutes

Source: The author

Once I completed the primary data collection, I analyzed the secondary data, such as company websites, reports, articles, presentations, and other public sources on corporate CE practices (Table 2). The secondary data provided further understanding and a descriptive overview of the context that was essential to complete the data collection.

Table 2. Secondary Data

Cases	Type of data	Source	URL	Date of publication	Date of visit
Brückner	Website	Brückner ServTec	Website -Brückner ServTec	n.d.	09/03/2023
	Report	Brückner Group	Sustainability Report	01/10/2022	09/03/2023
	Magazin	Brückner Group	Sustainability Magazin	01/10/2022	09/03/2023
	Interview	Schlütersche Fachmedien GmbH	Industry Interview	05/06/2019	18/03/2023
Heller	Magazin	Gebr. Heller Maschinenfabrik GmbH	Article Ressource Management	n.d.	10/03/2023
	Interview	Innovationspreis für Klima und Umwelt	Industry Interview	16/05/2019	10/03/2023
	Article	Hülthig GmbH	Article: How sustainability works	26/07/2017	10/03/2023
Kampf	Interview	Hüthig GmbH	Importance of connecting systems	01/06/2022	13/03/2023
	Article	ProData GmbH	R-Cycle Membership	14/01/2021	15/03/2023
	Website	Kampf Schneid- und Wickeltechnik GmbH & Co. KG	Company website	n.d.	13/03/2023
Company A	Podcast	Name of Podcast: Verpackt und Zugeklebt	Podcast: Circular packaging	07/2021	17/03/2023
	Article	Sustainable Packaging News	Index conference	15/03/2023	28/03/2023
	Article	Pan Media Matrix	Article: Future packaging	21/01/2021	25/03/2023
	Article	Company A packaging group	Newsroom	02/06/2022	17/03/2023
Company B	Report	Company B	Sustainability Report	2021/2022	11/03/2023
	Magazin	Ella Verlag & Medien GmbH	Importance of partnerships	13/12/2022	05/04/2023
	Website	Company B	Company Website	n.d.	03/04/2023
	Article	Hüthig GmbH	German packaging award	05/10/2021	03/04/2023

Source: The author

3.3 Data analysis

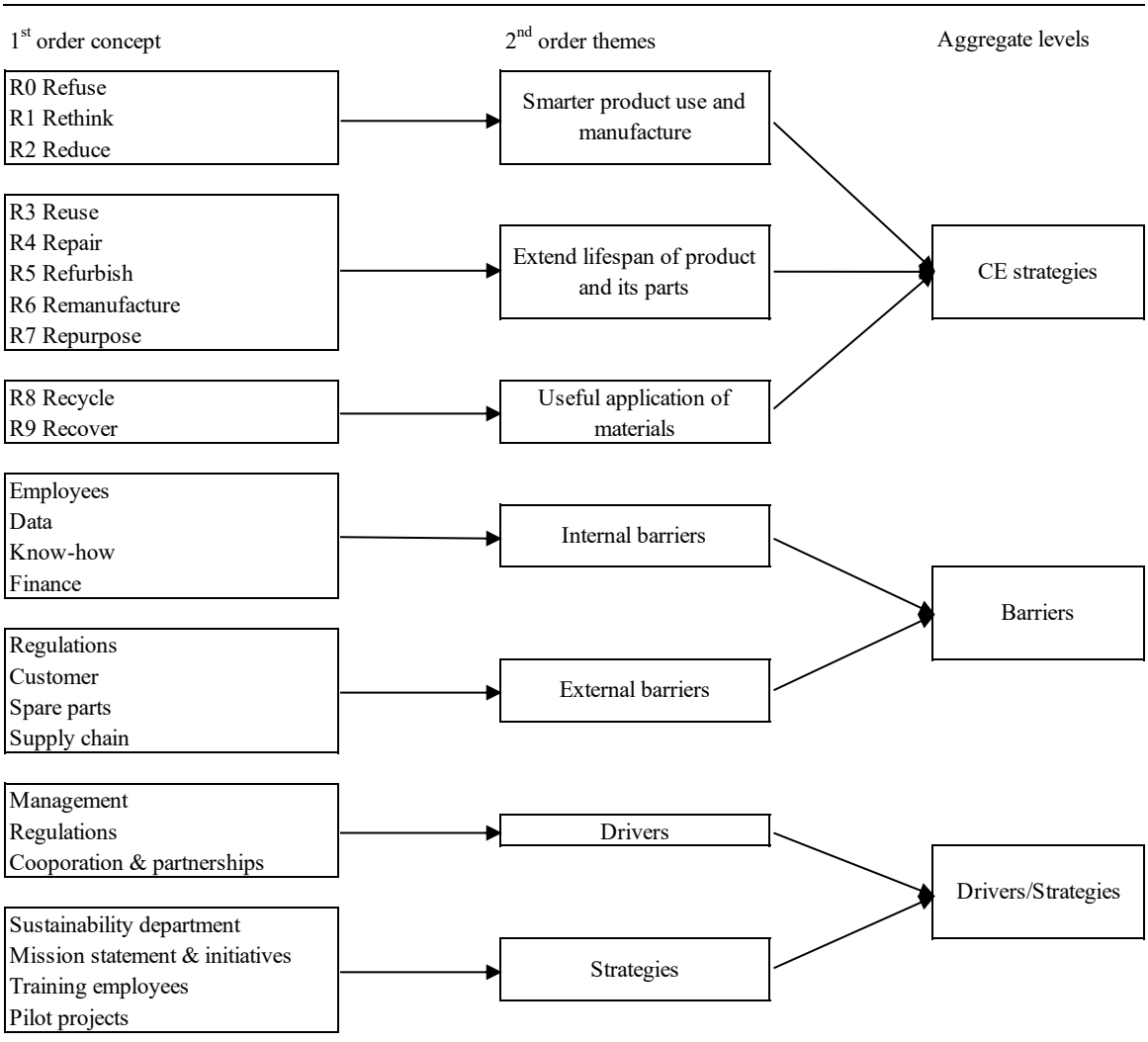
I used the approach proposed by Takacs et al. (2022) to analyze the collected data. After collecting the data, I analyzed the obtained information from interviews and secondary documents. Bringing together these various sources of data allowed for triangulation, which helped to inform and clarify certain aspects that were found ambiguous in individual data sources (such as interviews or secondary data) (De et al., 2022). I analyzed the data through coding, which involves organizing the information into categories and identifying connections between them (Dey, 2003).

Initially, I analyzed the data from each case to determine the main insights and contents. I began with a first-order analysis, which involved coding the content for the barriers and drivers close to the text in an open coding without categorization. I added the content regarding the implemented CE practices to the different Rs of the 10R framework of Potting et al. (2017). This required a different approach to data analysis for the categorization of the CE practices. The open coding without categorization, utilized for the content related to barriers and drivers,

allowed for summarizing the essence of the excerpts (Takacs et al., 2022). This descriptive coding method generated numerous codes (Saldaña, 2013). Afterwards, I employed axial coding to identify similarities and differences between codes and to reduce their number. The next step involved conducting a second-order analysis to form themes based on these codes. I labeled these themes in an informative manner and, if necessary, underwent reformulations and reclassifications (Gioia et al., 2013; Saldaña, 2013). I used the created second-order themes to form dimensions, visualizing them as aggregated levels. An example of first-order concepts, second-order themes and aggregated levels are illustrated in the coding tree used to structure the data (

Figure 2).

Figure 2. The coding tree



Source: The author

The research question relates to how companies in the ME industry implement CE principles. For this purpose, the implemented CE practices are examined on the one hand, and barriers and drivers are considered on the other hand. Consequently, the coding tree encompasses three dimensions: CE strategies, barriers, and drivers, each of which is further subdivided. As previously mentioned, I divided the themes into multiple codes that contained citations related to the theme. Table 3 provides with the use of the barriers an example of the coding organization. I divided the barriers into internal and external barriers. The internal barriers include employees, data, know-how, and finance, to which I have assigned appropriate quotes from the interviewees. The dimensions of barriers and drivers emerge from the data, as respondents indicated that they faced barriers during the implementation and that certain drivers were crucial to a successful CE adoption.

Table 3. Coding example

Quotes	1st order concept	2nd order concept	Aggregate levels
"There is rejection, especially in mechanical engineering. It is an industry with a relatively high average age of employees who are very, very entrenched in their values."	Employees	Internal barriers	Barriers
"Data is a big problem. As of today, we can't tell how many kilos of steel, how many kilos of which material we used in which machines, we simply don't have the data."	Data		
"Know-how building, of course. We had to build up many of these competencies first. And, of course, building up know-how takes time, a lot of time. But a lot of money is also spent on further training."	Know-how		
"Finance was a huge challenge, you know […] I guess pricing was always the main issue, right, where we had to make sure we were very competitive."	Finances		

Source: The author

As mentioned, I used a different approach for the categorization of the content for the implemented CE practices. Therefore, I interpreted the analyzed data in two steps to achieve the research objective. First, I used a deductive approach by using the 10R framework to categorize the adoption of each CE principle by the five companies. Then, I used an inductive approach to derive categories of barriers and drivers (Figure 2).

