Exploring the role of Niche Strategies in overcoming barriers to Circular Innovation

Exploratory Case Studies on Circular High-Tech firms in The Netherlands

<mark>Master's Thesis</mark> Raghav Shankar



Exploring the role of Niche Strategies in overcoming barriers to Circular Innovation

Exploratory Case Studies on Circular High-Tech firms in The Netherlands

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Executive Summary

The study embarks on a comprehensive investigation into the domain of circular innovation within Dutch high-tech firms, probing the dynamics of drivers, barriers, and the strategic impact of niche strategies. The research methodology builds upon the adaptable foundation of the Technological Innovation System (TIS) framework, adapting it to the unique contours of circular innovation. This framework guides the research objectives, which encompass discerning the propulsive forces driving circular innovation, unraveling the contextual intricacies, and critically evaluating the applicability of the adapted TIS framework.

Guided by this framework, the research addresses three pivotal sub-questions that delve into the nuances of drivers, barriers and the strategic potency of niche strategies within the circular innovation landscape. The methodology seamlessly interweaves an expansive literature review with in-depth case studies of four distinct Dutch circular high-tech firms. Through rigorous qualitative analysis, recurrent drivers emerge, including the catalytic influence of emerging regulations, collaborative partnerships, strategic product design and value proposition, and intrinsic motivation. On the flip side, barriers encompass the complexities of production systems, complementary products and services, network formation and coordination, and the intricate maze of customer engagement challenges.

Embedded within the empirical insights are four distinct niche strategies, meticulously tailored to specific contexts: the Redesign Niche Strategy, the Decentralization Niche Strategy, the Turnkey Product-Service System (PSS) Niche Strategy, and the Compliance-Driven Stepping-Stone Niche Strategy. These strategies come to light as potent tools in surmounting the entrenched barriers, underscoring the significance of strategic alignment with regulatory shifts, the formation of collaborative networks, and the innovation-driven approach to product design in propelling circular innovation.

The strategic adaptation of the TIS framework to circular innovation not only enriches analytical depth but also highlights its pragmatic relevance. Consultations with experts from HollandCircularHotspot - a platform driving the advancement of the circular economy by facilitating collaboration, knowledge sharing, and representing Dutch circular companies on an international stage, serve to validate the framework's utility, affirming its efficacy in dissecting the ever-evolving landscape of circular innovation. Acknowledging its limitations, such as the limited scope of case studies and the geographical focus on Dutch high-tech companies, the study sets the stage for future research endeavors.

In summation, this thesis offers a substantial contribution to comprehending the dynamics of circular innovation within Dutch high-tech enterprises. It underscores the pivotal role of specific strategies and reaffirms the pertinence of the adapted TIS framework. With its blend of empirical insights and theoretical foundations, the study illuminates potential pathways for circumventing barriers to circular innovation, paving the way for transformative change within the high-tech circular landscape.

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Nomenclature

This section includes the Abbreviations and definitions of key concepts used throughout the report.

Abbreviations

Abbreviation	Definition
CE	Circular Economy
CI	Circular Innovation
TIS	Technological Innovation System
BM	Business Model
BMI	Business Model Innovation
KPI	Key Performance Indicators
SDG	Sustainability Development Goals
PSS	Product-Service-Systems
PAAS	Product-as-a-Service

Key Concepts

Explanation
The circular economy is a model of production and con- sumption, which involves sharing, leasing, reusing, repair- ing, refurbishing and recycling existing materials and prod- ucts as long as possible
Circular innovation is an approach that aims to transition from a linear take-make-waste model to a circular one. It involves designing products or services and implementing them with circular economy principles in mind, emphasizing longevity, sustainability, and closed-loop systems.
Drivers can be defined as the factors or motivations that pro- pel and stimulate the adoption and implementation of circu- lar economy principles and practices.
Barriers to circular innovation are obstacles that impede the adoption and implementation of circular economy principles and practices.

Concept	Explanation
Niche (Strategy)	A niche prior to large-scale introduction into a mainstream market in situations where wide-spread diffusion can not take place.
Building Blocks	The building blocks of Technological Innovation Systems (TIS) represent the essential components necessary for large-scale diffusion of radically new technological innovations.
Influencing Conditions	Influencing conditions, within the context of the TIS frame- work, are the various factors and elements that affect the formation and development of the TIS building blocks.

Introduction

The pace of technological advancement and innovation is unprecedented, reshaping global dynamics. One of the most significant milestones in human history occurred in 1903 with the Wright brothers' inaugural manned flight, followed by the momentous achievement of landing a man on the moon just 66 years later in 1969. These occurrences serve as a testament to the rapid development of technology, emphasizing the criticality of comprehending and effectively harnessing its potential. The conventional supplier-customer relationship has undergone transformations in response to the evolving world economy. Advancements in communication, computer technology, and the establishment of open global trading networks have significantly expanded consumer choices, facilitated the fulfillment of diverse customer desires, and enhanced supply chain transparency. Nevertheless, these developments necessitate businesses to reassess their value propositions to clients, as the supply-side logic that characterized the industrial era is no longer applicable in numerous industries [Teece, 2010].

The prevailing perception regarding technology is its potential as a transformative force that positively impacts global quality of life. Within the business domain, considerable growth prospects are associated with high-tech firms, while manufacturing experiences enhanced efficiency through the adoption of novel machinery and automation. In the context of environmental concerns, the advent of green technology is regarded as offering significant opportunities for achieving decarbonization goals [Nayar, 2021]. Industrialization, fueled by technological advancements, has led to escalating levels of pollution, deforestation, habitat destruction, and resource depletion. For instance, the burning of fossil fuels for energy production has significantly contributed to the emission of greenhouse gases, exacerbating global climate change [Wuebbles and Jain, 2001]. Moreover, the proliferation of electronic waste generated by the constant turnover of consumer electronics poses a grave challenge for proper disposal and recycling, leading to soil and water contamination [Wu et al., 2018]. These are just a few examples highlighting the adverse environmental consequences resulting from the relentless pursuit of innovation and technological progress.

