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Circular Economy Practices in the HVAC Industry: Challenges and Opportunities

Master's thesis in Quality and Operations Management

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Abstract

The demand for improved heating, ventilation, and air conditioning (HVAC) systems continues to increase with the population expanding. However, increased usage of HVAC systems entails more energy consumption, and higher amounts of waste in terms of used materials. The aim of this thesis is therefore to explore and assess the opportunities, drivers, and barriers present in the HVAC industry in terms of implementing Circular Economy (CE) practices with the goal of reducing waste and improving sustainability while also positively impacting financial goals.

To begin, information related to both CE and HVAC such as scientific articles, online sources, and government publications was collected. This theoretical knowledge helped to construct the framework of questions for the semi-structured interviews. Responses then served the purpose of the empirical data an analyzed together with theoretical content to formulate a case study.

The results of this thesis report underlines the opportunities for implementing CE practices including circular business models and reverse supply chains. Some circular approaches were found viable to implement in the HVAC industry. The adoption of Product-as-a-Service models would incentivise product life extension and increasing revenues although requiring substantial changes related to the value chain. Reacquiring products to refurbish and resell them would increase revenue per unit at the cost of additional reverse supply chain costs and undetermined willingness to pay. Reacquiring products in order to disassemble them and return components to stock where they can be incorporated into new units and sold as new could drastically reduce material costs and increase profitability as long as incurred additional costs are lower than savings made in reduced material costs.

The study also identifies a number of barriers and drivers considering the reacquisition and refurbishment of the HVAC products. Drivers such as organizational drivers, competitive advantage, product and process development drivers. On the other hand, barriers are subject to raw material selection, lack of resources, cultural barriers, consumers & customer acceptance. The conclusion of the study helps the case company to consider the opportunities, drivers and barriers as mentioned in this report to form the initial foundation towards the step of transitioning to CE.

Keywords: Circular Economy, HVAC Industry, Sustainability, Circular Business Models, Case Study

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List of Abbreviations

Below is a list of abbreviations that have been used throughout this thesis listed in alphabetical order:

BM	Business Model
CBM	Circular Business Model
CE	Circular Economy
CPD	Circular Product Design
CSC	Circular Supply Chain
DER	Distributed Energy Resource
EPD	Environmental Product Declaration
GDP	Gross Domestic Product
HVAC	Heating, Ventilation, and Air Conditioning
IoT	Internet of Things
LCA	Life Cycle Analysis
PaaS	Product-as-a-Service
R&D	Research & Development
RES	Renewable-based Energy Sources
SBM	Sustainable Business Model
SBTI	Science-Based Targets Initiative
SCM	Supply Chain Management
UNSDGs	United Nations Sustainable Development Goals
WTP	Willingness To Pay

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1

Introduction

This section introduces the background of the thesis and articulates the research questions that will be addressed to fulfill the purpose of the thesis. Moreover, the delimitation of the study also outlined below.

1.1 Background

The growing population, technological progress, and lifestyles are all contributing to the increasing demand for heating, ventilation, and air conditioning (HVAC) systems (Asim et al., 2022). HVAC system aims to create a comfortable indoor environment by controlling the temperature, humidity, air quality, and airflow (Firouzfar et al., 2011). Additionally, the HVAC system plays an important role in the comfort and the safety of the indoor air quality (IAQ) (Asim et al., 2022). According to Asim et al. (2022), HVAC usage accounts for 40-60% of the energy consumption in buildings, while Rafique and Rehman (2018) claims that it represents 15% of the world's total energy consumption. Furthermore, researchers Ma et al. (2019) agree that innovation in HVAC systems is essential to create a better, healthier, more productive, and sustainable built environment for building occupants, while also minimizing energy consumption.

Pomeroy (2024) explores the future of the HVAC industry, highlighting a shift towards greater efficiency, innovative business models, and advanced automation. Technology advancements are driving rapid changes in equipment, maintenance protocols, and business models, emphasizing the need for flexibility and innovation. Subscription-based services, IoT integration, automation, and data analysis are reshaping customer service and operational efficiency in the HVAC industry. Overall, the future of HVAC revolves around sustainability, customer-centric services, and smart technology integration to deliver an eco-friendly and efficient air conditioning experience. Hence in the HVAC sector, the recovery, reconditioning, and reuse of refrigerants are of paramount importance, and embracing a Circular Economy (CE) offers a significant advantage by greatly diminishing waste, as materials are diverted away from landfills or other disposal methods (Dall'Ombra, 2024).

Within the context of this research, the definition of CE can be refined to signify that 'CE is treated as a solution to series of challenges such as waste generation, resource scarcity, and sustaining economic benefits' (Lieder & Rashid, 2016). In combination with the issue of CO2-emissions increasing globally, researchers in the 1970s responded to these issues by emphasizing that companies must address ecological problems and the environmental impacts of their activities (Alberto Alcalde-Calonge & Sáez-Martínez, 2022) and the concept of CE was subsequently introduced in 1970s, sparked by the concept of minimizing the use of resources in industrial production (Stahel, 2016).

Although the concept of CE continues to attract both scholars and practitioners, a Scopus query at the end of 2021 retrieved more than 13,000 documents containing the term "circular economy"- approximately 7,800 of these documents (about 60 percent) were published in 2020 or 2021 (Kirchherr et al., 2023). However, research on 'Circular Economy' within 'HVAC' is scarce, with only 15 documents identified until 2024 in Scopus. The identified documents specifically focused on the technical aspects of CE in HVAC systems, such as *Life Cycle Assessment* (LCA) and carbon emissions. However, challenges in the HVAC industry regarding CE also encompass the lack of material efficiency and *Circular Product Design* (CPD) among other practical aspects (Oosting, 2021). Additionally, when it comes to incorporating CE, the HVAC industry tends to focus primarily on energy consumption, often giving less priority to material efficiency. Another significant challenge in the HVAC industry is the supply chain, which is often substantially longer and more complex than in sectors like construction (Oosting, 2021).

CE encourages intelligent product design, maximizes resource efficiency, and fosters product reuse (Van Opstal & Smeets, 2023). Also, Oosting (2021) suggests that achieving a CE necessitates considering additional elements, such as the implementation of a circular business model. Therefore, this thesis explores the opportunities and challenges involved in implementing CE principles within the HVAC industry.

1.2 Purpose & Research Question

Existing research on CE within the HVAC industry lack emphasis on practical aspects of implementing CE practices. The aim of this thesis is therefore to explore and assess the opportunities, drivers, and barriers present in the HVAC industry in terms of implementing Circular Economy practices. To achieve this purpose, the goal is to address the following research questions:

RQ1: How can opportunities for implementing Circular Economy practices in the HVAC industry be assessed, considering factors such as technical feasibility, resource requirements, logistical ability, and alternative business models?

RQ2: What are the drivers and barriers associated with the reclaiming and refurbishment of HVAC products?

1.3 Case Company

The result of this project was achieved through a collaboration with the *Case Company*, a renowned HVAC manufacturer with a proven track record of effectively meeting market and customer demands. The Case Company operates sales and distribution companies primarily throughout Europe, while also maintaining production units in Europe, North America, and India. The Case Company offers a diverse array of products spanning air treatment, room solutions, system optimization, cooling and heating systems, and air distribution solutions. Additionally, the company is committed to delivering high-quality indoor environments through its product lines, aiming to enhance customer satisfaction, productivity, and efficiency.

The company is deliberately focusing on addressing the shifting demands of the world, particularly in areas such as reducing carbon footprint, enhancing waste management practices, and promoting sustainable resource utilization etc. Although the Case Company follows the sustainability goals set by its parent company, it has already established clear sustainability objectives according to the UNSDGs.

As part of its CE efforts, the Case Company has implemented the *"R3 Concept"*, which is based on the fundamental principles of circularity: Reduce, Reuse, and Remanufacture. Building on initiatives such as R3, the company has established a clear vision centered on reducing CO2 emissions, improving product energy efficiency, and extending product life cycles.

As the Case Company's transition to CE is still in its early stages, this thesis and the empirical data gathering mainly concentrates on a specific product, the *EcoVortex* (fictional name), among the various products manufactured by the Case Company. Another reason for narrowing the focus to this product line was that the company recently faced a decision whether or not to reclaim a substantial quantity of these products from a customer. This move was prompted by the customers' properties undergoing renovations, leading them to seek solutions beyond simply discarding the materials as scrap. Consequently, they reached out to the Case Company to coordinate the return process.

1.4 Delimitations

This study confines its scope to the specific domain of HVAC systems and their manufacturers, without considering alternatives to HVAC systems. The outcomes of this research will exclusively offer insights for manufacturers of HVAC systems and will not extend to manufacturers of other systems. The suggested recommendations, upon implementation, will not undergo measurement or evaluation of the outcomes.

This study focuses on the scope of the feasibility, resource, and capability assessment within the HVAC process systems. The study also briefly examines the economic implications of integrating CE. Due to time constraints, the research does not cover the social and environmental aspects of CE. It is important to note that this research presents a basis for a future longitudinal study that allows for the assessment of outcomes resulting from circularity implemented in the HVAC industry.

2

Method

2.1 Research Strategy & Design

The research strategy for this project utilizes inductive reasoning to derive comprehensive insights from a limited sample size (Bell et al., 2019; Clarke & Braun, 2013). Moreover, it prioritizes a qualitative methodology, focusing on analyzing words rather than simply gathering data (Bell et al., 2019). Additionally, the study began with a grounded theory approach, where, as mentioned in Bell et al. (2019), theories are derived from data and then systematically gathered and analyzed throughout the research process.