4. Empirical setting

All five companies analyzed in this thesis implemented CE principles in their company at an early stage and have continued to develop them steadily. It should also be emphasized that all the companies presented are global market leaders in their industry and are among the “hidden champions” of the German economy (Wirtschafts Woche, 2023). In the following, the five machine manufacturers are presented in detail. Insights are provided into the product portfolio, business orientation and sustainable activities.

4.1 Brückner

Brückner is a German ME company specializing in developing and manufacturing of machinery and equipment for the plastics and packaging industries. The company was founded in 1960 by Gernot Brückner and has been family-owned ever since. The product portfolio includes production lines for manufacturing of films for high-quality packaging and technical application areas, series and special machines for processing plastics, and special machines for the packaging industry. In addition to its machines, Brückner also offers services such as training, maintenance and reconditioning of machines and spare parts management. The foundation of Brückner is formed by the companies Brückner Maschinenbau, Brückner ServTec, PackSys Global and Kiefel. All four member companies are world market and technology leaders in their respective business fields.

Over the years, Brückner has aligned its activities worldwide and today has subsidiaries and sales offices in more than 40 countries. The company has production facilities in Germany, China, India, Russia and the USA. Brückner employs 2900 people and last year generated a turnover of 1,13 billion EUR, which is a 39 % increase in sales over the previous year.

The company is very committed to sustainability and CE. Through its various services and upgrade programs, the company tries to extend the life cycle of its machines significantly. With its own research center, the company can test its machines using recycled materials. The company published its first sustainability report in 2022. Brückner has also launched its own sustainability initiative named “Yes, we care!” to promote sustainability and CE within the company (Brückner Group, n. d.).

4.2 Heller

Heller is a leading German machine manufacturer in the field of metal cutting. Founded in Nürtingen in 1894, the company now develops and manufactures CNC machine tools and production systems for machining.

The company's product range includes 4-axis and 5-axis CNC machining centers, milling machines and turnkey systems. In addition, the company offers services such as maintenance offerings, training and spare parts management. With Heller4Industry, the company offers advanced solutions to increase manufacturing productivity. The company's subsidiary deals with purchasing and modernizing of Heller machines and ensures that old machines are brought up to date to be put back into operation.

Heller has a global presence, with sales and service offices in 30 locations worldwide and production facilities in Germany, Brazil, China, the USA and the Czech Republic. The company employs 2,600 people and had annual sales of around 366 million EUR in 2021. It had experienced a 4.3 % decline in sales from 2020 to 2021.

Heller is committed to sustainability and has implemented various measures to reduce its environmental impact. In 2018 the company got certified with the sustainability standard ISO 14001. Heller also has a sustainability strategy that includes goals such as reducing greenhouse gas emissions, promoting the use of renewable energy, improving machinery, and reducing waste. Moreover, the company is also a member of the sustainability initiative of the Association of German Machinery and Plant Manufacturers (VDMA) (Gebr Heller Maschinenfabrik, 2023).

4.3 Kampf

Kampf is a German engineering company specializing in developing and manufacturing machines for processing web-shaped materials such as films, composites, laminates, nonwovens and paper. The company was founded in 1920 by Erwin Kampf. The company offers a wide range of slitting, winding and coating machines and special machines for producing battery release films and packaging materials.

The company, headquartered in Wiehl, Germany, has been a technology leader in slitting and winding technology for more than 100 years and has itself been internationally successful for many years with its subsidiaries in the USA, India, Great Britain and China as well as

international service and sales offices. Kampf employs 1244 people and has annual sales of 274 million EUR in 2022.

Kampf has been making efforts toward sustainability for many years. The company has taken steps such as using energy-efficient technologies and materials and reducing waste. Through its subsidiary, Kampf has its used machinery upgraded to run more energy-efficiently, and machines are also repaired, disassembled and brought up to current standards on site. Kampf is also a member of the R-Cycle initiative (R-Cycle, 2023), which promotes a digital product passport for more efficient manufacturing, improved waste sorting and high-quality recyclates (Kampf - KAMPF Schneid- und Wickeltechnik, 2023).

4.4 Company A

As a solution and system provider, Company A develops individual, holistic filling and packaging concepts. Founded in 1922 and now in its third generation of family management, the company is divided into four business areas: Pharma, consumer, nonwovens and life science. Together with its subsidiaries, Company A designs and realizes everything from single machines to complex turnkey plants. The company's technologies are considered world leaders in many areas: For example, for sterile pharmaceutical liquids in conjunction with their freeze-drying, for the filling and packaging of coffee capsules, or for the packaging of paper hygiene products.

Company A is headquartered in Schwäbisch Hall, Germany, and operates in around 20 locations worldwide. The company employs 3000 people worldwide and generated annual sales of 500 million EUR in 2021, recording a 19 % increase compared to the previous year.

Company A has introduced a sustainability strategy. The company already develops and manufactures packaging equipment that is energy efficient and produces little waste. In addition, the company offers its customers more sustainable packaging solutions, such as recyclable and biodegradable materials. The company also extends the life cycle of its machines through services, maintenance and upgrades. Moreover, in cooperation with two other companies, the company has developed a complete CBM, namely a recyclable capsule system. This model guarantees a sustainable circular system from production, use to recycling of the packaging (Website Company A).

4.5 Company B

Company B is a German engineering company and the world's leading system supplier for packaging pharmaceuticals in bottles, blisters and cartons. The company was founded in 1948. It offers a wide range of machines, such as blister machines, cartoning machines, case packers and end-of-line packaging systems, services, software products and digital solutions for the pharmaceutical, healthcare, consumer goods, food and agricultural markets.

Company B is present in 14 countries at 19 locations around the globe. It employs 2600 people worldwide and generated sales of 428 million EUR, which is a 1.18% increase in sales.

The company is committed to sustainability and CE. As early as 2003, Company B introduced its "Rebuild" program, in which the company's own machines were repaired, upgraded, refurbished and resold. The company is constantly improving and expanding its "Rebuild"-program. In addition, the company has a long-standing partnership with a neighboring packaging equipment manufacturer specializing in sustainable packaging. Company B's machines are designed to process sustainable packaging materials on the machines, reducing material waste in the packaging process. In 2021, a subsidiary of Company B was awarded with the German Packaging Prize for its purely paper-based packaging "Cycleform" (Website Company B, n. d.).

5. Findings

This thesis addresses the research gap of how far CE implementation in the ME industry has progressed, considering the barriers and drivers faced by companies in the ME industry during implementation. The thesis is motivated by the following research question: *"How do companies in the mechanical engineering industry implement circular economy principles?"* To answer the research question, I conducted a multiple-case study on five companies in the ME industry: Brückner, Heller, Kampf, Company A, and Company B. The 10R framework, as described in subsection 2.4.1, is used to classify the already implemented CE practices better. It is essential to emphasize that all barriers and drivers presented in this thesis were mentioned by all ME companies under study and can be considered as common barriers and drivers encountered in this industry. The following section presents the findings on the implemented CE practices and the different barriers and drivers. The entire coding table, which includes the collected data, is presented in the appendix, providing the basis for the following findings.

5.1. Implemented circular economy principles

I primarily chose the 10R framework in this thesis to carefully determine the CE practices adopted by the ME companies. The results show that all five companies have implemented six or more CE practices (Table 4). The CE practices implemented by the companies mainly focus on extending the life of the machines. All companies give attention to smarter product use and manufacture through the two CE strategies of reduce and rethink. It is worth noting that none of the companies in this circularity level have implemented CE practices for the CE strategy refuse. Refuse aims to make the machine redundant by abandoning its function or offering the same function with a radically different machine. It has been confirmed that the implementation of refuse is complicated due to the individuality of each machine. Therefore, each machine is responsible for the production of only one specific component or product. The third circularity level is the useful application of materials and refers to recycle and recover. Of all companies, only Brückner implemented CE practices to process materials to obtain the same or lower quality (recycling) or to recover materials. Although Brückner does not use recycled materials in its machines, the company researches the use of recycled materials in film production in its own research center. Referring to the definition of recycling by Potting et al. (2017), Brückner has not yet implemented a CE practice for this CE strategy. In summary, the ME companies under study have extensively implemented CE principles, with an average of seven CE strategies already in place. The companies continue to strive to increase their number of

implemented CE practices. All companies confirmed that they faced various barriers during implementation that needed to be and still need to be overcome for CE implementations.

Table 4. CE strategies implemented by each case study company

Circularity levels	CE Strategies	Implemented CE practices	Cases					Total
			Brückner	Heller	Kampf	Company A	Company B	
Smarter product use and manufacture	R0 Refuse	-						**0**
	R1 Rethink	> Modular machine design, leads to components being easily exchanged and upgraded	X	X	X	X	X	**5**
	R2 Reduce	> Reduction of energy consumption due to energy recovery by using the braking energy of the machines	X	X	X	X	X	**5**
Extend live span of product and its parts	R3 Reuse	> Repurchase by the companies and resale of the machine to new customers or transfer of the machine to another location	X	X	X	X	X	**5**
	R4 Repair	> Service consultations throughout the entire life cycle, as well as repair-oriented construction	X	X	X	X	X	**5**
	R5 Refurbish	> Uprgrade packages to improve customers' installed machine base > Upgrades of machines with new more energy-efficient drives and switchgear	X	X	X	X	X	**5**
	R6 Remanufacture	> Machines are disassembled into individual parts, cleaned and repaired, and then reassembled into a new machine	X	X	X	X	X	**5**
	R7 Repurpose	> Used plant components are installed in another machine	X	X	X		X	**4**
Useful application of materials	R8 Recycle	> Research on the use of recycled materials in film production	X					**1**
	R9 Recover	> Heat recovery systems that increase raw material efficiency by recycling the edge trim sections into extruders	X					**1**
			"X" stands for the CE strategy that the case company has implemented.					