Influential individuals, like Swiss businessman and former Business Group for Sustainable Development chairman Stephen Schmidheiny, have forecast the advent of a new industrial revolution motivated by environmental concerns. These forecasts are supported by the paradigm change in corporate environmental management that occurred in the 1990s, which reflects a

fundamental rethinking of business operations. Environmental sustainability, which includes environmental protection and the preservation of natural resources, has emerged as a fundamental concept adopted by global corporations. This change calls for moving away from a reactive compliance strategy and toward proactive environmental management [Berry and Rondinelli, 1998].

As these values are increasingly integrated into corporate cultures and management processes, with environmental impacts being audited and accounted for as a vital aspect of corporate performance, forward-thinking firms explore opportunities to develop green products, processes, and technologies, tapping into expanding markets for eco-friendly solutions. As businesses recognize the inherent value of addressing environmental concerns, the vision of a new industrial revolution built on sustainable principles gains momentum, reshaping the future of global industry [Berry and Rondinelli, 1998].

Although it is noted that worldwide, organizations are becoming more concerned with environmental management [Barros et al., 2021]. Authors such as De Jesus et al. and Van den Bergh et al. argue that palliatives might not be sufficient in light of the fact that by 2050, global consumption is projected to have tripled from its current level. Global trends are changing, including consumer sensitivity to climate change and stricter environmental standards. In this context, the idea of a new economic model - Circular Economy is promoted as a strategy and driver towards sustainable business [Barros et al., 2021] in a world that is still competitive and dynamic but finite, working in closed-loops and encouraging innovation throughout the entire value chain [Van den Bergh et al., 2011; De Jesus et al., 2018].

The circular economy (CE), a new economic system, seeks to incorporate practices like reducing, reusing, recycling, and recovering into traditional systems [Kristensen and Mosgaard, 2020]. At its core, the circular economy aims to prolong the usefulness of products, materials, or resources [Gregson et al., 2015]. One central aspect of the circular economy is the utilization of closed-loop systems, wherein resources are kept within the system to minimize pollution and prevent resource leakage while supporting economic growth. Furthermore, this approach represents the latest endeavor to integrate environmental well-being with economic activities [Winans et al., 2017; Murray et al., 2017]. This perspective has been advanced, putting closed-loop thinking at the center of businesses, industrial organizations, and national agendas [De Jesus et al., 2018]. Both academics and practitioners are becoming more and more interested in Circular Economy as a concept. Yet, detractors contend that it might imply many different things to many individuals.

The following chapters will discuss the fundamental concepts, underlying motivation for this research, examine the current state of the field and highlight significant research to provide background and context to the Research Question and the sub questions. These include niche strategies, critical drivers to success, barriers to large scale diffusion and circular economies.

1.1. Circular Economy - The Concept

The Ellen MacArthur Foundation is often credited with providing the most well-known definition of Circular Economy. According to Geissdoerfer et al. and Schut et al., who state: "an industrial system that is restorative or regenerative by intention and design". It aims to eliminate waste through the superior design of materials, products, systems, and, within this, business models. It does this by replacing the "end-of-life" concept with "restoration," moving toward the use of

renewable energy, eliminating the use of toxic chemicals that prevent reuse, and eliminating waste. In the paper by Kirchherr et al., it is mentioned that this definition is the one that is most frequently used. It is also mentioned in other pieces of scientific literature, such as the ones by Charonis; Schut et al.; Hobson; Cullen; Skene; EMF, occasionally in truncated form, aside from by the Ellen MacArthur Foundation.



Figure 1.1: Impact Map of Circular Economy concepts in Business Management [Barros et al., 2021]

While existing literature acknowledges the potential of the circular economy in terms of sustainability, the specific implications for key business areas could remain unclear. The study by Barros et al. addresses this research gap by conducting a systematic review of the literature to identify the key impacts of circular economy practices within different business areas. Circular business models play a significant role in advancing sustainable practices [Barros et al., 2021], although their effectiveness in achieving sustainability in isolation remains uncertain.

The adoption of circular practices in businesses introduces complex managerial implications that necessitate fundamental alterations in business models, operational processes, and organizational culture. This includes the imperative to cultivate a cultural shift that embraces circularity and fosters changes in behaviors pertaining to product consumption, disposal, and management. Additionally, the successful implementation of circular initiatives entails navigating various challenges and barriers across diverse areas within the organization. Understanding these implications and proactively addressing the associated transformations could enable businesses to navigate the intricate path toward Circular innovation [Barros et al., 2021]. The different key impact areas noted by the authors is illustrated in figure 1.1 above.

In "Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy", the authors De Jesus and Mendonça state that the shift to a more sustainable eco-

nomic paradigm is being aided by the circular economy, which has become a crucial strategy. A "System that is restorative or regenerative by intention and design" is suggested in place of the linear "take-make-dispose" economy, which is highlighted as something that should be resisted. Circular Economy is also regarded as a feasible socio-technical strategy for achieving economic and ecological sustainability rather than as necessarily being a disruptive idea [De Jesus and Mendonça, 2018; EMF, 2012].

Given the theoretical improbability of achieving a fully closed-loop system [Zotti and Bigano, 2019; Skene, 2018], our conceptualization of a circular economy revolves around a dynamic perspective. Instead of pursuing an unattainable notion of a perfectly circular system with zero material and energy leakage, the focus is on the ongoing process of "going circular." This perspective acknowledges the inherent challenges and limitations while emphasizing the continuous efforts to increase circularity and minimize resource wastage and energy loss [Geiss-doerfer et al., 2020].

Further information on Circular Business Models, Value Hill and other related work by Geissdoerfer et al.; Bocken et al.; Hartley et al.; Den Hollander et al. can be found in Appendix A.