The study proceeded by employing a case study approach, allowing for a thorough and in-depth analysis of a single case (Bell et al., 2019). Further (Bocken et al., 2016) elaborates that the case study approach is particularly advantageous in conjunction with qualitative methods, such as unstructured interviews, enabling an exhaustive and comprehensive examination of the case. Moreover, a descriptive study approach was undertaken to investigate the current trends (Priya, 2021), particularly in the context of CE, where authors specifically emphasize the HVAC industry.

2.2 Case Study

According to Crowe et al. (2011), the case study method is suitable for gaining comprehensive and nuanced insights into complex issues. Apart from that, among single and multiple case study approaches, single case study approaches are more common among researchers (Priya, 2021). In section 1.3, an overview of the single case company is provided. Additionally, Stake (1995) suggests that employing the instrumental case study approach, which centers on specific and sometimes typical cases, can be highly effective. Therefore, researchers have chosen to narrow down their research scope and focus mainly on a particular product within the HVAC company for their study. However, due to anonymity concerns, the specific product name is also anonymized and the fictional name *EcoVortex* is used instead.

2.3 Data Collection

Kumar (2014) defines the data collection into two categories i.e. primary and secondary sources. Primary data can be collected through observations, interviews, and questionnaires, whereas secondary data sources like published articles and government publications are considered (Kumar, 2014). In this report, secondary data was initially gathered with a broad and open-ended approach to define the research aim. As the project progressed, articles were reviewed and their insights were correlated with the findings from the primary data. This process allowed the scope of the project to be refined and narrowed down. Additionally, as suggested by Myers (2019), the snowball technique was employed, where reading one article led to discovering another related one. Databases like Chalmers Library and Google Scholar were utilized to find relevant literature using the following keywords: *circular economy, circular business models, sustainability, sustainability goals, Supply chain, Reverse supply chain, closed-loop supply chain, barriers in CE, and drivers in CE.*

Additionally, in line with the methodology outlined in Tan et al. (2022) article, it's crucial to note that the terms "drivers" and "barriers" are considered metonyms, generally denoting positive and negative influences, respectively. In this context, synonyms for "drivers" include motives, accelerators, enablers, and opportunities, while accepted synonyms for "barriers" encompass constraints, challenges, and obstacles. Lastly, the primary data was gathered through interviews with respondents.

2.3.1 Primary Data collection

Semi-structured interviews were conducted with the key personnel at the case company to access in-depth knowledge of current processes and practices. The selection of appropriate respondents is conducted through theoretical sampling, a method in which researchers develop comprehensive theories and identify participants based on their anticipated contributions to the concepts and data (Bell et al., 2019). The rationale for employing this theoretical approach arises from acknowledging the integral role of the literature in the thesis, which will inform the formulation of interview questions during the initial stages of research. Appendix A includes a set of questions that was asked to all respondents, generally relating to sustainability and CE at the Case Company. Appendix B contains the complete set of specific questions regarding operations at the Case Company. Respondents were asked a sub-set of these questions depending on which department the respondent belonged to in order to keep the questions relevant to the respondents area of expertise.

Semi-structured interviews were conducted to identify empirical results. Firstly, these interviews were transcribed. After that the transcribed interviews were categorized according to relevant codes. Lastly, with appropriate coding, the empirical topics and literature topics were introduced. Table 2 in Section 4 provides a detailed overview of the data collection process.

2.3.2 Respondents

For this project, 10 in-depth, semi-structured interviews with 10 individual respondents were conducted. The rationale for selecting these respondents was based on the desire to gain a deeper understanding of the current situation within each operational and cooperative department of the Case Company primarily relating to their manufacturing operations. Moreover, to comprehend the current knowledge regarding CE, it was crucial to incorporate the most relevant departments into this particular thesis project. For these reasons, representatives from administrative departments such as Human Relations (HR) were not included in the empirical data gathering.

The respondents were selected by sending emails to individuals working in departments such as Sales & Marketing, Production, R& D, Logistics, Business Development, Project Management, and Sustainability. Before the beginning of the interview, all respondents were informed about the anonymity of the process, a detail also communicated in prior email communication. Table 1 lists the individuals who agreed to participate in the interviews.

Table 1: List of Respondents

Respondent	**Department**	**Title**
A	Business Development	Director
B	Product Management	Manager
C	R&D	Manager
D	Purchasing	Manager
E	Production & Quality	Director
F	Sustainability Expert	Manager
G	Sustainability Expert	Manager
H	Sales & Marketing	Engineer
I	Sales & Marketing	Engineer
J	Logistics	Manager

2.3.3 Background of Respondents

This section specifies the roles of all ten respondents based on their respective responsibilities in further detail. These interviews are considered as empirical data for this thesis project.

Respondent A: Respondent A has five years of experience in business development and currently hold the position of **Business Director** at the Case Company.

Respondent B: Respondent B works at the Case Company as a **Product Manager**, bringing seven years of experience in project management and application engineering. Additionally, the respondent is well-versed in the organization's current processes and product line.

Respondent C: The respondent works as a **Product Development Manager** specializing in creating products related to ventilation, air quality, and both hot and cold water systems. For example, the respondent and the team focus on developing chill beams and comfort modules for office spaces.

Respondent D: As a **Purchasing Manager**, Respondent D is tasked with sourcing the necessary direct materials for operations. Furthermore, the respondent is responsible for sourcing new suppliers, maintaining strong relationships with existing ones, and developing current ones.

Respondent E: The respondent holds the position of **Operations Director** for Northern Europe in the Case Company, managing several factories situated across Sweden. Previously, they occupied the role of Operations Manager within the same organization.

Respondent F: The respondent is a **Business Development Manager** specializing in sustainable business approaches and CE initiatives within their organization. They possess extensive knowledge of current operations and management practices.

Respondent G: The respondent is the pioneer of sustainability in the Case Company, having initiated sustainability initiatives four years ago. Currently, the respondent holds the position of **Sustainability Manager** in the Case Company, focusing specifically on strategic sustainability and life cycle analysis, considering both internal and external factors.

Respondent H: The respondent works in **sales** at the Case Company.

Respondent I: The respondent works in sales, primarily focusing on **Technical Advisory** and **Marketing** roles.

Respondent J: The respondent works as a **Logistics Manager** at the Case Company, overseeing a team of nine employees including engineers and blue-collar workers. The team is responsible for both internal and external material handling operations.

2.4 Data Analysis

In the analysis phase of this research, the thematic analysis framework proposed by Bell et al. (2019) was adopted. Additionally, the main features, processes, and outcomes from the semi-structured interviews were examined to present the analysis (Bell et al., 2019). During data collection and analysis, the themes that Ryan and Bernard (2003) have outlined in their research, such as repetition, categorization, metaphors, analogies, transitions, and comparisons of similarities and differences were incorporated. To get this data, semi-structured interviews initially being recorded. Later on, the recorded interviews were then transcribed to serve the purpose of coding. Insights obtained from the secondary data collection in terms of research articles served as the foundation for developing a framework of questions to base the semi-structured interviews in. These interviews in combination with additional insights obtained from the secondary data collection later facilitated the construction of the research analysis.

2.5 Research Quality

As per Bell et al. (2019), trustworthiness is important in qualitative research which can be described through four aspects such as credibility, transferability, dependability, and confirmability.

2.5.1 Credibility

According to Bell et al. (2019), uncertain writing lacks the power to persuade readers and it is important to convince all readers of the credibility of the authors' knowledge claims. Triangulation methods within credibility blend well with the qualitative research strategy in observations and interviews to analyze the view of the respondents (Bell et al., 2019). Hence, during the interviews, the authors formulated questions to confirm and validate the respondents' perspectives and ensure they were correctly understood by the authors.

2.5.2 Transferability

Transferability focuses on the research findings and the extent to which those findings are useful in other contexts and to other researchers (Bell et al., 2019). As suggested by Bell et al. (2019), the authors included a rich amount of details and information that could be valuable to other researchers. However, the findings of this study may not be generalizable, as it focuses specifically on HVAC manufacturing operations and processes.

2.5.3 Dependability

According to Bell et al. (2019), dependability involves the auditing approach where authors of the research keep a record of each phase of the research process in terms of notes, transcription, data analysis, and the decision. In this thesis, the authors included detailed information on all necessary activities to ensure robust dependability, such as the timing of the interviews, interview transcripts, documents, and data from the case company.

2.5.4 Confirmability

Confirmability refers to ensuring the complete objectivity of the research (Bell et al., 2019). Bell et al. (2019) also mentioned that individuals should not allow personal values or theoretical inclinations to influence the conduct of the research. To promote confirmability and avoid personal inclinations, all interviews were conducted by both authors. The recorded interviews were listened to multiple times to accurately understand the respondents' statements, which helped establish the empirical results and conclude the analysis part of the thesis.

2.6 Ethical Consideration

Bhandari (2021) emphasized the significance of ethical considerations in research, a principle embraced by the authors involved in this thesis project. To maintain confidentiality with the Case Company and individual respondents, a method was employed wherein the authors were aware of the identity of individual respondents but ensured respondents that this information would be excluded from the report. To hide the identity of respondents in the report, each respondent was labeled A-J with only a brief description of their background. The names of the company and its products are also excluded from the report, *Case Company* and *EcoVortex* are used instead.

As noted by Kacena et al. (2024), using AI tools in research articles can enhance vocabulary, grammar, and writing style. These tools are not only beneficial for improving the quality of writing but also help researchers save time. Therefore, in accordance with Chalmers University of Technology (2024) guidelines, AI tools were specifically and *exclusively* utilized to improve the vocabulary and grammar. AI was in no way used to rewrite or synthesize any text in the report but rather to ensure that the content is clear and well-structured while maintaining the focus on high-quality writing. Any grammatical or vocabulary suggestions were critically reviewed as to not allows for alternative interpretations from what the authors of the thesis intended.