Source: The author

5.2 Barriers to the implementation of circular economy principles

The introduction of CE in a company cannot be implemented overnight. The results show that many influencing factors hinder and complicate the transformation towards CE. These influencing factors represent barriers companies must overcome to implement CE successfully. This thesis found that the barriers mentioned can be divided into internal and external.

Internal barriers occur within the company and are caused by the companies themselves. If the barriers are internal, the company has greater leverage to act and, thus, a greater chance of successfully removing these barriers. In contrast, external barriers arise outside the corporate structure. These external barriers can only be controlled by the company to a limited extent. Consequently, the company's leverage for action is smaller, and the associated barriers are more difficult to overcome. The following subsections discuss the various internal and external barriers cited by the interviewed companies.

5.2.1 Internal barriers

Employees: The results show that for a successful implementation of CE, it is essential that all the people involved support this transformation. For employees, a transformation to CE means a change that can be equated with a step out of their comfort zone. Especially among older employees, such a change is initially faced with a lack of understanding and rejection. As the sustainability manager of Company A explains:

> *"There is rejection, especially in mechanical engineering. It is an industry with a relatively high average age of employees who are very, very entrenched in their values."*

Support from the company's employees is essential for implementing CE. Maik Krüger, Head of Business Development at Kampf, emphasizes the importance of raising employee awareness about sustainability and CE. He suggests explaining openly and transparently why such a transformation is essential for the company. Furthermore, Krüger stresses that successful CE implementation relies on support from everyone within the company. This view is also shared by his colleague Tim Kemper:

> *"But what is definitely still a challenge is to engage these employees and demonstrate that we need new ideas and that these ideas will mainly come from the employees. And that it is not enough top-down, to propose ideas and develop strategies, but these things have to come from the design engineer, they have to come from the product design so*

that we can really make a difference. And that is still a challenge, to raise that awareness and to create internal communication in terms of sustainability and circular economy and to drive the effect of sustainability and circular economy."

In the past, little attention was paid to the issue of sustainability in machine development and construction. The focus was mainly on the machines' excellent quality and function. This type of construction leads to a longer life span of the machine, positively affecting the environment as it reduces the need for resources. At the same time, it is accompanied by the unnecessary and not always sensible additional consumption of raw materials. The sustainability report of Brückner indicates that the use of recycled or secondary raw materials for machine production is excluded due to quality and standardization concerns. However, there is a need to sensitize departments such as development and construction to the concept of CE and sustainability to produce machines sustainably and in line with the principles of CE. The willingness to redesign machines accordingly is, in turn a question of the employees' attitude towards CE, as highlighted by Company A's sustainability manager:

"Topics like material efficiency have not been very important in some places where it could be useful in the past. But if, for example, we now say in development and construction that we will reduce the dimensions here a little and use a different material here, then production could be even more sustainable, or the CO_2 footprint of the machines could be reduced. However, these are also more the areas of work where this criticism in the direction of sustainability begins."

Another important point that should be mentioned here is that it was found that the topic of the circularity of machines is widely accepted by the employees of all the companies surveyed. This can be attributed to the direct benefits that customers receive from the service part, including repair, spare part management, and refurbishments. Additionally, these services provided financial added value to the companies. However, it also turned out that the employees did not accept and support the topic for a sustainable reason or for the motivation to push the implementation of a comprehensive CE, but rather for an economical and practical reason. Therefore, especially with the lifetime extending practices, the acceptance hurdles among employees are lower than within the actual development and construction departments, where innovations, ideas and changes are required and launched.

Data: Another significant barrier regularly cited is the lack of data. While companies are working with ERP systems, many have still failed to properly maintain the system in the past as stated by Stefan Wölffing and Tim Kemper:

> *"Data is a big problem. As of today, we can't tell how many kilos of steel, how many kilos of which material we used in which machines, we simply don't have the data."*
>
> (Stefan Wölffing, Management System Officer at Heller)

> *"We lack data on basic things like the exact weighting of materials. We have an ERP system where data is not yet fully maintained so that you can push a button and get all the weights of a machine out."*
>
> (Tim Kemper, Sustainability Manager at Kampf)

Without extensive collection of all relevant data, it is difficult to determine how much material is installed in a machine. Consequently, without this information, it is also challenging to determine where material savings could be made.

Know-how: Implementing CE practices requires know-how. This is what makes a successful transformation possible in the first place. The results show that the lack of knowledge and understanding of CE within the company is one of the biggest barriers, consuming time and money. This is because even if the motivation for CE is there, it usually fails regarding adoption and implementation, as the sustainability manager of Company A explains:

> *"Know-how building, of course. We had to build up many of these competencies first. And, of course, building up know-how takes time, a lot of time. But a lot of money is also spent on further training."*

Lack of know-how is not only a significant barrier to introducing CE but also to the regular activities and the already implemented CE practices. For example, a machine consists of countless parts and components, not all manufactured by the company itself. If a machine is adapted to the latest standards, rebuilt or refurbished, wear parts must be replaced. These are usually purchased externally. These components must then be returned to the supplier and reconditioned by them so that these components are ready for reuse. This process is necessary because the machine-building companies lack the know-how to recondition the external components.

Due to the long life span of machines, it can take years until a machine needs to be repaired, rebuilt or refurbished for the first time. Therefore, the company must still have employees who know the machine and have the necessary know-how to repair it. This emphasizes the importance of retaining or transferring know-how within the company, as stated by the corporate sustainability manager of Company B:

> *"The machines run for 20 to 25 years on average. And then you need experts in house who still knew that machine from back then, because every machine is so individually built and customized that no two machines are ever the same. And you actually need experts in house who were there 20, 30 years ago, who still know their way around, in order to repair the machine."*

Finances: One internal barrier that was raised most frequently was the issue of finances. A transformation from a linear to a CBM takes time, money and resources. This transformation represents a significant financial barrier for companies. The interviewees mentioned that adopting CE practices was only possible because the companies under study had already reached a certain business size. The companies also confirmed that they would not have implemented CE without the company size they had at the time. It would not have been financially possible.

> *"Finance was a huge challenge, you know […] I guess pricing was always the main issue, right, where we had to make sure we were very competitive."*
>
> (Person B2, Sales Engineer at Company B)

5.2.2 External barriers

Regulations: The results show that regulations represent a significant barrier. This puts pressure on companies to support the CE. At the same time, these regulations are associated with a large amount of bureaucracy, making it difficult for companies to comply with the specified obligations. In fact, the corporate sustainability manager of Company B acknowledges the barriers posed by these regulations and states:

> *"It is just difficult to cover all the requirements and set up circularly through other departments that don't have expertise in the area and also have a different daily business."*

Also, many laws are perceived by companies as not very conducive to implementing CE practices. The different legal frameworks at the national and international levels mainly pose challenges. These problems were reported primarily for the use of new raw materials and the use of secondary materials. The companies that specialize not only in manufacturing machines but also in researching the materials used for them raised these issues primarily, as explained by Quirin Weidacher and Person A2:

> *"The big problem, which is also in the market, many of our films are also used in the packaging and food sectors. And currently no post-consumer recyclates are approved in the EU to be used again in the food sector. The European Union actually says that it wants to have 30 % recycled content in films by 2030, but at the same time prohibits the use of recycled materials because some of them have been poorly recycled or because the purity is not good enough."*
>
> (Quirin Weidacher, Sustainability Manager at Brücker)

> *"There are machine manufacturers who mainly export, there the topic of circular economy has not yet arrived at all, accordingly these companies then also have other legal obligations."*
>
> (Person A2, Head of Sales at Wipf)

The EU has now passed the "Green Deal - carbon border adjustment mechanisms". According to person A1 this measure is putting significant pressure on the ME industry due to the anticipated sharp increase in purchase prices of components, causing medium-sized ME companies on their toes over the next few years.