1.1.1. Circular Economy: Drivers and Barriers

The paper "Innovation and the Circular Economy: A Systematic Literature Review" offers a thorough summary of the body of knowledge regarding the relationship between innovation and the circular economy. In order to pinpoint the key ideas and knowledge gaps pertaining to innovation and the circular economy, the authors conducted a systematic review of articles published between 2000 and 2018. The study emphasizes how adopting circular economy principles can benefit businesses financially and practically, including cost savings, improved competitiveness, and the emergence of new markets and employment opportunities. The need for new business models, legal obstacles, and a lack of consumer knowledge are just a few of the difficulties the authors mention when discussing the implementation of circular economy methods. With regard to the circular economy and innovation, the review cites a number of significant issues, including the function of design, the significance of networking and cooperation, the requirement for policy and regulatory support, and the function of digital technologies [Suchek et al., 2021].

There is a lot of research on the development of circular economies in nations, industries, and businesses. The works of Böttcher and Müller; Ilić and Nikolić for example give a very comprehensive review. According to a report for Chatham House [Preston, 2012], there are a number of obstacles to implementing Circular Economy, including high upfront costs, complicated international supply chains, resource-intensive infrastructure lock-in, failures in company cooperation, a lack of consumer enthusiasm, and limited innovation dissemination in both emerging economies and developed nations.

Despite increased efforts, there is still a need for a comprehensive identification of the prerequisites for a Circular Economy, particularly when the notion overlaps with innovation [Doranova et al., 2016]. In a similar vein, an innovation perspective on circular mechanisms is advanced by examining the role of technological and non-technological factors in the development of a new, circular, techno-economic paradigm. By moving beyond the linear-industrial model, such a diagnosis can assist policy-making. Economics, more often than not, focuses on hard forms of innovation, like R&D driven products or cost-cutting procedures. However,

innovation is actually a fragmented phenomenon [Stoneman and Bakhshi, 2009; Stoneman, 2010]. Thus, in the context of this thesis, "circular innovation" will be used to refer to these forms of innovations.

Although research suggests that implementation of circular innovation could boost towards a sustainable future, it is a complicated process with numerous drivers and barriers. Some studies have concentrated on the challenges that small and medium-sized enterprises (SMEs) face when implementing circular business models, while others have investigated the institutional drivers and barriers of the circular economy in various regions such as China, the United States, and Europe. One study looked at the predicted transition to a more balanced interaction of environmental and economic systems, while another looked at the integration of views and domains to identify hurdles to the circular economy.

As research indicates, there are still substantial obstacles to be overcome, circular innovation has the potential to transform our economic systems and move us toward a more sustainable future. A number of these barriers are mentioned in the paper "Exploring barriers to implementing different circular business models," including a lack of knowledge and understanding of circular business models, problems obtaining funding for circular projects, and a lack of supportive regulations [Vermunt et al., 2019].

As Pieroni et al. and Corvellec et al. point out, businesses still have a lot of trouble putting circular innovation into practice, despite the growing interest in it. This research can offer useful insights that can help overcome the difficulties and encourage the widespread diffusion of circular innovation by identifying the main forces driving and impeding it in high-tech companies in the Netherlands. This process can be significantly influenced by the use of niche strategies, making the research question extremely pertinent and important in the context of the circular economy. "How Incumbents Realize Disruptive Circular Innovation - Overcoming the Innovator's Dilemma for a Circular Economy" sheds light on the difficulties Incumbents encounter when implementing Circular Innovation, such as the challenge of integrating Circular Business Models with Existing Revenue Streams and the requirement for significant organizational change [Kuhlmann et al., 2022]. Focusing specifically on SMEs, "Implementation of Circular Economy Business Models by Small and Medium-Sized Enterprises (SMEs): Barriers and Enablers" identifies challenges like a lack of resources and expertise as well as a lack of demand for circular goods and services [Rizos et al., 2016].

A more comprehensive overview of the circular economy is given in "A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems," which also emphasizes the significance of policy frameworks and cross-sector cooperation [Ghisellini et al., 2016]. While "Barriers to the Circular Economy - Integration of Perspectives and Domains" emphasizes the need for a more integrated approach to understanding the barriers to circular innovation [Ritzén and Sandström, 2017], "Exploring Institutional Drivers and Barriers of the Circular Economy: A Cross-Regional Comparison of China, the US, and Europe" examines the role of institutions in promoting or impeding the transition towards a circular economy [Ranta et al., 2018]. Last but not least, "Barriers to the Circular Economy: Evidence From the European Union (EU)" offers a thorough analysis of the obstacles that EU member states must overcome, including issues with supply chains, product design, and consumer behavior [Kirchherr et al., 2018].

1.2. Research Gap

The concept of circular innovation adopts a systemic viewpoint, [De Jesus et al., 2018; De Jesus and Mendonça, 2018; De Jesus et al., 2019; Stirling, 2011; EC, 2015, 2016]. In the context of this thesis, circular innovation refers to a high-tech invention that has the potential to completely reform the value chain, anything from simply closing a loop to implementing "Circular by Design" at the conception stage. A more cleared out definition will be noted in the later sections in bullet points. It is important to note that circular innovation is not restricted to a specific piece of hardware or scientific breakthrough [Kemp, 2010; Andersen, 2008; Fagerberg et al., 2005]. Besides that, Suchek et al. also highlight the significance of the new firms in this context. This is where the thesis's research efforts are focused.

The paper, "A technological innovation system framework to formulate niche introduction strategies for companies prior to large-scale diffusion" is a highly valuable contribution to the literature on innovation and technology diffusion. The authors propose a framework for businesses to develop effective niche introduction strategies that can assist them in overcoming barriers to their innovative products or services [Ortt and Kamp, 2022].