3

Theory

This section presents the theoretical findings derived from the grounded theory approach applied to the topics, identified during data collection through semi-structured interviews.

3.1 The Circular Economy Concept

The origin of the circular economy concept can be traced back to the 1970's when Stahel and Reday-Mulvey (1981) in a research paper from 1976 that sought to describe strategies for waste prevention and resource efficiency conceptualized a loop economy (Geissdoerfer et al., 2017). Products in this loop economy were described as being part of a reconditioning loop and recycling loop in which products and materials circulated before reaching end-of-life disposal (Stahel & Reday-Mulvey, 1981). The modern interpretation of a circular economy has later been framed by using the antonym term linear economy as the description of a traditional economy to contrast the core differences between the two concepts (Murray et al., 2017). In terms of adoption and implementation throughout global economies, it is China that has taken the lead with Western economies gradually accepting and adopting the theoretical concept through businesses and European policymakers taking action in an effort to maximize the economic use of resources (Murray et al., 2017).

A puritanical interpretation of CE is an economy that has no net negative effect on the environment, rather it restores environmental damage done in the acquisition of resources while also generating as little waste as possible for the entire life cycle of the product (Murray et al., 2017). An optimal implementation of CE emulates a process similar to that of what occurs in our natural environment, where almost nothing is wasted as almost all would-be-waste is eventually recuperated by other species (Sauvé et al., 2016). Additionally, Homrich et al. (2018) defines CE as follows: "CE is a strategy that emerges to oppose the traditional open-ended system, aiming to face the challenge of resource scarcity and waste disposal in a win-win approach with economic and value perspective".

To achieve this win-win condition CE aspires to decouple economic prosperity from the consumption of virgin resources and proposes a system that provides a substitute to this in the form of reuse and recycling (Sauvé et al., 2016). In practice, a model of production based on CE may attempt to increase the useful life of the product, favor the ability to reuse, repair, and refurbish it as well as allow for it to be effectively recycled at its end-of-life (Sauvé et al., 2016). In order for CE to move past being a mere preventative approach of reducing pollution and in order to also achieve the desired restorative effect, the design of the systems within the entity of the industry itself need to be reimagined (Murray et al., 2017). In order for an industry to operate with no net negative impact on the environment, biomimetic approaches may be utilized where the processes and system design of the industry can be informed by that of natural systems. By emulating natural environments where competition and cooperation between species provides the flexibility and adaptability needed to maintain resource efficiency within the ecosystem, economic systems can also ensure healthy competition and high resource efficiency (Sauvé et al., 2016). In this interpretation, CE focuses on optimizing the entire structure of an industry, achieving value from redesign rather than solely focusing on improving resource utilization among the constituent businesses of the industry. By altering the design of a product to make it easier to take apart, implementing a reverse logistics cycle, and offering incentives to return the products for example, the cost of remanufacturing could be greatly decreased. This lowers the associated labor and energy costs as well as reduces emissions throughout the entire supply chain as a result of the reduced need for material inputs (Murray et al., 2017). The term circular economy thus encompasses all activities aimed at reducing, reusing, and recycling materials throughout production, distribution, and consumption processes as well as activities aimed at facilitating such initiatives within an industry (Murray et al., 2017).

3.1.1 Linear Vs Circular Economy

A circular economy is fundamentally different from that of a linear economy in which resources are extracted to produce a product that eventually gets consumed and discarded at the end of its useful life cycle (Sauvé et al., 2016). Figure 1 illustrates the core differences between the two concepts. At each step of the linear process additional pollutants and waste is generated which ends up contaminating our environment (Sauvé et al., 2016). Murray et al. (2017) mentions how most environmental problems stem from the same systematic error of linearly processing finite materials and that until a transition to cyclical processing of resources is made, public health and the global economy will continue to deteriorate. A circular approach thus aims to replace the linear model and reduce waste through emphasis on long lasting and repairable products that can be disassembled and recycled (Sauvé et al., 2016). By utilizing closed reuse and recycle loops, greater material and energy efficiency can be achieved by minimizing the input of virgin materials and output of waste (Homrich et al., 2018). While sustainable practices within a linear production model might also emphasize waste reduction and recycling of products, the lack of value chains in place to take advantage of recuperated products as raw materials in new production often lead to these products and materials being discarded anyway as manufacturing processes of today favor the use of virgin resources (Sauvé et al., 2016).

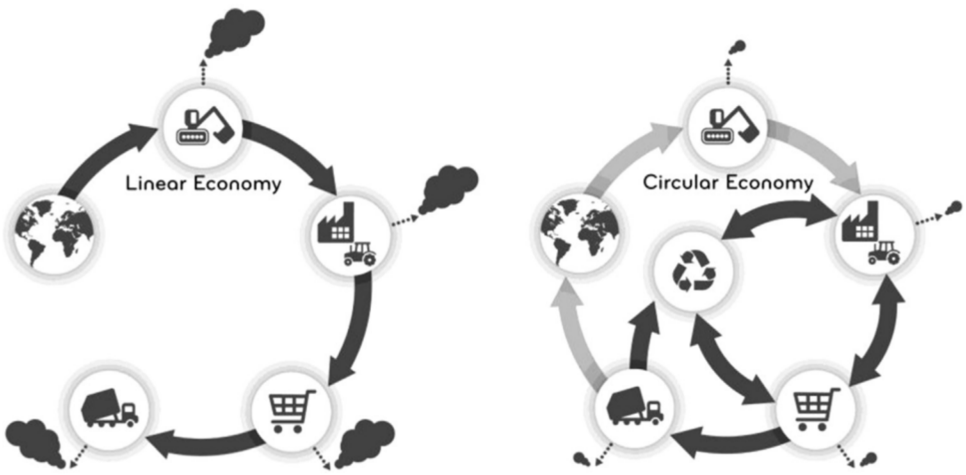

Figure 1: Linear and circular economy concept (Sauvé et al., 2016).

3.1.2 Sustainability and Circular Economy

A multitude of conceptual interpretations regarding both the CE and sustainability are evident in the literature dedicated to the circular economy (Walker et al., 2021). The concept of CE enhances the relatability of sustainability to environmental aspects (Geissdoerfer et al., 2018; Rigamonti & Mancini, 2021; Sauvé et al., 2016). Furthermore, Bocken et al. (2014) recognized circularity as one paradigm of sustainable business models, alongside others. In essence, sustainability and CE pursue distinct ultimate goals. Sustainability aims to achieve a balance across environmental, social, and economic dimensions (Hansmann et al., 2012). In contrast, the focus of CE is primarily on transforming the economic system into one that is more renewable and efficient in its use of bio-resources which involves the closure of materials and energy loops (Mancini & Raggi, 2021). The study by Walker et al. (2021) demonstrates that in industrial practices, promoting CE is advocated as a means to drive sustainability as is depicted in Figure 2. However, CE approaches have helped alleviate (reduce) global sustainability pressures (Bocken et al., 2016).

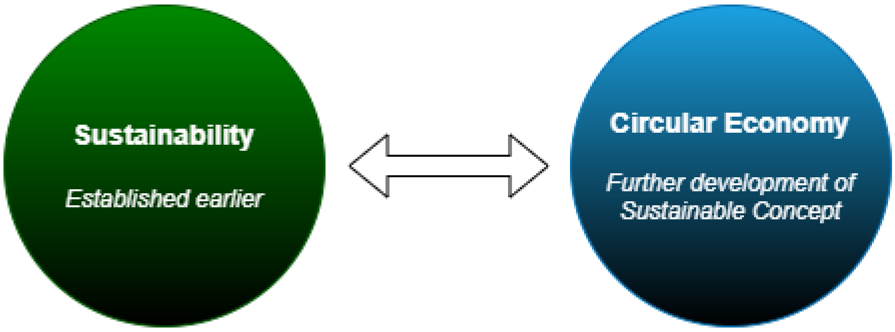

Figure 2: Perspective of Sustainability and Circular Economy by Walker et al. (2021)

The correlation between CE and sustainable development becomes more transparent when examining the Sustainable Development Goals (SDGs) targets, as CE practices have the potential to contribute significantly to achieving these targets (Schroeder et al., 2019). According to Schroeder et al. (2019), the Sustainable Development Goals 6 (Clean Water and Sanitation), 7 (Affordable and Clean Energy), 8 (Decent Work and Economic Growth), 12 (Responsible Consumption and Production), and 15 (Life on Land) are identified to have the strongest relationship with Circular Economy practices. Nevertheless, the study by Schroeder et al. (2019) also concurs that goals 3 (Good health and well-being), 4 (Quality Education), 5 (Gender equality), 10 (Reduced inequalities), and 16 (Peace, justice, and strong institutions) demonstrate a weak or negligible relationship with CE practices.

In Conclusion, Research studies offer evidence suggesting a symmetrical relationship between sustainable practices and CE (Sehnem et al., 2019). However, Sehnem et al. (2019) also acknowledge the potential for further advancements and opportunities in both areas.

3.2 The Circular Business Model (CBM)

Nußholz (2017) provides a definition of the circular business model as follows:

> A circular business model is how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending the useful life of products

and parts (e.g., through long-life design, repair, and remanufacturing) and closing material loops.

According to Geissdoerfer et al. (2018), the transition from a traditional business model (BM) towards a circular business model (CBM) involves a fundamental shift in organizational processes, strategies, and value propositions to embrace circularity principles and promote sustainability throughout the business ecosystem. In Figure 3, it is depicted that CBMs fall under the category of Sustainable business models, emphasizing value creation through stakeholder management and long-term goal consideration.