Customers: One central barrier shown in the results is the customer, who often lacks the understanding and willingness to adopt CE principles. Additionally, there is a lack of pressure from end consumers to demand circular products, leading to a scarcity of machines capable of processing recycled or secondary materials or having energy-efficient upgrades. In the packaging industry, for which most companies under study manufacture machines, legal regulations represent a significant barrier. Moreover, end consumers often fear quality losses and therefore prefer to stick to the status quo. The lack of pressure from end consumers means that packaging manufacturers are unwilling to pay a higher price for a machine to produce circular products. Therefore, they are often unwilling to pay more for recyclable products or

materials, which leads to a lack of activity towards circular product design in the packaging industry. Person A1 and person A2 state:

> *"We are also often advised against sustainable innovations and changes in the machine by our sales department. Or that sustainable changes to the machine are offered as an option rather than as standard because our customers are not yet willing to pay more. For example, they only see okay, this machine is already expensive, and it will now be 10% more expensive due to sustainable changes. Then it's simply not an option to buy it, even if, for example, these additional costs are amortized within a year through energy efficiency measures on the machine."*
>
> (Person A1, Sustainability Manager at Company A)

> *"At the moment, unfortunately, it is not yet the case that you can pass on these price differences one-to-one […] the trade is not yet ready, or the pressure is not yet great enough to get these high prices that you would actually need because the material is more expensive. [...] Unfortunately, the consumer is not yet ready to pay 0.20 EUR more on the shelf because it is sustainable packaging."*
>
> (Person A2, Head of Sales at Wipf)

The difficulty lies in comparing the price or cost of non-sustainable actions with the additional costs involved in manufacturing circular products or adopting sustainable production processes. It is crucial to convince the customers that CE and sustainable practices may lead to increased costs, but so does non-sustainable action.

Spare parts: CE in the ME is only possible if the machines can be repaired and refurbished whenever necessary to maximize the machine's life span. For this purpose, the fitting spare parts must still be available many years after the machine's fabrication. If the necessary spare parts are no longer available, for example, because they are no longer produced, often more than necessary have to be replaced on the machine, as stated by Fabian Held, emphasizing the importance of long-term availability of spare parts to minimize unnecessary replacements:

> *"Some spare parts for machines are limited, they are only available for 10 to 15 years, and then there are no more spare parts at some point. And then it is new parts that you have to use, which unfortunately entail that you have to rework and replace more than would actually be necessary completely."*

Supply chain: The respondents mentioned barriers in the supply chain several times. Companies often desire to make more progress towards CE. However, they are inhibited by dependencies on other suppliers. Especially when suppliers do not have the understanding, willingness or even the will to embrace circular production methods. It was also mentioned that the influence of one single company on the entire supply chain is limited. The sustainability manager of Company A highlights that it is hardly possible to enforce demands for more circularity by stating the following:

> *"Sustainability in the supply chain is definitely also a sore point. [...] our leverage for more circularity in our production processes are accordingly limited because we are heavily tied to cooperation in the supply chain. Moreover, if there is neither the know-how, nor the understanding, readiness and the will to act accordingly in terms of sustainability and deal with the issue more, then it is difficult."*

5.3 Drivers and strategies to the implementation of circular economy principles

To drive the adoption of CE practices despite the barriers that occur, the interviewed companies highlighted the need for drivers and strategies to support and promote CE transformation actively. Management, regulations, collaborations, and partnerships were key drivers for successfully adopting CE practices. With these drivers, the companies could develop strategies to adopt CE practices and drive CE further within each company. The following subsection will introduce the individual drivers and companies' strategies to overcome the outlined barriers.

5.3.1 Drivers

Management: The company's management is the biggest driver for development towards CE. As a top-level decision maker, senior management is critical in setting a company's strategic direction and allocating resources needed for the CE transformation. By prioritizing the transformation towards CE, senior management can ensure that the entire company is aligned with this goal. In addition, it is up to senior management to develop strategies that support the CE transformation. In particular, corporate mission statements play an important role in this process, as mentioned by Person A1, Quirin Weidacher, and Person B1:

> *"We are really fortunate there and are in this comfortable situation that the topic of sustainability and circular economy is highly valued by the management. Sustainability*

represents an important pillar in our overall corporate strategy. We have had a new mission statement for a few months now, with these points of vision, mission and strategy, and also sustainability has been added to one of these four essential pillars."

(Person A1, Sustainability Manager at Company A)

"It always all comes out of a long-term strategy. [...] the bottom line is that building circular business models is not well enforceable at any company if the management is not behind it. [...] But we are fortunate that our management supports the topic of circular economy and sees the need for it and sees the future as it comes."

(Quirin Weidacher, Sustainability Manager at Brückner)

"It is definitely important, especially with large strategic topics that affect business models or that affect the transformation of the entire company in the direction of circular business models, that it affects several departments, from product management to purchasing, strategy departments, and developments. So it affects quite a few departments in the company, and it is particularly important that there is a consensus from the top, i.e. in the management, and that a decision is made that the topic is relevant."

(Person B1, Corporate Sustainability Manager at Company B)

Regulations: Regulations were perceived by companies not only as barriers but also as drivers, as mentioned by the corporate sustainability manager of Company B. This is because they put pressure on companies, which forces them to take action. Regulations also provide a direction for the next steps towards sustainability. For example, passed legislation or legislative changes mean that companies are now working on topics related to CE or sustainability that they either previously paid little attention to or had not yet put on their agendas:

"The main drivers are actually legal obligations."

Cooperation & partnerships: The companies mentioned that cooperation and partnerships with companies and universities is an essential driver for CE transformation. Brückner writes in its sustainability report that sustainability thrives on partnerships and relies on an established network of experienced suppliers, business, and research partners to share know-how. In working groups or consortia, the companies collaborate with other companies in and across industries to research new circular solutions. Bernhard Winklhofer and Maik Krüger explain

that companies in these working groups come together to advance the topic of CE and do not see themselves as competitors:

> *"We work together in consortia, even beyond our cycle. […] We form working groups where we collaborate to look at how products have to be manufactured so that they can be recycled to the maximum afterwards."*
>
> (Bernhard Winklhofer, Head of Process Technology Upgrading & Service at Brückner)

> *"The introduction of a working group is important in order to be able to talk, discuss and design with each other at eye level, even beyond competitive boundaries. And that is also a very important aspect. Especially in topics like digitalization, sustainability and the circular economy, you simply have to think away from competitive boundaries."*
>
> (Maik Krüger, Head of Business Development at Kampf)

Partnerships not only help to share ideas but also make it possible to implement projects that the companies themselves would not realize. For example, it was only due to a well-working partnership that Company A could develop a comprehensive recycling system. Person A2 mentioned the success of their recyclable capsule system as a direct result of this collaborative effort.

> *"We did a joint project GreenLution. That is a recyclable capsule system that is a completely sustainable closed-loop system from production, use to recycling. That is only possible by working with the machine manufacturer to test the films on the machine."*

The interdependence of sustainable packaging solutions and the machines used to process them is particularly evident in the packaging industry. Without machines that can effectively process sustainable materials, it is impossible to offer sustainable packaging solutions. Accordingly, packaging manufacturers depend on the machines' functionalities and thus on the machine manufacturers, as Company B also illustrates:

> *"A sustainable packaging solution can only be target-oriented for the customer if it can be optimally processed on the packaging machine. This was only achieved through decades of cooperation and development with Etimex."*
>
> (Valentin Kupfer, Company B – Article: Sustainability through company cooperation)

5.3.2 Strategies

Implementing a sustainability department: Establishing a sustainability department proved to be a game changer for the companies in implementing CE. Quirin Weidacher mentioned that for the department, employees with expertise in sustainability and CE were recruited to focus solely on this area on a daily basis:

> *"We have a dedicated sustainability department, so that is several people where the circular economy topic is anchored, and they take care of the circular economy area."*

In addition, by implementing a dedicated sustainability department, the companies can ensure that the topic of sustainability receives the attention and resources it requires. This department ensures that sustainability is integrated into all aspects of the company and serves as a multiplier by educating employees about sustainability issues through internal communication and persuasion, as Maik Krüger explains:

> *"Especially in the beginning, you need multipliers to push the idea in the company, but of course, it is very important to convince people first."*

The corporate sustainability manager of Company B states that introducing a sustainability department also facilitates cooperation between different departments by implementing change management in the individual departments and training the employees. This ensures that CE practices can be integrated into all company areas:

> *"But not only that, just because a decision is made at the top does not mean that it will also reach the departments, but there still needs to be an intermediate area, in our case, the sustainability department, which brings the topic of the circular economy into the departments and also does a bit of change management and trains and enables the departments."*

Introducing a mission statement & initiatives: The interviewees often mentioned the introduction of a mission statement. A mission statement, set by management with appropriate enthusiasm and conviction, is perceived as an essential factor in achieving success with CE strategies. This is because it enables the management to emphasize the importance and the potential of the topic and motivate and inspire the employees for the CE transformation. Company A says that the entire management will strongly promote the mission statement in the future. Brückner also writes that its initiative "Yes, we care!" is a commitment to its responsibility in terms of sustainability and a promise to its employees. The company goes on

to write that everyone in the company wants to act together, develop visions, drive innovation, and contribute solutions.