By adopting a business viewpoint, the author's work also fills a gap in the literature on socio-technical systems. According to a number of experts in the field of socio-technical systems, company strategies are a crucial component of these systems, but current frameworks for socio-technical systems and technological innovation systems largely lack them [Ortt and Kamp, 2022]. In the paper, the authors investigate the formation of Technological Innovation Systems (TIS) with a focus on hardware-related innovations, including technological systems, products, and parts. They examine various aspects of the system surrounding this hardware, such as complementary services and organizational networks. The authors also suggest a direction for future research, to explore the applicability of their approach to radically new service innovations. Taking into consideration the "Product-Service-System" nature of circular innovations [Lewandowski, 2016; De Jesus et al., 2018, 2019; EC, 2016], the TIS framework to circular innovations.

The work by Suchek et al. set out to identify the necessary conditions in which Circular Economy is advanced through innovation. The authors had strong inputs on the future work and the direction it ought to take. According to the them, future work should investigate the capabilities of dynamic resources as well as the internal resources and activities required to capitalize on circular innovation opportunities. Furthermore, given that many studies concentrate on the fashion and manufacturing sectors and that sectors dealing with the biological cycle lose out in profile, the literature reflects the need to broaden research on innovation in the circular economy to all sectors. Approaching new businesses and companies is suggested as they might present a more effective and efficient way to introduce radical innovations and find niche opportunities [Suchek et al., 2021]. It is crucial to remember that the circular economy is complicated and necessitates a multidisciplinary strategy involving a range of players from the public, private, and civil sectors.

To put everything into perspective, even though numerous studies have examined the motivators and impediments to circular innovation, further study is still required to have a complete comprehension of the subject. The aforementioned studies offer a place to begin delving into the subject, but a more thorough investigation is required in various contexts [Suchek et al., 2021; De Jesus et al., 2018; De Jesus and Mendonça, 2018; De Jesus et al., 2019]. This thesis aims to develop and contribute to this pool of knowledge further and bridge the gap particularly in terms of the drivers and barriers to circular innovation by Dutch high-tech companies.

Putting the aforementioned predicaments and critiques, suggested future research directions from academicians and the overall multi-dimensional complexity of the concept itself, an argument is be made in support of the research question and it's pertinence.

1.3. Research Question

"What are the key drivers and barriers to circular innovation in high-tech companies in the Netherlands, and how can the application of niche strategies help overcome these challenges?"

Although the TIS framework was originally developed for radical innovations [Ortt and Kamp, 2022], its underlying principles and components could be adapted to the context of circular innovation. By utilizing the TIS framework, this research aims to identify the barriers that influence the implementation of circular innovation by high-tech companies. Additionally, the examination of drivers and niche strategies will provide insights into effective approaches to overcome barriers and facilitate the adoption of circular innovation. The drivers could provide insights on the conditions that facilitate successful implementation of a circular economy, therefore contributing to the field of Circular Economy as well.

1.3.1. Sub-Questions

The study's research question aims to investigate the key drivers and barriers to circular innovation by Dutch high-tech companies, as well as how the use of niche strategies can help overcome these challenges and achieve large-scale diffusion. Three sub questions are framed. The first sub-question seeks to identify the driving factors to circular innovation in high-tech companies, thereby providing a better understanding of the underlying factors that either facilitate or hinder circular innovation adoption.

1. What are the key driving factors to circular innovation by high-tech companies?

Finally, the second and third sub-questions delves into the barriers to circular innovation and the niche strategies that have been successful in the adoption and implementation of circular innovation in Dutch high-tech companies, providing valuable insights that can guide future efforts to promote circular innovation in this context.

- 2. What are the barriers to the introduction of circular innovation by high-tech companies in the Netherlands?
- 3. What specific niche strategies have been successful in introducing circular innovation in the Netherlands?

1.4. Objectives

 Identify the key drivers that influence circular innovation by high-tech companies operating in the Netherlands. Explore the barriers and challenges faced by high-tech companies in the Netherlands when implementing circular innovation.

The first two objectives address the driving factors and barriers to circular innovation by high tech companies in the Netherlands. By addressing these objectives, the study aims to contribute to the scientific understanding of the key drivers and barriers to circular innovation in high-tech companies in the Netherlands, without making generalizations or broad claims.

- Examine the contextual factors, including policies and industry landscape, that influence circular innovation within high-tech companies in the Netherlands.
- Analyze the applicability of the Technological Innovation System (TIS) framework as an approach to understanding circular innovation and developing niche strategies to address barriers.

The third objective aims to analyze the specific contextual factors within the Netherlands, such as policies and the industry landscape, to understand their influence on circular innovation in high-tech companies operating in the country. The fourth focuses on examining the relevance and applicability of the Technological Innovation System (TIS) framework for understanding circular innovation within the high-tech sector in the Netherlands. Additionally, it aims to explore how the TIS framework can be utilized to formulate targeted niche strategies that address specific barriers high-tech companies face during the implementation of circular innovation.

The research objectives collectively aim to provide a comprehensive understanding of the drivers and barriers to circular innovation in high-tech companies in the Netherlands. By lever-aging the insights gained from the TIS framework, the research seeks to inform the development of niche strategies tailored to overcome the identified barriers and promote effective circular innovation practices within the high-tech sector.

1.5. Scope of Research

This research adopts a systemic perspective to investigate circular innovation within the hightech sector of the Netherlands. The study aims to elucidate the intricate interconnections, dependencies, and interactions among diverse actors, institutions, technologies, and policies that influence the adoption and implementation of circular practices. Through in-depth case studies, the research explores the complexities inherent in the innovation system, encompassing aspects such as product design, material sourcing, manufacturing processes, waste management, and product life cycle management. The application of the Technological Innovation System (TIS) framework guides the research framework, concentrating on systemic dynamics. However, it is important to acknowledge certain limitations, including the complexity of data collection, the need for systemic-level analysis, and the potential constraints on generalizability. Nonetheless, this research contributes to the scientific understanding of circular innovation in the high-tech sector, offering valuable insights to policymakers and industry stakeholders in their efforts to foster sustainable transformation.