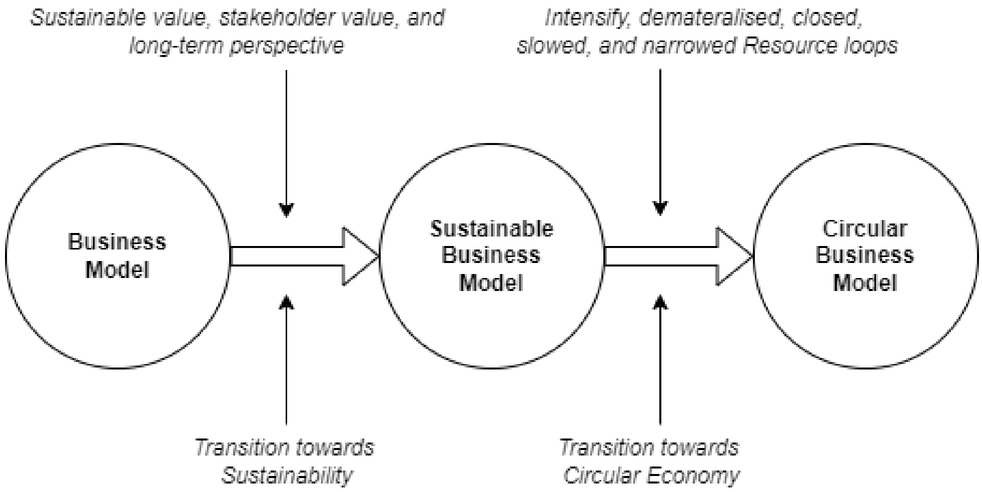

Figure 3: Transition from traditional business model towards the circular business model by Geissdoerfer et al. (2018)

Homrich et al. (2018) also mentions how changing to a CE demands changes in areas such as product design, manufacturing processes, and supply chain management approaches. They emphasize the adoption of circular supply chain management as this is a crucial part in enabling the closing of the loop to form a circular CE. Product life cycle thinking is furthermore mentioned as a fundamental approach to be adopted in order to make appropriate changes to manufacturing processes and product design that enables possibility of disassembly and reuse (Homrich et al., 2018). Stahel (2016) categorizes CBMs in two groups: those that promote reuse and increase the useful lifetime of the product through repairability, upgrading, or remanufacturing; and those that produce new products with recycled materials. Designing products for reuse by utilizing modular systems and standardized components is a major key to enable a CE according to Stahel (2016) further emphasizing the importance of product design when undertaking CE initiatives.

3.2.1 CBM Framework: Product as a Service, Product Life Extension, Circular Product Design

A revenue model enables the capture of revenue based on the value that the business model provides (Parida & Frishammar, 2024) The revenue model therefore plays an important role in allowing businesses to recuperate the costs associated with implementing CBMs (Parida & Frishammar, 2024). As industrial firms have been experimenting with different models, the *product-as-a-service (PaaS)* approach has risen in popularity. With this approach, revenue is captured through customers paying for the usage of a product rather than by taking ownership of the physical product itself. Using a PaaS model also incentivizes industrial firms to extend product life cycles as they retain ownership of the products (Parida & Frishammar, 2024). Geissdoerfer et al. (2017) points out that Stahel as early as 1982 emphasized utilization as the most relevant model for a CE as opposed to ownership of goods. This is because such a model would allow for businesses to profit while the costs and risks associated with waste are internalized and passed on to the customers through appropriate pricing. With changing to a model based on the usage or functionality of a product comes the need to inform and re-orient customer thinking so that they become aware and see the benefits in this new way of satisfying their needs where they no longer need to be concerned with maintenance, ensuring performance, or with replacement of the goods (Sauvé et al., 2016).

The *product life extension* circular business model focuses on prolonging the life cycle of a product or asset by repairing, upgrading, refurbishing, and remanufacturing (Golsteijn, 2022). Additionally, this model supports the intermediate phase of a product's lifecycle within the context of a PaaS model (Khan et al., 2018). According to Khan et al. (2018), extending the lifespan of products is advantageous for reducing environmental impact. A study by the European Commission shows that a 1% increase in value added from activities related to extending product lifetimes could generate an additional 7.9 billion EUR annually for the European economy (Rietveld, 2016). The research study conducted by (Whalen, 2020) mentions that a significant portion of existing research concerning firms and their adoption of product life extension strategies has concentrated on remanufacturing and OEMs (original equipment manufacturers). However, as highlighted in the article by Khan et al. (2018), a major barrier to this model is the perception that product life extension strategies diminish the manufacturer's opportunity to increase sales of new products.

Another essential step to implementing CE effectively is *Circular Product Design (CPD)* (Aguiar et al., 2021). Indeed, Cayzer et al. (2017) explains various strategies to enhance product circularity, including modularization, remanufacturing, reuse, and the design of products with few materials. The primary objective of CPD is to eliminate waste by removing unnecessary elements that consume significant materials or generate waste (Stretton, 2023). The World Without Waste initiative by Coca-Cola is a prominent example of CPD implementation (Courie, 2023). According to the World Without Waste (2021) report from Coca-Cola, the company aims to design 100% of its product packaging circular by 2025, where, the company has achieved a commendable 90% contribution towards this goal.

3.3 Reverse Supply Chain

In the article by Antikainen and Valkokari (2016), two types of *closed-loop supply chains* are discussed: forward and reverse chains. The article elaborates that in the reverse chain, returned products are reintegrated into the forward chain through business models that offer solutions and services. Jayaraman and Luo (2007) suggests that viewing reverse logistics as a competitive advantage can contrast with the traditional approach of many companies, which is to simply disregard returned products. Implementing reverse logistics successfully can lead to profitability through reduced materials usage, while also enhancing a company's environmental reputation in the market (Jayaraman & Luo, 2007). However, Jayaraman and Luo (2007) also mentioned the uncertainty in the supply of returned products regarding timing, quality, and quantity. The article also proposes that engaging in remanufacturing activities through reverse logistics proves to be cost-effective. According to Parker et al. (2015), the adoption of remanufacturing practices offers substantial benefits, particularly within service-oriented business models, as they prioritize product services over traditional make-sell models, thereby promoting remanufacturing as a sustainable alternative to product replacement. However, studies also indicate that reverse logistics costs, particularly for transporting large and bulky items, can pose significant challenges. These costs could deter the remanufacturing of certain products or render it financially unfeasible, especially in sparsely populated areas.

Remanufacturing of products involves processes such as inspection, cleaning, disassembly, reprocessing, reassembly, testing, and storage (Kurilova-Palisaitiene & Sundin, 2014). Furthermore, Sundin (2006) drew some conclusions while studying the remanufacturing process across different companies: *(1)* The quantity and flow of received materials are uncertain and unpredictable. *(2)* Cleaning, reprocessing, and inspections are also critical steps found in most companies handling the remanufacturing process. *(3)* Due to the remanufacturing of products, half-finished items in storage require significant space and capital while waiting for customer orders. Research by Parker et al. (2015) also concurs that storing large volumes of reused components represents a significant expense in remanufacturing processes. However, the study also agrees that space in the facilities is often not used efficiently. Additionally, high levels of inventory accumulate due to incomplete spare parts or products that have not yet found a customer (Sundin, 2006). These issues could be addressed by adopting effective designs for remanufacturing and implementing efficient functional sales strategies (Sundin, 2006).

3.4 Drivers to Circular Economy Adoption

Transitioning to a CE effectively aligns with achieving the Sustainable Development Goals, meeting the targets in the Paris Climate Agreement, and advancing the aim to achieve carbon neutrality by 2050 (EEA-ETC, 2021; PA, 2015; United Nations, 2015). Furthermore, these supportive measures such as legislation and policies alleviate the financial burden on businesses and assist stakeholders in transitioning to a Circular Economy (Tan et al., 2022). Achieving this transition hinges on reducing resource consumption while emphasizing the importance of material reuse, repair, and recycling (EEA-ETC, 2021). The central concept of CE revolves around establishing a system where materials, products, and components are utilized to their fullest potential, creating a closed loop of resource utilization (Donner et al., 2020; Geissdoerfer et al., 2018; Parida & Frishammar, 2024). Hence, a CE undoubtedly helps to emphasize environmental factors by effectively addressing waste generation through the reuse and recycling of materials (Neves & Marques, 2022).

The transition to a circular economy contributes to various environmental aspects, including the reduction of climate change impact, ecosystem degradation, and the development of natural capital (de Jesus & Mendonça, 2018; Interreg Europe, n.d.). The extraction and dumping of raw materials have a negative impact on natural reserves, prompting primarily governmental organizations to protect nature from such activities, a goal that can be achieved through transitioning to a circular economy (Berg et al., 2019). Reducing energy consumption and CO2 emissions also becomes a significant impact after the implementation of a circular economy (Andrew Llanwarne, 2016).

While implementing CE within a business or company can pose challenges and require significant time and resources, its adoption follows numerous benefits across economic dimensions, where these benefits encompass factors such as company growth, revenue generation, and job creation (Postan, 2021). Furthermore, stakeholders play a pivotal role as drivers in the transition to a Circular Economy by adopting a long-term perspective and pursuing complementary strategies. Govindan and Hasanagic (2018) article also concurs that integrating Circular Economy practices into the supply chain, such as recycling and remanufacturing, can aid organizations in achieving long-term revenue generation.