Training employees: The results show that another strategy employed to drive CE transformation was employee training. Georg Preu and the corporate sustainability manager of Company B confirmed that employee training was and continues to be essential for a successful transition to a CE. Training provides the opportunity to equip employees with the necessary skills and knowledge to implement CE in their daily work. This is because it is crucial for employees to have a clear understanding of the principles of CE and to know how to effectively implement them to drive a successful CE transformation. Training sessions allow employees to look at their operations with a CE and sustainability perspective, leading to more employee generated solutions for integrating circular processes into their daily work and throughout the company:

> *"We have trained all employees from the top management to division managers, department managers, to floor employees, sales employees, we have done training, site-wide. We have made our employees aware of sustainability."*
>
> (Georg Preu, Occupational Safety Specialist, Environmental Protection & Environmental Management Officer)

> *"[...] because the topic is now becoming increasingly important and the employees have also been trained and sensitized to it, you also notice that the departments intrinsically want to tackle the topic on their own."*
>
> (Person B1, Corporate Sustainability Manager at Company B)

Pilot project: When asked how the companies specifically started implementing CE, the sales manager of Company B replied that it is necessary to start small and that it makes sense, to begin with individual departments or focus on specific machines that can be expanded step by step:

> *"The approaches were to focus on a specific machine that is extremely available on the market. So we deliberately chose a machine type where we knew that many customers had this machine and that it was well-established and popular. We will take that one and start with that one, and that is how we got going."*

Launching pilot projects, as mentioned by Maik Krüger, also proved to be instrumental in facilitating the implementation of CE:

> *"It is important to approach a topic like the circular economy as a pilot project, that is, to start small."*

6. Discussion

To explain how companies adopt CE practices, this thesis provides insights into the barriers, drivers, and strategies for the CE implementation. Firstly, it provides an overview of the barriers in the ME industry needed to be overcome in the implementation of CE. Secondly, the thesis highlights the drivers of CE implementation. Lastly, it presents the strategies that the companies used to be able to adopt CE practices in the first place. The barriers to CE implementation that I found align with the results of previous studies. For example, Daian & Ozarska (2009) also found that the lack of data is a significant barrier to CE implementation. As found in this thesis, previous studies named finance to be perceived by companies as a significant challenge for the implementation of CE (Cristoni & Tonelli, 2018; Kirchherr et al., 2018). In contrast to previous studies (Rizos et al., 2016), this thesis found that employees who are not open to CE, are among the most significant internal barriers to CE implementation. A barrier that is less important in other industries, as it is not mentioned in other literature as the literature review shows are non-existent or discontinued spare parts.

The drivers identified in this thesis are management, cooperation and partnerships as well as regulations. The companies perceived management as the most crucial driver, as it lays the foundation for a successful CE transformation and develops strategies to implement CE. The introduction of a sustainability department represents one such CE strategy. It was confirmed that with a committed management, the implementation of a dedicated sustainability department was possible. That management is essential for CE transformation could also be found in previous studies (Rizos et al., 2016; Siemieniuch et al., 2015; Sohal & De Vass, 2022). Other drivers, such as collaborations, partnerships, and regulations, align with the findings from other studies. For example, Q. Liu et al. (2022) also found that partnerships between companies and across company boundaries are essential drivers. Similarly, Kazancoglu et al. (2021) found that regulations also play an important role in the implementation of CE. Nevertheless, it should be emphasized that the companies perceived regulations not only as a driver but also as a significant barrier.

Introducing a sustainability department was found to be one of the company's main strategies for implementing CE. This strategy was not mentioned in previous studies. Moreover, Sharma et al. (2021) and Sohal & De Vass (2022) found that employee training is essential for implementing CE. This result can be additionally confirmed with the present thesis. The last

strategy considered necessary by the investigated companies is to start the CE transformation as a pilot project. This finding can also be confirmed by Barford & Ahmad (2022).

This thesis has several implications. It reveals that all companies implemented CE strategies for extending the life span of machines and that the adoption of the already implemented CE practices was easier to achieve. Thus, the companies targeted an earlier implementation. It was emphasized that for the implementation of these CE strategies, the drivers were decisive in order to implement CE practices successfully. However, the CE strategies of refuse, recycle, and recover have been poorly implemented. With interviews revealing that the barriers are responsible for it. It is, therefore, imperative to address internal barriers consistently and mitigate external barriers. Policymakers should become aware of the importance of these barriers and should work together with the companies to minimize them through exchanges and feedback loops. It is important to highlight that this thesis has shown that CE practices are economically justified, and CE practices are not a cost center for the companies. Thus, these CE practices demonstrate the contribution to sustainable value preservation and creation as well as the promotion of long-term competitiveness.

From these findings, it can be concluded that a successful CE implementation requires several key factors. The attitude of employees towards CE and the corporate culture driven by a mission statement is crucial. Therefore, companies should practice change management and promote know-how building through training. It is important that companies begin to adopt a long-term human resource policy. Furthermore, CE should be deeply embedded in the corporate philosophy with its values and employees and managers should be selected according to these values. It is also crucial to engage with customers, as their willingness to pay for technology and circularity of their machines is a significant factor in whether the ME industry will produce circular machines. This clearly shows the links within the value chain and, thus, the influence that end consumers can have on the entire value chain and an upstream industry. Therefore, communication and cooperation within the value chain beyond company boundaries are important to look for common solutions.

Furthermore, participation in partnerships within the supply chain is also crucial for a successful transformation towards CE. Machines are large, complex, expensive, and highly customized products that require a lot of resources. This makes ME companies dependent on their suppliers since the construction of a machine requires not only thousands of individual parts but also the participation of several thousand suppliers. The relationships within this supply chain are long-

term relationships that entail product-related dependencies. Accordingly, the supply chain in the ME industry is a rigid construct, and the lack of flexibility makes it impossible to change suppliers overnight. This complicates the more sustainable and circular production of machines and, thus, the implementation of CE. Therefore, it is necessary to train the suppliers towards CE and to enable an exchange of knowledge.

Given the complexity of implementing CE, a quick introduction is not feasible. This is because many different interfaces in the company are addressed simultaneously during such an implementation. Accordingly, the importance of the pilot project strategy becomes very apparent, as it allows the complexity of barriers to be addressed and overcome step by step. To make this possible, it is necessary to implement a department in the company that deals with the topics of CE and sustainability. This sustainability department should serve as a staff office and focus on training, linking, and organizing the various departments within the company with regard to sustainability.

7. Conclusion

Implementing CE in ME companies as part of a sustainable strategy is increasingly important. CE is adopted and practiced in many industries worldwide. Especially, CE in manufacturing has received increased attention in the literature in recent years (e.g. Lieder & Rashid, 2016). Nevertheless, the overall adoption is still low. For this reason, this thesis ventured into the reasonably traditional ME industry, known for its use of a linear economic model, by examining five machinery manufacturers and their CE activities. I used the 10R framework to categorize the CE practices introduced. To conduct an in-depth analysis of the CE practices, I examined the companies' barriers, drivers and strategies for implementing CE.

The analysis showed that the companies introduced CE practices from a more economic point of view and less from a sustainability point of view. Nevertheless, implementing CE requires liquidity, as the transition is time-, cost- and resource-intensive. This often makes it impossible for smaller machine-building companies to introduce CE practices. This thesis found that barriers, drivers and strategies are crucial factors for introducing CE. Especially a company's management was mentioned to be the most important driver, as it gives the cornerstone for developing and implementing strategies that are crucial for CE implementation. The most highlighted barriers are employees without an understanding of CE. Although they know to build the machines, they need more understanding of sustainability and especially of CE.

Nevertheless, this thesis had several limitations. One major limitation stems from the small sample size of only five companies. A larger sample of cases would have enriched the results and led to more meaningful findings. The second limitation of this thesis is the sole focus on German companies, which could limit the representativeness of the results, possibly leading to differences in the relevance of certain barriers, drivers and strategies. Third, the results of this thesis are mainly based on the primary data, as the secondary data did not provide additional relevant information.

To further improve the applicability of the results of this thesis, future studies may focus on the implemented CE practices in the ME industry in a larger sample size to assess the transferability of my findings. Furthermore, future studies could reveal a more specific view of barriers and drivers and provide detailed insight into which barriers specifically occur in implementing individual CE practice and what drivers and strategies are crucial to overcome each barrier.

References

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: Current awareness, challenges and enablers. *Proceedings of the Institution of Civil Engineers - Waste and Resource Management*, *170*(1), 15–24.

Barford, A., & Ahmad, S. R. (2022). Levers for a corporate transition to a plastics circular economy. *Business Strategy and the Environment*, *n/a*(n/a).

Bening, C. R., Pruess, J. T., & Blum, N. U. (2021). Towards a circular plastics economy: Interacting barriers and contested solutions for flexible packaging recycling. *Journal of Cleaner Production*, *302*, 126966.

Bonciu, F. (2014). The European economy: From a linear to a circular economy. *Romanian Journal of European Affairs*, *14*(4), 78–91. Scopus.

Brückner Group. (n. d.). Abgerufen 29. Mai 2023, von https://www.brueckner.com/de

CGR 2022. (n. d.). Abgerufen 25. Mai 2023, von https://www.circularity-gap.world/2022#Download

Christmann, P. (2000). Effects of "Best Practices" of Environmental Management on Cost Advantage: The Role of Complementary Assets. *Academy of Management Journal*, *43*(4), 663–680.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*. SAGE Publications.

Cristoni, N., & Tonelli, M. (2018). Perceptions of Firms Participating in a Circular Economy. *European Journal of Sustainable Development*, *7*(4), Article 4.