1.6. Research Methodology

To effectively address the research questions posed in this study, a comprehensive and multifaceted approach is employed. This approach is rooted in the recognition that a nuanced understanding of the complex landscape of circular innovation demands a multi-dimensional exploration. To begin, an extensive literature review is undertaken, serving as the foundational cornerstone of the study. This literature review not only establishes a robust theoretical framework but also sheds light on existing drivers, barriers, and strategies within the realm of circular innovation.

Recognizing the potential limitations of relying solely on theoretical constructs, a complementary methodological dimension is introduced: case studies. These case studies zoom in on high-tech companies operating within the Netherlands, contextualizing circular innovation within a specific geographical and industry setting.

The significance of these case studies lies in their capacity to bridge the gap between theory and practice. While the literature review furnishes a foundational understanding, it is the case studies that bring theory to life. These real-world cases allow for the exploration of intricacies that might not be fully encapsulated within the theoretical framework alone. By examining the practical applications, challenges, and successes of circular innovation within specific high-tech organizations, the study ensures that its findings are not only theoretically grounded but also practically relevant and actionable.

Moreover, in recognition of the dynamic and evolving nature of circular innovation, the study integrates expert validation into its methodology. This validation process involves engaging with industry experts and professionals, such as representatives from BlueCity Rotterdam and Holland Circular Hotspot.

Through this holistic approach, encompassing literature review, contextual case studies, and expert validation, the study aims to provide a comprehensive and insightful exploration of circular innovation within the high-tech sector in the Netherlands. This methodological tapestry weaves together theoretical foundations, practical realities, and expert perspectives, ensuring a well-rounded and robust analysis that contributes valuable insights to the field of circular



Figure 1.2: Visualised Research Methodology

innovation.

1.6.1. Sampling and Selection

This thesis's sample and selection section carefully selects Dutch high-tech firms at the forefront of technological advancements and adept at introducing and implementing circular innovations in the market. A rigorous selection process will ensure a representative sample. This process will involve thorough searches of reputable online directories, databases, and circular economy and high-tech expert recommendations. The company's market traction, product or service introduction, and circularity commitment are key selection criteria. The research seeks to understand circular innovation through advanced technologies in high-tech companies that are committed to circular principles. The next case study chapter will explain each selection and ensure research methodology transparency and validity.

1.6.2. Data Collection

Interviews will be conducted using a semi-structured format, which is suitable for exploring circular innovation drivers and barriers among Dutch high-tech companies. This method is well-suited to capture the potential diversity in products and services offered by these firms. A set of open-ended questions, aligned with the research sub-questions, will guide the interviews. Participants will receive comprehensive information about the research objectives and study scope prior to the interview. Interviews can be conducted either in-person or through online platforms, accommodating respondent preferences. All interviews will be recorded with explicit permission and transcribed verbatim using specialized software. The transcription accuracy will be ensured through careful review. Access to interview data will be restricted to the research team, safeguarding privacy and security. Any identifying information will be promptly anonymized to adhere to stringent data protection standards. Following data collection, a thorough preprocessing procedure will prepare the collected information for subsequent analysis stages.

1.6.3. Data Analysis

The data analysis process commences following the collection and pre-processing of the interview data. This transcription procedure entails attentive listening to the interview recordings to accurately capture the spoken content. Subsequently, the transcribed data is subjected to coding, which involves identifying and categorizing themes and patterns within the data into various codes.

The identified themes and patterns are further analyzed to extract insights and draw conclusions from the data. This analytical approach contributes to addressing the research questions and sheds light on the factors that facilitate or impede circular innovation within Dutch hightech firms. By systematically examining the data, this process aids in elucidating the dynamics surrounding circular innovation and provides valuable insights into its drivers and barriers in the context of high-tech companies.

1.7. Project Planning and Timeline

The project plan is given in the Gantt Chart attached below. The dates for the milestones have been decided keeping in mind the timeline, suggested dates on the graduation portal of the faculty of Technology, Policy and Management as well as in-depth discussion with the first supervisor.

1.8. Academic Relevance

Bocken et al. suggested avenues for future work offer a valuable foundation for addressing the primary and secondary research questions. To address barriers to circular innovation in high-tech companies, it is proposed that case studies be conducted to test the identified strategies, with a further breakdown of each strategy into sub-strategies. Additionally, the development of assessment techniques for evaluating the sustainability of circular products and business models can aid in identifying key drivers and deterrents to innovation in this field. Further investigation into infrastructure, enabling technologies, and supply chains can also provide



Figure 1.3: Projected Timeline of the Thesis

valuable insights into the challenges and opportunities associated with the implementation of circular innovation in high-tech firms. These research directions have the potential to enhance our understanding and offer practical solutions for fostering circular innovation in the high-tech sector [Bocken et al., 2016].

The future work that is suggested by Bocken et al. offers a helpful foundation for addressing the primary and secondary research questions. To overcome obstacles to circular innovation in high-tech companies, it has been suggested that case studies be created to test the discovered strategies, and that each strategy be further broken down into sub-strategies. The creation of techniques for evaluating the sustainability of circular products and business models can also help in pinpointing the major motivating factors and deterrents to innovation in this field. The need for more investigation into infrastructure, enabling technologies, and supply chains can also offer important insights into the challenges and possibilities for implementing circular innovation in high-tech firms[Bocken et al., 2016].

By addressing these gaps in knowledge, future research endeavors have the opportunity to advance the understanding of circular innovation in high-tech companies and provide more comprehensive insights into the barriers and drivers specific to this context.