3.5 Barriers to Circular Economy Adoption

One of the main barriers of a CE is the unfavorable economic relationship between manufacturing durable, longer-lasting products rather than making lower quality, disposable products (Sauvé et al., 2016). As durable and longer-lasting products tend to be more costly, it disincentives the manufacturing of them which makes for a less resource efficient economy. This stems from the fact that the benefit of choosing to produce the cheaper alternative is private, meaning it is advantageous for the manufacturer, while the environmental cost is public, meaning customers and the general public has to deal with the consequences (Sauvé et al., 2016). The CE must therefore provide economic incentives where the environmental costs are internalized and integrated into the price that consumers pay. In addition to this, using long-lasting materials will likely make it more difficult and expensive to break them down once the product's useful life has ended and the materials need to be circulated leading to a more energy-intensive process (Murray et al., 2017). Stahel (2016) further mentions how "creating wealth by making things last is the opposite of what they [economists focusing on GDP] learned in school". As a CE conserves physical stocks it undermines the use of GDP as a measure of economic prosperity since it measures financial flow over a period of time, i.e. the consumption of goods and services. Increased environmental consciousness may come to shift society's view of materials as resources to be preserved rather than consumed (Stahel, 2016).

According to Kirchherr et al. (2018), two core cultural barriers identified in their study are a lack of 'customer interest and awareness', as well as a 'hesitant company culture'. Developing and selecting an appropriate revenue model is something that needs to be done carefully while taking one's operational processes into consideration. Selecting a revenue model that inappropriately pairs with the business operations may otherwise cause serious problems (Parida & Frishammar, 2024). A crucial part of developing a revenue model for a circular offering is the assessment of the customer's willingness to pay (WTP). Incorrectly differentiating whether the need for a circular offering stems from customer demand or provider-driven motives may lead to unprofitable revenue models as the actual WTP will be skewed compared to the expectations of the industrial firm (Parida & Frishammar, 2024).

The prevailing linear production system within the company contributes to cultural factors, limiting the implementation of CE practices within the organization (Hartley et al., 2022). Furthermore, the study conducted by Kirchherr et al. (2018) indicates that while companies may opt to transition to a CE model, this decision doesn't necessarily reflect the willingness of the entire supply chain to embrace it. Additionally, Kirchherr et al. (2017) discovered that interviewees frequently identified company culture as a barrier, resembling a mindset issue within the organization. However, Barros et al. (2021) emphasizes that organizations need to integrate circular behaviors within their culture, as culture plays a critical role when considering the transition to a CE.

In a status report of the Nordic manufacturing industry, Nordic Innovation (2023) divides identified barriers for implementing CBMs into four categories (numbered 1-4). They go on to mention that barriers related to *people and culture (1)* include the challenge of customer adaptation in trying to shift to a CBM. Companies that struggle with customer adaptation tend to have difficulty promoting the right value of the new product and service offerings. Shifting to an as-a-service business model when customers are used to owning the product will require a new commercial logic to be followed which will disrupt the already established processes within the ecosystem (Parida & Frishammar, 2024). The second category, *collaborations (2)*, signifies the importance of developing partnerships and networks in order to properly establish a circular business model (Nordic Innovation, 2023). The need to share potentially sensitive data and formulate mutually beneficial partnerships can make for an unstable partnership as businesses naturally want to keep their trade secrets secret and maximize their yield of return. In addition, the collaborative networks necessary for service customization and co-creating value with customers take time to be developed, which may lead to less than ideal solutions being formulated in the short term (Parida & Frishammar, 2024).

Financing (3) is another barrier category prevalent in CE initiatives according to Nordic Innovation (2023). Due to increased short-term costs when undertaking a circular business model, economies of scale are often required to make it a profitable initiative. Hesitation from management may lead to insufficient funding being allocated towards pursuing circular pilot projects. This, in combination with a limited amount of resources that other projects are competing for internally generally makes it difficult for CE initiatives to continue from the pilot stage. Making the necessary investments increases the price of the circular offerings, making them less appealing to customers (Parida & Frishammar, 2024). This emphasizes the need of properly be able to convey the additional environmental benefits of circular offerings. The last category involves *regulations (4)*, specifically the lack of regulations to incentivize and drive the transition to a more circular economy. Companies included in the study by Nordic Innovation (2023) mentioned how regulations have the ability to strongly influence businesses to adjust and when regulations are unclear or not in place they instead become barriers to change.

4

Empirical Result

For the empirical results in this report, data was collected through semi-structured interviews. These interviews were organised based on category codes, literature topic, and empirical topics, as illustrated in Table 2.

Table 2: Category coding, literature, and empirical topics based on the interview findings.

Category code	Literature Topic	Empirical Topic
Operations	Circular economy concept, Circular business model, Linear business model	Linear practices in current model, Reverse supply chain
Drivers	Long-term business perspective, competitive advantage, regulatory benefits	Motivation for adopting circular model, Organisational driver, Regulatory targets, product and process development, environmental consideration
Barriers	Remanufacturing, Product design, Lack of resources, Supply chain, internal stakeholders, consumer acceptance	Challenges in transitioning to CE, Cultural barrier, financial constraint, Consumers and customer acceptance

4.1 Current state of operations

This section will describe and give insights into the current state of operations at the Case Company as told by interviewees employed at various roles in the company. The findings are intended to not only document the current state of operations but also to be used as a basis for analyzing feasibility of adopting CE practices in the HVAC industry, aligning with the broader research objectives of the thesis.

With the Case Company being a manufacturer of HVAC products, to get an idea of how they operate it makes sense to follow the flow of materials in and out of their operations. Respondent D, the Purchasing manager explains how the process begins as follows:

> It all starts with receiving orders from customers. Then our system calculates the components needed for operations. Our owner manages ordering from suppliers, ensuring minimum quantities are met. When goods arrive at our factory, they're scanned into stock before being sent to production. It's a streamlined process.

Other respondents echoed this sentiment of having a so-called make-to-order approach for their manufacturing operations. Though many parts are maintained in stock in order to maintain "efficient production processes" (Respondent A) and because "most of the components are the same for all products that we produce" (Respondent D). Respondent E, the Operations Director mentions that:

> For unique parts like special hoses, we order exactly what's included in the customer order. But for general electronics, valves, activators, etc., we maintain a stock in the factory[...]We rely on historical data and forecasts to ensure we have the necessary components on hand to meet anticipated demand.

Respondent J, the Logistics Manager goes on to explain that "our suppliers need to adhere to fixed lead times, but there's often a big variation in order intake. Sometimes, suppliers can't deliver as planned, requiring us to reschedule orders." Though oftentimes they receive early notifications about delays from their suppliers "allowing us to inform customers and re-plan installations accordingly". When it comes to the geographic distribution of suppliers where materials and components are sourced from, Respondent D informs that "most of the suppliers are located in Sweden. And the rest are located in Europe."

Manufacturing begins when customer orders have been received and material is available in the factory. Respondent E goes on to explain that for simpler products, like attenuators (units that minimize sound that travels through the ducts of an HVAC system and consists of less than 10 components), sheet metal is first manipulated by machines that cut, punch, and bend it into the correct form. Sound dampening material is then added, before everything is secured with pop rivets or screws. The finished product is then carefully wrapped and placed on a pallet to be picked up for delivery.

For one of their more advanced products, an in-room climate control unit here given the fictional name of EcoVortex, the process starts in a similar manner where the sheet metal is first bent, punched, and cut into the desired shape. Components are assembled using various methods like pressing, riveting, or screws making for a durable product but difficult to disassemble. Additional components like heat exchangers, valves, and electronics are added before the product is packed into cardboard boxes and put onto wooden pallets. When asked about assembly time and number of operators required to manufacture an EcoVortex unit, Respondent E explains that:

> The final assembly of an EcoVortex unit, on average, takes about 45 minutes. Adding machining and bending times, it totals to about one hour per unit. The punch machines have one operator running two machines, with very high capacity, requiring only seconds of operator time per product. Bending is done by one operator, taking only a couple of minutes. On the EcoVortex line itself, there are usually five operators. The total assembly time of 45 minutes is divided among these operators.

Respondent D provided a breakdown of some of the costs for the EcoVortex as percentages of the total production cost (per unit) as can be seen in Table 3. The table shows a breakdown of the costs as a percentage of the *total production cost* (per unit) for the EcoVortex. Distribution cost and consumer price is also shown as a percentage of production cost. The table shows clearly that most of the production cost comes from materials (73% of total production cost) and that just a few types of critical components make up most (62% of total production cost) of the production cost for this type of product.

Table 3: Breakdown of costs as percentage of total production cost (per unit) for the EcoVortex.

Cost category	Percentage
Standard components	11%
Critical components:	*62%*
Heat exchanger	16%
Sheet metal parts	16%
Electronic components	30%
Total Material cost	73%
Production/Assembly	27%
Total production cost	**100%**
Distribution cost	8%
Consumer price	160-180%

When it comes to quality, rather than having a final quality control step for each unit at the end of the line, Respondent E explains that "Quality assurance is integrated into the assembly process itself starting from the design phase to ensure products are designed for assembly and quality." Quality is ensured at each station throughout the production flow and "...if we detect quality issues during operations, we halt production and address the problem." (Respondent D).