Daian, G., & Ozarska, B. (2009). Wood waste management practices and strategies to increase sustainability standards in the Australian wooden furniture manufacturing sector. *Journal of Cleaner Production*, *17*(17), 1594–1602.

De, V. T., Nand, A. A., Bhattacharya, A., Prajogo, D., Croy, G., Sohal, A., & Rotaru, K. (2022). Transitioning to a circular economy: Lessons from the wood industry. *The International Journal of Logistics Management*, *ahead-of-print*(ahead-of-print).

Dey, I. (2003). *Qualitative Data Analysis: A User Friendly Guide for Social Scientists*. Routledge.

Ellen MacArthur Foundation. (2015). *Delivering the circular economy: A toolkit for policymakers*. https://ellenmacarthurfoundation.org/a-toolkit-for-policymakers

European Commission. (2012). *An introduction to Mechanical Engineering: Study on the Competitiveness of the EU Mechanical Engineering*. https://single-market-economy.ec.europa.eu/sectors/mechanical-engineering_en

Franco, M. A. (2017). Circular economy at the micro level: A dynamic view of incumbents' struggles and challenges in the textile industry. *Journal of Cleaner Production*, *168*, 833–845.

Fusch, P., Fusch, G., & Ness, L. (2018). Denzin's Paradigm Shift: Revisiting Triangulation in Qualitative Research. *Journal of Sustainable Social Change*, *10*(1).

Gebr Heller Maschinenfabrik, G. H. M. (2023, Mai 9). *HELLER | CNC-Werkzeugmaschinen für die Zerspanung*. Gebr. Heller Maschinenfabrik GmbH. https://www.heller.biz/de

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768.

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving „leapfrog development". *International Journal of Sustainable Development & World Ecology*, *15*(3), 231–239.

Geng, Y., Sarkis, J., & Bleischwitz, R. (2019). How to globalize the circular economy. *Nature*, *565*(7738), 153–155.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational research methods*, *16*(1), 15–31.

Gregson, N., Crang, M., Fuller, S., & Holmes, H. (2015). Interrogating the circular economy: The moral economy of resource recovery in the EU. *Economy and Society*, *44*(2), 218–243.

Guerra, B. C., Shahi, S., Mollaei, A., Skaf, N., Weber, O., Leite, F., & Haas, C. (2021). Circular economy applications in the construction industry: A global scan of trends and opportunities. *Journal of Cleaner Production*, *324*, 129125.

Hazen, B. T., Russo, I., Confente, I., & Pellathy, D. (2020). Supply chain management for circular economy: Conceptual framework and research agenda. *The International Journal of Logistics Management*, *32*(2), 510–537.

Johansen, K., & Rönnbäck, A. Ö. (2021). Small Automation Technology Solution Providers: Facilitators for Sustainable Manufacturing. *Procedia CIRP*, *104*, 677–682.

Kampf—KAMPF Schneid- und Wickeltechnik. (2023, März 17). https://www.kampf.de/de/

Kazancoglu, I., Sagnak, M., Kumar Mangla, S., & Kazancoglu, Y. (2021). Circular economy and the policy: A framework for improving the corporate environmental management in supply chains. *Business Strategy and the Environment*, *30*(1), 590–608.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence From the European Union (EU). *Ecological Economics*, *150*, 264–272.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, *127*, 221–232.

Kissling, R., Coughlan, D., Fitzpatrick, C., Boeni, H., Luepschen, C., Andrew, S., & Dickenson, J. (2013). Success factors and barriers in re-use of electrical and electronic equipment. *Resources, Conservation and Recycling*, *80*, 21–31.

Kok, L., Wurpel, G., & Ten Wolde, A. (2013). *Unleashing the Power of the Circular Economy*. https://www.osti.gov/etdeweb/biblio/22174941

Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D. R. S., & AL-Shboul, M. A. (2019). Circular economy in the manufacturing sector: Benefits, opportunities and barriers. *Management Decision*, *57*(4), 1067–1086.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51.

Lindahl, E., Dahlin, J.-E., & Bellgran, M. (2023). A framework on circular production principles and a way to operationalise circularity in production industry. *Cleaner Production Letters*, *4*, 100038.

Liu, Q., Trevisan, A. H., Yang, M., & Mascarenhas, J. (2022). *A framework of digital technologies for the circular economy: Digital functions and mechanisms—Liu—2022—Business Strategy and the Environment—Wiley Online Library*.

Mays, N., & Pope, C. (2020). Quality in Qualitative Research. In *Qualitative Research in Health Care* (S. 211–233).

Merriam, S. B., & Merriam, S. B. (1998). *Qualitative research and case study applications in education* (2nd ed). Jossey-Bass Publishers.

Mhatre, P., Panchal, R., Singh, A., & Bibyan, S. (2021). A systematic literature review on the circular economy initiatives in the European Union. *Sustainable Production and Consumption*, *26*, 187–202.

Mittal, V. K., & Sangwan, K. S. (2014). Development of a model of barriers to environmentally conscious manufacturing implementation. *International Journal of Production Research*, *52*(2), 584–594.

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. *Journal of Cleaner Production*, *174*, 1366–1380.

Morseletto, P. (2020). Restorative and regenerative: Exploring the concepts in the circular economy. *Journal of Industrial Ecology*, *24*(4), 763–773.

Oliveira, F. R. de, França, S. L. B., & Rangel, L. A. D. (2018). Challenges and opportunities in a circular economy for a local productive arrangement of furniture in Brazil. *Resources, Conservation and Recycling*, *135*, 202–209.

OPTIMA - Verpackungsmaschinen und Abfüllanlagen vom führenden Hersteller. (o. J.). Abgerufen 13. Mai 2023, von https://www.optima-packaging.com/de-de

Ormazabal, M., Prieto-Sandoval, V., Puga-Leal, R., & Jaca, C. (2018). Circular Economy in Spanish SMEs: Challenges and opportunities. *Journal of Cleaner Production*, *185*, 157–167.

Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: Measuring innovation in the product chain. *Planbureau voor de Leefomgeving*, *2544*.

Rais, A. (2018, Dezember 4). *Global development of the mechanical engineering industry*.

https://www.maschinenmarkt.international/global-development-of-the-mechanical-engineering-industry-a-781471/

Ranta, V., Aarikka-Stenroos, L., & Mäkinen, S. J. (2018). Creating value in the circular economy: A structured multiple-case analysis of business models. *Journal of Cleaner Production*, *201*, 988–1000.

R-Cycle. (2023). *Home*. R-Cycle. https://www.r-cycle.org/

Ritzén, S., & Sandström, G. Ö. (2017). Barriers to the Circular Economy – Integration of Perspectives and Domains. *Procedia CIRP*, *64*, 7–12.

Rizos, V., Behrens, A., Van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers. *Sustainability*, *8*(11), Article 11.

Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd ed). SAGE.

Sartal, A., Ozcelik, N., & Rodríguez, M. (2020). Bringing the circular economy closer to small and medium enterprises: Improving water circularity without damaging plant productivity. *Journal of Cleaner Production*, *256*, 120363.

Sauvé, S., Bernard, S., & Sloan, P. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research. *Environmental Development*, *17*, 48–56.

Shahbazi, S., Wiktorsson, M., Kurdve, M., Jönsson, C., & Bjelkemyr, M. (2016). Material efficiency in manufacturing: Swedish evidence on potential, barriers and strategies. *Journal of Cleaner Production*, *127*, 438–450.

Sharma, N. K., Govindan, K., Lai, K. K., Chen, W. K., & Kumar, V. (2021). The transition from linear economy to circular economy for sustainability among SMEs: A study on prospects, impediments, and prerequisites. *Business Strategy and the Environment*, *30*(4), 1803–1822.

Siemieniuch, C. E., Sinclair, M. A., & Henshaw, M. J. deC. (2015). Global drivers, sustainable manufacturing and systems ergonomics. *Applied Ergonomics*, *51*, 104–119.

Simpson, M., Taylor, N., & Barker, K. (2004). Environmental responsibility in SMEs: Does it deliver competitive advantage? *Business Strategy and the Environment*, *13*(3), 156–171.

Smol, M., Kulczycka, J., Henclik, A., Gorazda, K., & Wzorek, Z. (2015). The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. *Journal of Cleaner Production*, *95*, 45–54.

Sohal, A., & De Vass, T. (2022). Australian SME's experience in transitioning to circular economy. *Journal of Business Research*, *142*, 594–604.

Stake, R. E. (2013). *Multiple Case Study Analysis*. Guilford Press.

Statista. (2023). *Themenseite: Maschinenbau*. Statista. https://de.statista.com/themen/256/maschinenbau/

Stewart, H., & Gapp, R. (2014). Achieving Effective Sustainable Management: A Small-

Medium Enterprise Case Study. *Corporate Social Responsibility and Environmental Management*, *21*(1), 52–64.

Takacs, F., Brunner, D., & Frankenberger, K. (2022). Barriers to a circular economy in small- and medium-sized enterprises and their integration in a sustainable strategic management framework. *Journal of Cleaner Production*, *362*, 132227.