1.9. Practical Relevance

By understanding the specific elements that drive or hinder circular innovation, entrepreneurs can strategically position their companies to seize opportunities in the circular economy. Additionally, knowledge of niche strategies enables business owners to identify market niches where they can add value and differentiate themselves from competitors. This knowledge is particularly valuable for high-tech companies, as they often face unique challenges in implementing circular innovation. By leveraging niche strategies, entrepreneurs can overcome these challenges and develop groundbreaking and economically viable solutions.

Accelerators and business incubators play a vital role in supporting new businesses, and their understanding of circular innovation drivers and barriers enables them to identify highpotential ventures and provide targeted support to address specific challenges. For impact investors and venture capital firms, understanding the forces that drive and impede circular innovation in high-tech businesses is essential. Additionally, knowledge of niche strategies can help them identify firms that are developing unique solutions with the potential for significant impact. Policymakers also recognize the importance of circular innovation in high-tech firms, as it aligns with national and international efforts to promote the circular economy. By identifying the main drivers and barriers of circular innovation, policymakers can pinpoint areas where supportive legislation and regulations can encourage the growth of circular enterprises. This information could be instrumental in the development of public-private initiatives and partnerships that foster circular innovation.

Overall, this research provides actionable insights to businesses, policymakers, and relevant stakeholders on how to encourage the adoption and diffusion of circular innovation in the high-tech sector. By identifying key drivers and barriers and proposing niche strategies to overcome challenges, this study contributes to the development of a more comprehensive understanding of the techno-social system behind a particular innovation.

2

Literature Study

With the research problem, objectives, and methodology now established, a rigorous examination of the literature is warranted to gain a deeper understanding of circular innovation, particularly with regard to the drivers and barriers within the high-tech industry. This research draws upon a rigorous examination of academic literature from reputable journals in the field. The investigation focuses on prominent journals known for their contributions to the study of circular innovation, including the Journal of Industrial Ecology, Journal of Cleaner Production, Journal of Environmental Management, International Journal of Sustainable Development, and World Ecology. These journals were selected based on their relevance and high publication frequency of articles related to circular innovation and sustainable development.

To ensure the reliability and comprehensiveness of the literature review, articles were systematically collected from these top journals. The search process involved utilizing keywords and relevant terms related to Circular Economy, circular innovation, drivers, and barriers. In addition, synonyms and related concepts such as eco-innovation, Circularity, enablers, hindrances, opportunities were included to capture a broad range of literature. Furthermore, this research recognizes the importance of considering grey literature from authoritative sources such as the European Union, Economic Commission, and other industry-specific organizations. Grey literature, consisting of reports, white papers, guidelines, and policy documents, offers valuable practical insights and industry perspectives on circular innovation.

This chapter will begin with an introduction to the concept of Circular Economy, providing a comprehensive understanding of its key principles and ideas. It will also address some critical viewpoints and critiques surrounding the Circular Economy, while emphasizing the importance of a systemic perspective in its implementation with further related work that can be found in Appendix A. Furthermore, the chapter will present an operational definition of Circular Innovation supported by relevant literature. In addition, it will explore the concept of Technological Innovation Systems (TIS), highlighting the various building blocks and their respective areas of focus within the context of Circular Innovation. The chapter will delve into the drivers that propel circular innovation forward, as well as the barriers that pose challenges to its realization.

2.1. Towards Circular Economy

The Industrial Revolution and the two World Wars brought about systemic socioeconomic changes that affected how products were extracted, created, delivered, consumed, and discarded [Womack et al., 2007]. Schot and Kanger referred to these shifts as the "First Deep Transition," because they had serious cumulative effects on the environment, including climate change, ecological degradation, and the depletion of natural capital [Schot and Kanger, 2018]. Even with major environmental improvements in both rich and developing nations, the current global patterns in production and consumption will continue to be an issue for both the present and the future generations. As De Jesus and Mendonça point out in their 2017 paper, throughout the 2000s, the concept of Circular Economy matured as a synthetic idea. It covers a wide range of subjects, such as product-life extension activities (reuse, repair, recycling), material efficiency, product-service systems, sustainable consumption and production interactions, waste management and networks of recovery, closed-loop supply chains, cleaner production, green/regenerative design, and "cradle to cradle" approaches [De Jesus and Mendonça, 2018]. In line with this, circular business models are intended to lower costs, boost revenues, manage risks, as well as open up opportunities for the financial sector to aid in the transition to sustainability [Corvellec et al., 2022; MacArthur, 2020].

2.2. Critiques of Circular Economy

Despite having broad support, Circular Economy has only recently seen a small amount of implementation [Kirchherr et al., 2018]. As Corvellec et al. point out, With stakeholders, scales, and various sectors identified, the concept of Circular Economy is widely discussed as an idea as well as an ideal; however, the concept's "practicalities" and actual implementations are few and fragile. This is explained by criticisms that highlight implementation issues at the three levels of policies, organizations, and individual consumers [Corvellec et al., 2022].

When it comes to circular business models, similar problems arise at the organizational level. First of all, there are many different circular business models with various approaches to Circular Economy [Geissdoerfer et al., 2018a], and while some companies claim to promote Circular Economy, Stål and Corvellec found that they actually focused their efforts on just a few aspects of their operations [Corvellec et al., 2022].

However, researchers put forward an argument that, even if the goal would be to recirculate materials just once, circular business models are not validated until a certain number of recirculated products have been sold. This is in contrast to linear business models, which are validated as soon as a specific number of products or services have been sold. The development of circular business models is hampered by a number of factors, including but not limited to "technical barriers such as an inappropriate technology, or a lack of technical support and training"; "economic barriers such as capital requirements, high initial costs, or uncertain return and profit"; institutional and regulatory barriers such as a lack of a supportive legal system, or a weak institutional framework"; and "social and cultural barriers such as a rigidity of consumer behavior" [Corvellec et al., 2022; Khan et al., 2021; Pieroni et al., 2021; Linder and Williander, 2017; De Jesus and Mendonça, 2018].