When the final products have been put in packaging or loaded onto pallets they are ready to be distributed to the customers. The Case Company utilizes third-party transport companies for their distribution as "...we don't have our own transport company." (Respondent J). To keep transport costs down they "... choose [transport company] based on price or quality. We also optimize loading on the truck and have developed packaging for each product to fit best for transportation." (Respondent D). Respondent J further explains regarding the packaging that "We don't have a system to retrieve pallets; we use special-sized pallets for our products, which are not reused." If something is damaged during transport, the quality team receives a claim and makes a decision on whether to replace the damaged product. Once the products reach the customers the Case Company does not handle the installation. Respondent G explains that "Installation services are primarily handled by entrepreneurs. We do not have capabilities in-house for installation." although Respondent A also mentions that "Some installers are trained by us, while others have their own experienced professionals. We also provide detailed manuals and technical specifications to guide the installation process." Respondent H clarifies that "During the warranty period, which is typically five years, we provide support to entrepreneurs for maintenance. After that, maintenance is typically outsourced to external firms, and we provide support as needed." When it is time for the products to be removed it is done by the installers themselves or a demolition crew without any involvement from the Case Company.

When asked to describe the sales process and transfer of ownership, Respondent I emphasizes the distinction between the customer and buyer "While our immediate customer is always the entrepreneur, in reality, it's often the real estate owner who acts as the buyer." The entrepreneur initially becomes the owner after the sale, Respondent I goes on to explain that "The entrepreneur then resells the products to the real estate owner. So, the ownership transfers from the entrepreneur initially to the real estate owner once the products are installed." The Case Company thus never sells products directly to the owner of the real estate in which the products will be installed. When selling directly to companies hired by the real estate owner to install the HVAC products, after-sale communication with either the customer or owner is essentially limited to maintenance and warranty matters for the duration of the warranty period. The Case Company also sells products to retailers and wholesalers, in this case, after-sale communication is virtually non-existent. Respondent A explicitly states that “communication with end users can sometimes be challenging to establish” and that as a result “we are uncertain about the total number of products in circulation” though for some more advanced products that are equipped with an IoT-solution, tracking is possible.

4.2 Why transition to a Circular Economy?

Considering most of the interviews, Respondents have a clear understanding of the importance of transitioning to CE. Respondent A, the Business Director at the Case Company, states that ” ...first of all, it’s the right thing to do.” Respondent A means to say that leading toward sustainable solutions is beneficial. Respondent D, the Purchasing Manager at the Case Company matches the vision towards being more sustainable or circular. Respondent D states, ”...making the world a better place and lowering the CO2 emission.” Additionally, Respondent B, the Product manager, sees transitioning to CE would be beneficial for the company to satisfy customer requirements, the Respondent states that ” *Case Company* has always been a value-driven company. And energy consumption goes very well into the value-driven approach where you want to improve for the customers.” Based on these statements, the Case Company sees CE as a way to further emphasize their value-driven approach to ensure customer satisfaction.

Respondent G highlights that the Case Company’s motivations for embracing sustainability or circularity focus on long-term objectives, profitability, responsibility, and environmental & social well-being. Respondent F expresses a similar viewpoint, stating that it originates from a directive from the parent company to proactively address evolving demands and maintain a competitive edge, which also aligns with the statement of Respondent A that ”...if we don’t do it, we will be left behind...”. Respondent I, the Technical Advisor and Marketing representative at the Case Company, also share the belief that initiatives towards sustainability or a CE will enhance their ability to attract customers and maintain a leading position. In a precise statement, they emphasize, ”Sustainability is crucial for preserving our reputation as a knowledgeable company and remaining competitive in the market.”. Additionally, Respondent D defines being circular as ”...the most scientifically based and trustworthy approach to take...”

Additionally, Respondent E, the Operations Director at the company in question, views sustainability as both profitable and risky, particularly in the division tasked with refurbishing and reusing products. Stressing the relation between profitability and circularity, Respondent E advocates that "all companies should consider how to handle the costs and profits from reused materials." This involves the intricate process of disassembling and segregating returned materials for reuse or remanufacturing, which adds complexity to operations before reintroducing products into the market. Moreover, Respondent C, the Product Development Manager, acknowledges the sustainability initiatives underway at the company, yet expresses limited exposure to the specifics of these projects. Finally, the Logistics Manager, Respondent J, expresses optimism about integrating CE principles into the system, stating that "...this will reduce environmental impact and increase profitability."

4.3 Empirical results on drivers

Respondent A, Business Director at the Case Company, emphasizes that transitioning to a circular economy is the right thing to do and critical for maintaining leadership in the industry. Respondent A states "Being a leader in sustainability can prevent the Case Company from being left behind." Additionally, Respondent A confirmed that the motivation to become sustainable and transition towards CE is driven by the vision articulated by the CEO of the parent company. Respondent D, Purchasing Manager points out that the Case Company aims to be the most sustainable company in its business, reinforcing the company's commitment to sustainability and improving its market position. Additionally, Respondent I, the Technical advisor and Marketing expert at the Case Company highlights that "sustainability is crucial for maintaining the Case Company's reputation as a knowledgeable company and staying competitive in the market." Respondent D further emphasizes the idea that "committing to sustainability and lowering emissions supports the company's reputation and competitiveness."

Respondent E, the Operations Director discusses the potential for reusing stock items without alterations and the need for alterations in customer-specified products, indicating opportunities for innovation in product design and manufacturing processes. Respondent E highlights, "There are opportunities for innovation in product design and manufacturing processes, particularly in reusing stock items without alterations." Similarly, Respondent C, the Product Development Manager discussed about the feasibility of reusing components like heat exchangers and the importance of integrating circular economy principles into project models to ensure consistent implementation. On the financial front, Respondent G, the sustainability manager at the Case Company notes that circular business models can be economically attractive, suggesting a potential for profitability while reducing environmental harm. Additionally, Respondent I, the Technical Advisor and Marketing Expert at the Case Company emphasizes, "The internal campaign 'R3 Concept' focuses on extending product lifecycles and using recycled materials, aiming to achieve cost savings in manufacturing."

Respondent I, the Technical Advisor and Marketing Expert underscores the rising demand for sustainability initiatives from the customers and consumers. They indicate a notable market shift towards environmentally conscious practices, stating, "There is a rising demand for Environmental Product Declarations (EPDs) and increasing interest from real estate owners in sustainability, signaling a market shift towards environmentally conscious practices." Additionally, Respondent B, the Product Manager at the Case Company noted "Our company's value-driven approach to energy consumption is in line with improving customer satisfaction."

The Purchasing Manager, Respondent D, from the Case Company, highlights the value of their commitment to the Science-Based Targets Initiative (SBTI), stating, "Our initiative to SBTI enables us to proactively address regulatory mandates and showcase alignment with global sustainability standards." Similarly, Respondent A, the Business Director, expresses support for SBTI, stating,

> Science Based Targets Initiative and it's basically that you plan to Fulfill the Paris agreement which is net zero by 2050...So we have pledge that we will do it.

Respondent B, the Product Manager underscores the potential for significant CO2 reduction through product reuse, emphasizing the enduring lifespan of steel and its environmental advantages. Respondent J also emphasizes the importance of reusing steel plates and coils, particularly highlighting their role in diminishing environmental impact, stating, "Reuse of materials like steel plates from products such as the EcoVortex can significantly lower environmental impact." Respondent D, the Purchasing Manager discussed calculating CO2 emissions and setting targets to lower them, indicating a structured approach to reducing the environmental footprint. Lastly, Respondent G, Sustainability Manager confirms that "The lower carbon footprint of second or third-life materials and products highlights the environmental advantages of a circular economy."

4.4 Empirical results on barriers

Respondent J, the Logistics Manager, confirms that steel is a vital and essential raw material in most of their products. However, according to Respondent C, the Product Development Manager at the Case Company, "...95% of the CO2 footprint in the company's products comes from their steel components." While alternative methods are feasible, they are also more expensive. Respondent A notes that the cost of recycled steel is higher, which increases the total cost of the product. Additionally, Respondent D, the Purchasing Manager at the Case Company, notes that historically, component selection was based on price, quality, and lead time. Respondent E, the Operations Manager at the Case Company, emphasizes that designing for disassembly should be a key consideration for the design department to enhance the recycling of returned products.

Additionally, Respondents identified material related barriers in a particular component of their top-selling product, the EcoVortex. Respondent D, highlights a technical barrier associated with the heat exchangers "...their small pipe diameter makes them challenging to rework in case of leaks. Respondent B and C, both emphasize that the heat exchangers used in the EcoVortex contain copper pipes, and is thus sensitive to acidic water, hard water, contaminated water, and high levels of oxygen in the water as these aspects all increase the risk and rate of corrosion. The Case Company is therefore concerned about water handling in the buildings where their products are installed to prevent scrap due to excessive corrosion.

The Space is the primary concern regarding resource management for the Case Company. Respondent B, highlights, "Currently, our focus is on manufacturing. However, if we receive 800 products or more for recycling, reusing, and remanufacturing, how will the Case Company handle this?". The statement from Respondent E, the Operations Director at the Case Company, mirrors Respondent B's concern that "...we may not have sufficient space for long-term operations... we're not fully prepared in terms of warehouse space for handling returned materials."

Respondent A is also concerned about the handling of the return products, especially with the large scale returns where resource constraint may limit the ability to handle a large volume of returns efficiently. However, Respondent J, confirms that "... it [space] depends on the volume... If we're dealing with only a small amount of returned products each week, then perhaps we can allocate a small area for that purpose..."

Understanding resource allocation in terms of cost and time is crucial for assessing resource efficiency during the processing of returned products. Respondent E, emphasizes that "the processing time of returned products is critical from both operational and cost perspectives. It influences the required number of operators and can significantly impact profitability if the actual processing time exceeds expectations." Respondent F, the Business Development Manager, further adds, "...even if the product is received at the factory for free, however, we still have the manufacturing cost" this raises questions about resource efficiency in terms of risk.