Todeschini, B. V., Cortimiglia, M. N., Callegaro-de-Menezes, D., & Ghezzi, A. (2017). Innovative and sustainable business models in the fashion industry: Entrepreneurial drivers, opportunities, and challenges. *Business Horizons*, *60*(6), 759–770.

Trisyulianti, E., Prihartono, B., Andriani, M., & Suryadi, K. (2022). Sustainability Performance Management Framework for Circular Economy Implementation in State-Owned Plantation Enterprises. *Sustainability*, *14*(1), Article 1.

Tserng, H.-P., Chou, C.-M., & Chang, Y.-T. (2021). The Key Strategies to Implement Circular Economy in Building Projects—A Case Study of Taiwan. *Sustainability*, *13*(2), Article 2.

Tukker, A. (2015). Product services for a resource-efficient and circular economy – a review. *Journal of Cleaner Production*, *97*, 76–91.

Company B. (n. D.). Abgerufen 13. Mai 2023, von https://www.uhlmann-group.com/de/

Umwelt Bundesamt. (2021). Die globale Umweltinanspruchnahme des deutschen Maschinenbaus. *www.umweltbundesamt.de/publikationen*. https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/uba_maschinenbau_bf.pdf

van Houten. (2021). *Philips CEO Frans van Houten announces introduction of the PACE Circular Economy Action Agendas*. Philips. https://www.philips.com/a-w/about/news/archive/standard/news/articles/2021/20210203-philips-ceo-frans-van-houten-announces-introduction-of-the-pace-circular-economy-action-agendas.html

van Keulen, M., & Kirchherr, J. (2021). The implementation of the Circular Economy: Barriers and enablers in the coffee value chain. *Journal of Cleaner Production*, *281*, 125033.

VDMA. (2021). *Circular Economy—Vdma.org—VDMA*. https://www.vdma.org/circular-economy

VDMA, & McKinsey. (2022). *Nachhaltigkeit—Chance für den Maschinen- und Anlagenbau in Deutschland*. https://www.mckinsey.com/de/~/media/mckinsey/locations/europe%20and%20middle%20east/deutschland/publikationen/2022-07-21%20maschinenbau%20nachhaltigkeit/mckinsey_vdma_juli%202022.pdf

Whalen, K. A., Milios, L., & Nussholz, J. (2018). Bridging the gap: Barriers and potential for scaling reuse practices in the Swedish ICT sector. *Resources, Conservation and Recycling*, *135*, 123–131.

Wirtschafts Woche. (2023). *Die 500 heimlichen Weltmarktführer 2023*. https://emagazin.wiwo.de/read/186/186/2022-11-07/1#wt_eid=2168536216369500187&wt_t=1685362167103

Yin, R. K. (2017). *Case Study Research and Applications: Design and Methods*. SAGE

Publications.

Zainal, Z. (2007). *Case Study As a Research Method*.

Zhu, Q., & Geng, Y. (2013). Drivers and barriers of extended supply chain practices for energy saving and emission reduction among Chinese manufacturers. *Journal of Cleaner Production*, *40*, 6–12.

Appendix – The coding table

			Cases				
Aggregate levels	**2nd order concept**	**1st order concept**	**Brückner**	**Heller**	**Kampf**	**Company A**	**Company B**
CE strategies		R0 Refuse					
	Smarter product use and manufacture	R1 Rethink	Replacement of plant components/replacements and wear parts the norm - modular machine design.		Modular machines customizable according to customer requirements.	Modular machine design.	Modular machine design.
		R2 Reduce	Developments to reduce energy consumption in operation.	Increase energy efficieny of the machines.	Energy recovery by using the braking energy of the machine.	Driven here primarily by disruptive innovations, i.e. certain redesigns that require less energy or operating resources.	Preconfigured assemblies, up-to-date machine software and components according to the new standard and with lower energy consumption extend the service life while increasing production reliability, machine availability and energy efficiency.
	Extend lifespan of product and ist parts	R3 Reuse	Used maschines can be operated profitably and thus sustainably again by relocating them to other countries. In order to create these various individual and customized solutions, existing plants are inspected on site during special Process & Line Audits.	Relocation of machines.	Repurchase by Ritter company and then sell reconditioned.	Repurchase old machines and resale them afterwards.	Energy monitoring solution.
		R4 Repair	Offering digital service platforms that, for example, provide transparent and secure remote access for service purposes, offer further plant documents, maintenance instructions, or learning videos, or enable ordering requests for spare parts around the clock worldwide. The digital solutions offered also support the customers of the Brückner companies in reducing their energy, water and material consumption as well as emissions, among other things.	Our service is called Retro fit. Customers can have their old machines overhauled by us.	Digital software for better identification of repairs and parts; Service advice and repair recommendations through international field service; Digital spare parts identification and integration of maintenance tutorials into documentation; Web-based customer portal with integrated online store for easy spare parts procurement.	Repair and maintenance as normal services; Service as support over the entire live cycle of the machine.	In which we buy back our machine, our old machines from the customers or take them back and then either upgrade them completely if they are still in good condition and sell them as a rebuild machine, i.e. as a used machine but with new functionalities or just recycle the parts of the machine and install the material in new machine.
		Refurbish	Upgrades extend the life cycle of a machine to more than 30 years.	The topic of energy consumption of our machines is important to us. There are various packages that we sell, some of which are already standard, to make our machines more energy-efficient. We call this HellerBlue and it is simply a product line.	Upgrades of machines with new energy-efficient drives and switchgears; Upgrades of machines for new areas of application in order to transfer them to a further phase of use.	Retrofit/Refurbishment service.	When machines reach age-related performance or safety limits, compatible mechanical rebuilds and electrical upgrades enable an extension of the operating life. Preconfigured assemblies, up-to-date machine software and components according to new standards and with lower energy consumption extend the service life while increasing production reliability, machine availability and energy efficiency.
		R6 Remanufacture	Machies are disassemled into individual parts, cleaned and repaired, and than reassembled into a new machine.	Machies are disassemled into individual parts, cleaned and repaired, and than reassembled into a new machine	In the upgrades area, combat machines are reworked and brought to an optimum state for the required application.	We also offer to take back used machines at the end of their life cycle and give us the parts that we have in the machine, not all components in the machine have the same service life, quite clearly. And that's why we offer to take the machine back and then also reuse components that can be reused.	The complete rebuild. That means we replace all discontinued components. We renew all wear parts. We renew the electronics. The machine is dismantled down to the frame, the frame is repainted and everything is rebuilt.
		R7 Repurpose	Used maschine components are used again.	In which we buy back our machine, our old machines from the customers or take them back and then either upgrade them completely if they are still in good condition and sell them as a rebuild machine, i.e. as a used machine but with new functionalities or just recycle the parts of the machine and install the material in new machine.	Due to the fact that we also have large stocks of old machines, we are flexible to reinstall reconditioned parts from other machines.		In which we buy back our machine, our old machines from the customers or take them back and then either upgrade them completely if they are still in good condition and sell them as a rebuild machine, i.e. as a used machine but with new functionalities or just recycle the parts of the machine and install the material in new machine.
	Useful application of materials	R8 Recycle	Research on the use of recycled materials in film production.				
		R9 Recover	Heat recovery systems that increase raw material efficiancy by recycling the edge trim section into extruders.				

Barriers	**Internal Barriers**	Employees	"Employees who query a lot and regularly are important for the implementation of circular economy. We have grown a lot in recent years and have hired a lot of young people. From them, the topic of sustainability is being pushed more and more."	"The question arose, do we need it? Or what's the point? Those were the standard sayings, and it took time for the employees to accept the topic of sustainability."	"But what is definitely still a challenge is to engage these employees and demonstrate that we need new ideas and that these ideas will mainly come from the employees. And that it is not enough top-down, to propose ideas and develop strategies, but these things have to come from the designer, from the design engineer, they have to come from the product design so that we can really make a difference. And that is still a challenge, to raise that awareness and to create internal communication in terms of sustainability and circular economy and to drive the effect of sustainability and circular economy."	"But what is definitely still a challenge is to engage these employees and demonstrate that we need new ideas and that these ideas will mainly come from the employees. And that it is not enough top-down, to propose ideas and develop strategies, but these things have to come from the designer, from the design engineer, they have to come from the product design so that we can really make a difference. And that is still a challenge, to raise that awareness and to create internal communication in terms of sustainability and circular economy and to drive the effect of sustainability and circular economy."	"There is rejection, especially in mechanical engineering. It is an industry with a relatively high average age of employees who are very, very entrenched in their values."
		Data		"Data is a big problem. As of today, we can't tell how many kilos of steel, how many kilos of which material we used in which machines, we simply don't have the data."	"We lack data on basic things like the exact weighting of materials. We have an ERP system where data is not yet fully maintained so that you can push a button and get all the weights of a machine out."	"A major challenge is data, where we have simply been blind on one or both eyes and have not collected data that is really relevant for sustainability, or have hardly collected any. Of course, this is also due in part to a lack of infrastructure. Such data may not even be collected in the first place, let alone then collected in the second step."	
						"A very simple example is data for component weights. So if you want to know, for example, what kind of CO2 imprint my component has, then I should know, okay, what is its actual weight? How big is it, how much steel is ultimately in this component? And if I don't have this information, then I will have a hard time getting results in this direction, where I can't get results. In the end, I can't control what I can't calculate."	
		Know-how				"Know-how building, of course. We had to build up many of these competencies first. And, of course, building up know-how takes time, a lot of time. But a lot of money is also spent on further training."	"The machines run for 20 to 25 years on average. And then you need experts in house who still knew that machine from back then, because every machine is so individually built and customized that no two machines are ever the same. And you actually need experts in-house who were there 20, 30 years ago, who still know their way around, in order to repair the machine."
		Finance					"Finance was a huge challenge. Because we have to be competitive, but we also didn't want to make it too attractive because then that would not make our new machines very attractive. Yeah. So we were like competing, competing a bit against new Uhlmann machines."
							"I guess pricing was always the main issue, right, where we had to make sure we were very competitive."
		Regulations	"The big problem, which is also in the market, many of our films are also used in the packaging and food sectors. And currently no post-consumer recyclates are approved in the EU to be used again in the food sector. The European Union actually says that it wants to have 30% recycled content in films by 2030, but at the same time prohibits the use of recycled materials because some of them have been poorly recycled or because the purity is not good enough."			"Regulation, which is simply associated with a very, very large amount of bureaucracy and which is already keeping medium-sized companies on their toes, but will also do so in the next few years."	"It is just difficult to cover all the requirements and set up circularly through other departments that don't have expertise in the area and also have a different daily business."
						"There are machine manufacturers who mainly export, there the topic of circular economy has not yet arrived at all, accordingly these companies then also have other legal obligations."	