Additionally Pieroni et al. state that, most firms are failing to translate the concept of being circular into their business operations and most firms lack the capabilities to implement circular business model innovation. The authors also mention that there are unresolved questions

that remain on how to navigate linear lock-ins and trade-off decisions and especially on how to scale up circular innovations [Corvellec et al., 2022]. On the other hand [Sariatli, 2017] in 2017 published a SWOT analysis of Circular Economy and in it one of the weaknesses identified was "No specific guidelines to sectors on how to implement Circular Economy" and a key opportunity noted was "Developing expertise in sectoral or cross-sectoral challenges in circular solutions opens business opportunity for the enablers" Sariatli [2017].

2.3. Innovation for Circular Economy

Since Joseph Schumpeter's pioneering writings in 1928, it has been recognized that innovation is more than just novelty. It is rather a "new combination" of theories and production factors. Innovation is the introduction of an original idea into a particular, and sometimes peculiar, institutional and economic setting. It is not just about technical sophistication; it also involves adaptation to a usage context [De Jesus et al., 2018; wik, 2023; Schumpeter and Backhaus, 2003; Fagerberg et al., 2005]. Related work and further contextual information can be found in Appendix A.

Therefore, innovation that is pro-circular can be defined as new or augmented socio-technical solutions that protect resources, lessen environmental deterioration, and/or enable the recovery of value from resources already in use in the economy. It is regarded as a systemic problem-solving tool for enabling a holistic and transformative *departure from the present unsustainable state of affairs*. In order to provide an explicit (dynamic) conceptual backdrop for the discussion of circular innovation, the neo-Schumpeterian systems view is combined with the newly emerging "transformation turn" in innovation studies [De Jesus and Mendonça, 2018; wik, 2023]. However, it must be noted that Circular Innovation is not the same as Circular Business Model Innovation. ¹

2.4. Circular Innovation

Circular innovation is a new approach to sustainable development that aims to shift production and consumption away from the linear take-make-waste model and toward a circular one. This is accomplished by developing closed-loop systems that prioritize material and energy reduction, reuse, and recycling. Circular innovation has received a lot of attention as a solution to environmental issues such resource depletion, pollution, and climate change. Because it calls for the creation of new products, services, and business models that are intended for reuse and recycling, innovation is essential to the circular economy's success.

For the scope of this study, the following criteria will be used as a baseline for the definition of Circular Innovation:

• The product or service should be circular by design. It should not be an afterthought. Explicit transition towards sustainability is seen. Product or service was designed and

¹The concept of circular business model innovation encompasses the conceptualization and implementation of circular business models, which can involve various approaches such as establishing circular start-ups, expanding into diverse circular business models, acquiring existing circular business models, or transforming an existing business model into a circular one [Geissdoerfer et al., 2020]. These principles are important to keep in context as literature has revealed that circular business models and strategies are interlinked [Schulte, 2013; Bocken et al., 2016; Blomsma et al., 2018; Lewandowski, 2016]. Refer Appendix A.

developed with the sustainability goals in mind. Adheres to one or more of the 9 R's defined by Kirchherr et al. - Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Re-purpose, Recycle and Recover [Kirchherr et al., 2017; Suchek et al., 2021].

- The product or service has high longevity. This is ensured by conducting Life Cycle Analysis and the significant improvements in relative sense are observed. There is a certain degree of transparency, accountability and responsibility [De Jesus et al., 2018, 2019].
- Circular Economy is implemented and observed system wide, overall energy reduction, waste reduction and emphasis on perishable materials (resources) and net-zero (carbon). The materials used are also better in nature, circular in nature (mono-materials) [Kirchherr et al., 2017, 2018; Sehnem et al., 2019].
- Significant loops are closed (energy, material, parts, components, and/or product) [Lewandowski, 2016]
- From the customers' point of view, a certain degree of modularity is expected. "Product-Service Systems" or "Product-as-a-service" as an operational approach to Circular Economy. This can be done to any degree of the business [Lewandowski, 2016].

2.5. Systemic Perspective towards Circular Economy

The aptly titled paper "Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy" clearly summarized and concluded with some solid directions for future research. One key point being that although the majority of academic literature still focuses on technologically-based innovation, systemic innovation is becoming more and more prevalent in grey literature sources, especially EU reports. Another important conclusion, underscoring the issue's diversity, is that when thinking about the move toward Circular Economy, it's important to keep the innovation system's viewpoint at the forefront.

Additionally, In order to address interactions, linkages, trade-offs, and mismatches between technological and socio-institutional systems in the context of Circular Economy and circular-friendly innovations, more knowledge is needed with respect to it's implementation itself. The nuances and specific innovation tools needed to achieve a transformative and systemic transition need to be better understood [De Jesus and Mendonça, 2018; Stirling, 2011].

Additional Contextual information and related work can be found in Appendix A.

2.6. Technological Innovation System by Ortt and Kamp

As described by Ortt and Kamp, A Technological Innovation System is a specific representation of a socio-technical system around a technological innovation and can be defined as 'a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology.

The authors identify seven building blocks that combined will form the TIS. The building blocks are as follows:



Figure 2.1: Building Blocks of Technological Innovation System Framework by [Ortt and Kamp, 2022]

The seven components come together to create the Technological Innovation System (TIS). Radically new high-tech innovations can only be widely adopted if a full system, in which all the components are complete and interoperable, is present. On the other hand, a missing, imperfect, or incompatible building block or set of building blocks might impede widespread distribution. Such blocks then serve as a barrier. Explanation and description of each of the building blocks can be found in Table B.1 in the Appendix Appendix B.