Respondent G addressed challenges related to cultural, psychological, and operational as well. As an internal stakeholder, Respondent G, the Sustainability Manager, at the Case Company states, "Considering internally, the barrier could be the entire operation's mindset, as everything has been optimized for linear thinking... and now this thinking is the opposite, circular."

Respondent A, Business Director at the Case Company states that "Products are different and very. So it would be a lot of products and then we need to build a warehouse, and that also takes time. . . so where we store it [returned products] and for how long we store it and transporting as well." Respondent F, the Business Development Manager, also shows concern about the warehouse and the transportation of the returned products. Respondent F states "Currently, space is very limited in factories. . . is long-distance transport worth it in terms of CO2 emissions?" Contradictory, interviewing Respondent G, stated that reverse logistics would not make so much difference than just transporting them in one direction or transporting them back. However, Respondent G agreed that the handling process is crucial in terms of disassembling the products from the sites. On the other hand, Respondent J, the Logistics Manager at the Case Company mentioned:

> I mean, when we send out the goods from our factory in big volumes, that's when we'll take them back from the building site. It can be one or two products, but then the transport costs might be a little bit higher, I think.

During interviews, Respondents indicated that marketing second-hand products is perceived as a risky endeavor. Respondent A, the Business Director at the Case Company, discussed their recent initiative and its outcomes:

> We're looking now at the recycled steel in some products, which is positive, but it's a little bit increased cost, and we're not sure how it will affect how it will be received by the market yet. So we have launched it for some products, but it's a bit of a price premium in order to cover it. And so far, we haven't seen any interest in it.

Respondent A further explained the risk that consumers might shift to competitors due to the high cost of their products, potentially resulting in a significant loss in sales. Respondent G mirrors this concern, stating,

> From the market and customer perspective, there can be negative associations with circular products, especially when labeled as secondhand or used. Who wants to buy old things? This creates a psychological barrier on the customer side.

Respondent E, the Operations Director, when asked whether returning products could be considered as produced products and used to fulfill production targets replied: "In theory, yes, but due to the variability of returning products and customer requirements, it's challenging to directly integrate them into production."

5

Empirical Analysis

5.1 Opportunities and Risks for Implementing CE in the HVAC Industry

This section discusses the opportunities and risks related to the adoption of certain CE practices in the HVAC industry based on the case study that was carried out at the Case Company.

5.1.1 Implementing Circular Business Model

The Respondent D, the Purchasing Manager at the case company, explains the process overview, highlighting the company's focus on a make-to-order approach. This aligns with the article by Sauvé et al. (2016), which discusses the linear economy, wherein resources are extracted, products are produced, and eventually consumed. However, when integrating CE into operations and processes, adopting a PaaS model and a Product Life Extension business model could be beneficial for the case company. As discussed by (Khan et al., 2018), implementing product life extension could be advantageous from an environmental aspects, extending the product life-cycle through re-manufacturing, repairing, upgrading, and refurbishing (Golsteijn, 2022). Pursuing a PaaS approach could, in theory, be a viable option since HVAC systems typically involve large upfront costs for real estate developers to acquire and install. These customers might prefer to trade these upfront costs for variable costs over time with a PaaS solution. Additionally, the case company can explore the re-manufacturing approach for returned products and offer these systems to customers through a PaaS model. Such a solution would effectively incentivise HVAC systems manufacturers to extend product life cycles as they retain ownership of the products and in order to facilitate re-usability of their products (Parida & Frishammar, 2024).

Though as evident from the empirical study that was carried out, the HVAC manufacturers' customers are never the end owners of the HVAC systems. The additional transfer of ownership that takes place after the initial sale and subsequent installation greatly complicates the potential viability of a PaaS solution. When transitioning to a PaaS solution the installer would effectively need to be cut out as the middleman between the HVAC systems manufacturers and real estate developers as the benefits of a service can not be passed on through a value chain. To actualize such a transition, new customer relationships would need to be built at the cost of existing ones and the industry as a whole would need to restructure how the value chain cooperates.

5.1.2 Implementing Reverse Supply Chain

Another option is to stick with their current sales model and simply refurbish and resell used products. This maintains the incentives for making durable products as it directly correlates to keeping down costs of refurbishment. If the cost of activities related to refurbishment and reverse logistics are lower than that of manufacturing a new unit, there is a case to be made that it can be profitable. However, it also hinges on the WTP for reused and refurbished products. If refurbished products cannot be sold as new they are bound to have a different WTP which can make the degree of profitability unpredictable. Parida and Frishammar (2024) mentions the importance of correctly differentiating where the demand for a circular offering stems from, whether it'd be customer or provider driven. If demand for a circular offering is customer driven one could argue the possibility of the WTP to be higher than that of products manufactured from "virgin" materials. If, on the other hand, demand is provider-driven, WTP is likely to be lower for reused and refurbished products.

As the Case Company currently operates with a make-to-order approach, receiving used products in order to refurbish them and later resell them can be in contrast with this approach. As different customers have different needs there is no guarantee that there is a new customer with the same product requirements that is willing to buy the refurbished products as soon as they are ready (Parker et al., 2015). This can result in extensive stockpiling of refurbished products which is something that the Case Company does not have the capacity to handle at their current facility which may lead to significant additional expenses (Parker et al., 2015). Stockpiling itself is not necessarily undesirable as it can provide flexibility and increase speed in fulfillment of customer orders but it requires additional resources and investments to facilitate.

In order to make an informed decision regarding the appropriate size of investment the manufacturing company needs to know how many products they can expect to get returned over the coming years (Sundin, 2006). Considering the Case Company, it can be argued that they currently lack sufficient information about their existing product fleet in order to do so. This in part as a result of their minimal after sale communication with customers and product owners. Investing resources in facilitating reverse logistics and developing refurbishment capabilities with unknown or inconsistent reverse product flow may result in a greatly unprofitable and ineffective CE initiative (Jayaraman & Luo, 2007). Respondent J, the Logistic Manager at the Case Company, has expressed concerns about the planning and rescheduling of the current forward flow of the supply chain, which is reducing efficiency and increasing costs. The reverse logistics costs, particularly for bulky items like EcoVortex, pose a significant challenge, as described by Parker et al. (2015).

Respondents did mention that some components are kept in stock even though they maintain a make-to-order approach with regard to manufacturing. Within the definition of circularity in and in the spirit of reducing waste there is an opportunity to simultaneously reduce material costs by disassembling used products and returning certain components to stock. Processing and storing returned materials for manufacturing naturally require significant storage capacity (Kurilova-Palisaitiene & Sundin, 2014). The current warehouse space is insufficient to accommodate the reverse logistics and stockpiling of complete products, however, existing inventory of components already occupies considerable storage space at the Case Company. Examining the cost breakdown of the EcoVortex in Table 3, it can be seen that certain components contribute significantly to the overall cost. If these components can be safely removed and pass a quality inspection, they could be returned to stock and used in the next batch of products sold as new. This approach would not only lead to cost savings and larger profit margins for the manufacturer but also reduce the CO2 footprint through component reuse. Additionally, it would alleviate the cost and space constraints otherwise associated with reverse logistics.

To facilitate effective disassembly without damaging components, the manufacturing company might need to alter the design according to design for disassembly principles (Homrich et al., 2018). With the relatively long product development cycles within the HVAC industry and low degree of innovation, certain components can remain relevant and usable in newer design iterations despite having been used in a product that was manufactured and sold early in the cycle.

5.2 Drivers within the Case Company

The interviews with respondents from the Case Company revealed several key drivers motivating the transition to CE practices. A prominent driver identified was a long-term business perspective, shaping the vision of individuals to embrace CE. Indeed, Hina et al. (2021) also agrees that *organizational drivers* play a crucial role in motivating companies to implement circular business models. Additionally, good leadership is essential for implementing CE practices (Hina et al., 2021), as confirmed by Respondent A, who emphasized that the parent company's vision supports this approach.

Moreover, gaining a *competitive advantage* appears to be a common aspiration among most respondents, which is driving their interest in adopting CE practices. Govindan and Hasanagic (2018) suggests that companies can achieve a competitive advantage by implementing sustainability practices, enhancing employee satisfaction, and improving customer satisfaction. However, Tan et al. (2022) argues that leaders must recognize the importance of sharing initiatives with other ecosystem players, including competitors, as this collective effort is essential for advancing society towards a CE.

Respondent F mentioned that the parent company's directive to address evolving *regulatory demands* proactively was a key motivator for embracing sustainability initiatives. Compliance with environmental regulations and the pursuit of certifications related to circular economy principles were identified as drivers that incentivized HVAC companies to prioritize sustainability and resource efficiency. Similarly, In the study conducted by Nordic Innovation (2023), clear and essential regulations have the power to significantly drive businesses towards adaptation, providing both the mandate and momentum for change. Conversely, in situations where regulations are ambiguous, discretionary, or still in development, they can pose obstacles to progress. Additionally, researches also reveals that the support from government is currently lacking, characterized by slow implementation, lack of coordination, and a failure to address on the ground concerns (Tan et al., 2022).

Respondents proposed innovative solutions for advancing towards a CE when discussing the factors influencing *product and process development drivers*. Respondents confirmed opportunities such as design for disassembly, reuse of returned product components, and circular design considering sustainable materials. However, in a circular business model, products are designed with future expansion and modification in mind, while also prioritizing product quality (Hina et al., 2021). Furthermore, when remanufacturing products, the design should prioritize both effectiveness and efficiency (Sundin, 2006). Empirical findings have concluded a deficiency in circular design integration within the system, indicating room for improvement in product development where the Case Company is actively addressing this issue. Furthermore, while the "R3 Concept" within the Case Company has succeeded in reducing, reusing, and re-manufacturing, it's worth noting that this initiative is currently focused on a limited range of product variants.