	External Barriers					"The EU in particular has now set the carbon border adjustment mechanism in motion within the framework of its Green Deal, and it is now being adopted and will actually lead to a sharp upward trend in our purchase prices for components."	
		Customer			"It is difficult to make the employees but also the customers concerned about the topic sustainability or also circular economy especially also about the topic R-Circle."	"The difficulty lies in presenting the price or the costs for non-sustainable action, and that is a difficult argumentation, also with the customer, because it is very difficult to say yes, the topic of sustainability will be associated with increasing costs, but not acting sustainably also so you just have to compare it."	"I think that's the biggest barrier, that you also make it palatable to the customer why it might be worthwhile to sell the machine back to us and not just scrap it or resell it to smaller producers. With less effort."
					So both. On the one hand, saying exactly that to everyone How do you address such a topic with the customer to convince him of it? But who do you also address at the customer? Who deals with these forward-looking topics intensively to find the right contacts to simply there also in turn with multipliers at the customer level?	"We are also often advised against sustainable innovations and changes in the machine by our sales department. Or that sustainable changes to the machine are offered as an option rather than as standard because our customers are not yet willing to pay more. For example, they only see okay, this machine is already expensive, and it will now be 10% more expensive due to sustainable changes. Then it's simply not an option to buy it, even if, for example, these additional costs are amortized within a year through energy efficiency measures on the machine."	
						"At the moment, unfortunately, it is not yet the case that you can pass on these price differences one-to-one...the trade is not yet ready, or the pressure is not yet great enough to get these high prices that you would actually need because the material is more expensive. ... Unfortunately, the consumer is not yet ready to pay 0.20€ more on the shelf because it is sustainable packaging."	
		Spare parts			"Some spare parts for machines are limited, they are only available for 10 to 15 years and then at some point there are no more spare parts. And then there are new parts that you have to use, which unfortunately also mean that you have to completely overhaul and replace more than would actually be necessary."		
		Supply chain				"Sustainability in the supply chain is definitely also a sore point. [...] our leverage for more circularity in our production processes are accordingly limited because we are heavily tied to cooperation in the supply chain. Moreover, if there is neither the know-how, nor the understanding, readiness and the will to act accordingly in terms of sustainability and deal with the issue more, then it is difficult."	

Drivers/Strategies	**Drivers**	Management	“It always all comes out of a long-term strategy. [...] the bottom line is that building circular business models is not well enforceable at any company if the management is not behind it. ... But we are fortunate that our management supports the topic of circular economy and sees the need for it and sees the future as it comes.”	"The corporate management sets the goals, which are then pursued over the year."		“We are really fortunate there and are in this comfortable situation that the topic of sustainability and circular economy is highly valued by the management. Sustainability represents an important pillar in our overall corporate strategy. We have had a new mission statement for a few months now, with these points of vision, mission and strategy, and also sustainability has been added to one of these four essential pillars.”	“It is definitely important, especially with large strategic topics that affect business models or that affect the transformation of the entire company in the direction of circular business models, that it affects several departments, from product management to purchasing, strategy departments, and developments. So it affects quite a few departments in the company, and it is particularly important that there is a consensus from the top, i.e. in the management, and that a decision is made that the topic is relevant.”
		Regulations				"The EU has now set in motion the carbon border adjustment mechanism as part of its Green Deal, which is now being adopted and will actually lead to a strong upward trend in our purchase prices for components, depending on this. How much CO2 is produced in the manufacturing process, for example, if we produce outside of Europe. In this context, it will therefore be interesting for us to look at how our supply chains are actually structured. At what point do they leave the European internal market and where do we source raw steel, for example? - From China? This raises the question of whether we don't want to take a look right now at whether we can perhaps secure European suppliers, i.e., change our supplier structure right now, in order to be prepared from 2026 or 2027 onwards for our prices to rise, but perhaps not to the same extent as would happen now as a result of this mechanism. And that's why it's fair to say that regulations and legislation are also driving us to act and are drivers."	“The main drivers are actually legal obligations.”
		Cooperations & Partnerships	"However, we are active in many cooperative ventures on the subject of sustainability or the circular economy, where we also want to contribute our share, because we don't just see ourselves as machine builders, but also as process developers."		“The introduction of a working group is important in order to be able to talk, discuss and design with each other at eye level, even beyond competitive boundaries. And that is also a very important aspect. Especially in topics like digitalization, sustainability and the circular economy, you simply have to think away from competitive boundaries.”	“We did a joint project GreenLution. That is a recyclable capsule system that is a completely sustainable closed-loop system from production, use to recycling. That is only possible by working with the machine manufacturer to test the films on the machine.”	“A sustainable packaging solution can only be target-oriented for the customer if it can be optimally processed on the packaging machine. This was only achieved through decades of cooperation and development with Etimex.”
			“We work together in consortia, even beyond our cycle. ... We form working groups where we collaborate to look at how products have to be manufactured so that they can be recycled to the maximum afterwards.”		"That's why we have now also decided to continue working in networks, for example in the Innovation Hub of the Technical University of Cologne, simply to find this exchange with companies. It's also important for the VDMA to realize that others have the same questions."		
			“We have a dedicated sustainability department, so that is several people where the circular economy topic is anchored, and they take care of the circular economy area.”		“Especially in the beginning, you need multipliers to push the idea in the company, but of course, it is very important to convince people first.”	"We have set up an internal sustainability department that operates across all groups, but mainly, I would say, intervenes in the consumer market and observes trends there."	“But not only that, just because a decision is made at the top does not mean that it will also reach the departments, but there still needs to be an intermediate area, in our case, the sustainability department, which brings the topic of the circular economy into the departments and also does a bit of change management and trains and enables the departments.”

		Sustainability department				"The sustainability team is basically a bit like a staff unit. In other words, it's not actually part of the classic corporate hierarchy - you can't really assign it to the organizational chart - but rather a more or less independent team that stands on its own and reports to the highest level of management. And that's why we're in this comfortable situation of having a management team for which the topic is also very important and which is also involved in it and doesn't dismiss it as a niche topic or as nice to have, but actually takes it on board as an important strategic process."	
	Strategies	Mission statement & initiatives	"Our own initiative "Yes, we care!" of the Brückner Group is a commitment to our own responsibility in terms of plastics and sustainability, but also a promise to our employees. Everyone wants to act together, develop visions, drive innovations and contribute solutions."			"In the future, the sustainability strategy will be powerfully driven centrally by the entire management team - we are convinced that we can offer our customers real added value in achieving their sustainability goals."	
		Trainings	"So there are various formats that we also run, where these future topics are then also carried out, such as scouting or the future workshop, as we call it. Here, department heads are invited at the appropriate level, but specialists from a wide range of areas are also invited for several days to develop concepts for the future. Be it digitization, be it in the area of sustainability. This is then also carried out together with the company. This is where strategies for the future are derived. Regardless of whether it's digitization or the circular economy. All these trends that are still waiting for us in the future."	"We have trained all employees from the top management to division managers, department managers, to floor employees, sales employees, we have done training, site-wide. We have made our employees aware of sustainability."	"Raw material use, emissions and waste volumes are determined, evaluated and, if possible, optimized. We raise awareness among our employees and encourage personal commitment to environmental protection."		"[...] because the topic is now becoming increasingly important and the employees have also been trained and sensitized to it, you also notice that the departments intrinsically want to tackle the topic on their own."
		Pilot projects			"It is important to approach a topic like the circular economy as a pilot project, that is, to start small."		"The approaches were to focus on a specific machine that is extremely available on the market. So we deliberately chose a machine type where we knew that many customers had this machine and that it was well-established and popular. We will take that one and start with that one, and that is how we got going."

Source: The author