Respondents underscore the significant potential of material reuse and improving material lifespan for *environmental* benefits. Articles such as Berg et al. (2019), de Jesus and Mendonça (2018), and Interreg Europe (n.d.) highlight how CE initiatives contribute to reducing CO2 emissions, preventing ecosystem degradation, and minimizing energy consumption. The responses from respondents indicate a clear motivation and awareness of the environmental advantages achievable by integrating CE into the system.

5.3 Barriers within the Case Company

Based on empirical results, *raw material selection* is identified as a crucial barrier. In the Case Company, steel contributes significantly to CO2 emissions. Although alternative materials are available, they tend to be more expensive than steel. The article by Rizos et al. (2021) also highlights a comparable challenge associated with the elevated expense of raw materials. Additionally, as previously noted, product design is currently not taking circularity into account. As emphasized by Lieder and Rashid (2016) in 2021, resource scarcity stands as another critical consideration in the approach to CE. This encompasses factors pertaining to regenerative resource utilization and the amplification of industrial activities. Nonetheless, empirical findings reveal that the warehouse and the operations involved in returning products pose significant obstacles for the Case Company.

The transition to a CE appears to be hindered by a *lack of resources and capability* in terms of processing time and ability to manage the returned products, as highlighted by respondents E and F. While maximizing resource efficiency can help a company achieve profitability by considering economic aspects (Sauvé et al., 2016), Postan (2021) argues that implementing CE within a company poses challenges and demands substantial time and resources. However, meeting these demands can lead the company to generate additional revenue and growth (Postan, 2021).

Ambiguous responses were received from the participants regarding *consumer and customer acceptance*. Respondent I noted that customers are crucial drivers, requesting EPD documents and expressing greater concern for sustainability. This aligns with the study by Bucur (2023), which mentions that consumer awareness related to CE can lead them to make sustainable purchasing decisions. On the contrary, certain respondents have voiced apprehensions regarding the WTP of customers, an essential consideration given that acknowledging the genuine demand of the customer holds equal significance (Parida & Frishammar, 2024). Consumers may be disinterested if the product becomes more expensive than usual due to the implementation of circular practices and the unfavorable economic relationship in manufacturing durable and longer-lasting products, as Sauvé et al. (2016) mentions.

Taking cultural aspects into consideration, Respondent G is concerned about the psychology of the internal stakeholders regarding the implementation within the system. Respondent G, the Sustainability Manager at the Case Company, suggests that linear operational thinking might hinder the transition to a CE. This idea is echoed in an article by Hartley et al. (2022), which highlights how linear production systems can pose a challenge to embracing a CE model. The culture of the company plays a crucial role that the Case company must consider during its transition to a CE. To address issues such as the mindset and behavior of stakeholders, as highlighted by Kirchherr et al. (2017), the organization must take proactive steps toward knowledge sharing, raising awareness, and facilitating discussions on these matters in various forums.

6

Conclusion

6.1 Conclusion

The conclusion of this thesis addresses two research questions:

RQ1: "How can opportunities for implementing Circular Economy practices in the HVAC industry be assessed, considering factors such as technical feasibility, resource requirements, logistical ability, and alternative business models?"

This thesis has found several viable approaches to implementing CE practices within the HVAC industry supported by theory and empirical findings. Each approach with varying degree of inherent risk and amount of resources required to implement said approach.

Transitioning to a CBM in the form of a PaaS model entails favourable incentives in terms of optimizing design for product life extension as ownership is retained with the manufacturer and recurring revenues can be generated over the products' entire life time. A longer product life time would thus lead to larger revenues. However, such a transition would require substantial changes related to how the value chain cooperates, businesses acting as middlemen in the current linear economy are likely to combat such a change.

Reacquiring products to refurbish and resell them maintains the current value chain while still enabling CE practices. By establishing a reverse supply chain HVAC companies can effectively reacquire their products in order to refurbish and resell them to increase revenue per unit. However, the profitability of this endeavor is dependent on the costs associated with the additional labour required to refurbish reacquired products and with establishing and maintaining the reverse supply chain. On this note, being able to forecast demand to return products is vital to determine appropriate investment size. Reselling refurbished products also puts customers' WTP into question, an aspect critical to assess profitability of adopting this approach. For companies employing a make-to-order approach in their manufacturing, there is also the added risk of incurring a large stockpile of unwanted products.

Instead of refurbishing reacquired products, an alternative approach is to instead disassemble the products and return the components to stock. This approach still requires the establishing of a reverse supply chain although products do not risk ending up in costly stockpiles. Products could potentially be sold as new, given that components pass a quality inspection, with the added benefits of significantly lowering CO2-footprint from materials and maintaining WTP. With materials making up 73% of total production cost of the EcoVortex for the Case Company, there are large cost savings that can be made from reusing components from HVAC products. Profitability of this approach depends on whether the additional costs associated with reverse supply chain, disassembly, and additional quality inspections outweigh savings made in reduced material costs. Redesigning for disassembly could make this approach more viable.

RQ2: "What are the drivers and barriers associated with the reclaiming and refurbishment of HVAC products?"

The critical motives, drivers, and barriers associated with transitioning to a CE within the HVAC manufacturing industry are organized into two domains: internal and external factors as shown in Table 4. Several factors are important when considering the initiation of a CE within the HVAC industry. The characteristics and factors listed below are based on empirical data collected from interviews. This data was analyzed in conjunction with a theoretical background on circular economy, circular business models, remanufacturing aspects, and customers in consideration.

Table 4: Identified motives or drivers and the barriers connected to the HVAC industry

Category	Internal Factors	External Factors
Motives and Drivers	Organistaional Drivers, Competitive advantage, Product and process development drivers	Regulatory demands, Environmental aspect
Barriers	Raw material selection, Lack of resources, Cultural barrier	Consumers and customer acceptance

Moreover, the article by Hina et al. (2021) also underscores the significance of internal and external drivers and barriers during the transition to a CE. However, it was found that the factors mentioned above were most commonly observed while analyzing the empirical results. Research also agrees that all these factors are crucial considerations as primary steps toward achieving the goals.

6.2 Future Research

To expand on the findings of this study, future research avenues in CE and HVAC systems could be explored. Firstly, conducting a longitudinal study to assess the outcomes of implementing CE practices in the HVAC industry would offer valuable insights into the sustainability and effectiveness of the suggested strategies. Additionally, broadening the research to include a comprehensive analysis of CE integration's social and environmental impacts on HVAC systems is crucial for achieving holistic sustainability objectives. Moreover, comparative analyses with other industries could provide valuable insights into best practices, barriers, and opportunities for cross-industry knowledge transfer. Addressing these gaps and exploring these future research directions will deepen the understanding of CE implementation in the HVAC sector, fostering sustainable innovation in this vital industry.

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A

Interview Guide 1

Circularity and Sustainability related questionnaires (Common to all respondents)

1. What are the sustainability goals/focuses/targets for the *Case company*?
2. Why is being sustainable important for the *Case Company*? What does the *Case company* hope to achieve by reaching its sustainability goals?
3. How does the *Case company* view potential benefits and opportunities associated with transitioning to a CE approach?
4. How does the *Case company* view potential barriers and the risk associated with transitioning to a CE approach?

B

Interview Guide 2

Complete set of specific questions. Condensed into smaller subset for each interview according to the respondents area of expertise.

- Business, Sales and Marketing
  - Business Model
    - Who are the Stakeholders of the *Case company*?
    - Who are the target customers and what are the targeted Regions for the *Case company*?
  - Transfer of Ownership
    - Can you elaborate on the after-sale communication/contact process?
    - Can you elaborate on the after-sale customer support/care?
  - Distribution
    - Who is responsible for the distribution/shipping of products?
    - Opportunities for reverse logistics?
  - Installation
    - Installation services provided by the *Case company* or by a third party?
    - Type of communication post-installation
  - Maintenance

    * Who carries out the maintenance i.e. the *Case company* or third party?
    * How often maintenance/ servicing is recommended/required?
    * Is maintenance customer initiated/set intervals/sensor triggered?
  - Warranty
    * What is the product warranty?
    * What is the average product lifetime with customers?
    * Does the product lifetime vary with customer type?
    * Who's responsible for maintenance during the warranty period and after?
- Product Development Cycle
  - What is the product cycle length, NPD to next-gen dev start?
  - When will EcoVortex be outdated?
  - What are the critical components of the product EcoVortex?
  - Is the product developed with sustainability goals in mind or just performance-focused?
  - Are there any plans or strategies in the product development to begin incorporating circularity into your operation?
- Production and Purchasing
  - Material Sourcing and Supply
    * From which suppliers does the *Case company* procure/source the materials and components?
    * What are the geographic locations of those suppliers?

        * Does the *Case company* store the inventory in bulk storage or on an order basis?

    - Operations

        * What is the single-unit assembly time?

        * How many man-hours are required to complete one unit?

        * What are the in-house operations performed to complete one unit?

        * What is the current rejection percentage?

        * Current resource count? (How many people are working in the assembly line)

    - Quality assurance

        * How does the QA function operate today?

        * Which components or materials are being inspected?

        * Is every produced unit tested?

        * Would the quality assurance testing differ on returned products?

        * What would need to be tested and how?

- Potential for reverse logistics handling

    - Does the Case company have the warehouse space to perform the operations on returning products?

    - Distribution

        * Can you please elaborate on the current transportation ownership, in-house or outsourced?

    - Centralized product handling

        * Would all products need to be returned to the main plant?

* Can quality assurance be decentralized?

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