However, before all building blocks are in place and large-scale diffusion becomes possible, it is often possible to introduce a specific version of the innovation in a niche segment[Ortt and Kamp, 2022]. In such cases, when some of the building blocks are in place yet a few others are missing, not yet complete or not compatible, a niche introduction strategy may be possible. This has been very clearly explained with the examples of Poly-ethylene fibre and Photovoltaic cells in the paper. Ortt and Kamp explain with examples that it is possible to determine the timing and scope of introduction strategies if a TIS building block is insufficient, missing, or incompatible, indicating that a barrier is impeding large-scale diffusion. The barrier's existence necessitates the employment of a small-scale niche introduction approach. But sometimes the nature of the barrier does not offer enough details to evaluate the kind of niche introduction approach. Studying the barrier's root cause might yield additional details that can be utilised to create a particular kind of niche introduction approach [Ortt and Kamp, 2022].

As a result, knowledge of influencing conditions may be utilized to determine the source of a barrier, and that cause can then be used to develop the sort of niche introduction approach. That is, influencing factors can give useful information for developing niche introduction tactics. Detailed description of the Influencing conditions can be found under Appendix B in Table B.2.

Seven influencing conditions were also identified and noted in the paper. They are as follows:



Figure 2.2: Influencing Conditions of Technological Innovation System Framework by [Ortt and Kamp, 2022]

2.7. Niche Strategies

According to prevalent literature, niche strategies are workable methods for introducing radically new innovations to the market in cases where large scale diffusion is not possible. It has been noted that in a high-tech environment, niche market strategies are found to be relatively successful [Ortt and Kamp, 2022; Hultink et al., 1997].

As published in the paper by Ortt and Kamp, for about 20 percent of the cases investigated, a mass market strategy was a viable option, contingent on the fact that they are able to get to an industrial level of production and large scale diffusion relatively soon after the market introduction [Ortt et al., 2013]. However, it is important to note that core technological, market and contextual factors are appropriate and do not hinder this process. This would allow the firm to attain large scale diffusion by lowering the production costs by achieving economies of scale. However, it is critical to point out here that this is not plausible at all instances and therefore, companies end up moving forward with a niche strategy.

In the context of this thesis, niche strategies refer to focused approaches employed to introduce novel products or services within a particular market segment. These strategies aim to address barriers to large scale diffusion by initially launching the product in a smaller market characterized by a distinct group of consumers who possess specific needs and preferences. By targeting this niche market, companies might be able to overcome barriers to large-scale diffusion. The paper by [Ortt et al., 2013] identifies ten niche strategies that could serve as a starting point in terms of Niche strategies that can be applied by high-tech startups engaged in circular innovation. The list of strategies can be found in Appendix C along with some related work on Niche Strategies.

2.8. Drivers of Circular Innovation

This section will explore various factors that drives the adoption and implementation of circular innovation. It will analyze scholarly writings, business reports, and grey literature to identify the key drivers associated with circular innovation. Based on the Literature review, the following factors act as drivers to Circular Innovation.

2.8.1. Product/Services

Circular high-tech innovation distinguishes itself as an alternative approach to product development, exhibiting notable deviations from traditional innovation practices [Gedam et al., 2021]. The effectiveness of circular high-tech innovation relies on the ability to introduce groundbreaking high-tech products that not only excel in performance and quality but also adhere to the principles of circularity [De Jesus et al., 2018]. In the realm of circular high-tech innovation, the focus extends beyond mere compliance with performance and quality criteria, encompassing the imperative of designing products that optimize resource efficiency, minimize waste generation, and facilitate prolonged product utilization and reusability.

This serves as one of the more important factors. De Jesus et al.; Gedam et al.; Ritzén and Sandström; Hina et al.; Kirchherr et al. mention this and have noted how this is a critical driving factor all the while noting the conditions where it could turn into a barrier in publications ranging from 2017 to 2022.

2.8.2. Technical Prowess and capabilities

Research indicates that technical prowess and capabilities play a crucial role in driving circular innovation. The presence of advanced technologies enables efficient resource optimization, facilitates the re-manufacturing process, and supports the regeneration of by-products for utilization in other processes. However, despite these potential benefits, several challenges and barriers need to be addressed to ensure a successful transition towards circular practices. One such challenge is the imperative need for high-quality re-manufactured products that meet stringent standards and customer expectations. Seamless integration of circular designs into existing production processes poses another hurdle that demands careful planning and execution. Furthermore, the timely adoption and diffusion of circular innovations are critical to drive systemic change and maximize their impact [De Jesus et al., 2018; Bicket et al., 2014].

For example, products intended to be rented and restored repeatedly require in-depth knowledge about ongoing improvements and the optimization of part replacement, which is a prerequisite for designing optimal product life-cycle scenarios for new products and processes. The availability of technical solutions is also a prerequisite for balancing product durability, efficiency, and quality. This has been highlighted, not only in academic literature, but grey literature as well [EMF, 2021, 2012].

2.8.3. Economic/Financial/Market

There are many different economic, financial, and commercial elements that might have an impact on circular innovation. Solutions that encourage cost savings and stability may be necessary in response to rising resource demand and the resulting pressures on resource

depletion. The implementation of circular innovation, however, may be hampered by reasons such as a lack of financial resources, substantial expenses, and profit and return uncertainties. The adoption of circular innovation can also be hampered by asymmetric knowledge, the present linear system in place, cheap pricing for virgin materials, and a lack of standardization Ritzén and Sandström [2017]; De Jesus et al. [2018]; Kirchherr et al. [2018].

Technical solutions may already be "out there" in some circumstances, but due to market and economic constraints, their practical applicability is frequently constrained. New investments are constrained by challenges including high startup costs and unpredictable market conditions. Additionally, current socio-technical systems are frequently characterized by lockins and inertia, which are made worse by strong route dependencies that are hard to overcome [De Jesus et al., 2018].

The significance of economic factors is emphasized in the grey literature. In terms of obstacles, the grey literature emphasizes market imperfections, such as incomplete information and investment costs [EC, 2015]. The adoption of new circular business models is constrained by significant financial barriers related to the cost of developing and implementing innovation as well as the challenge of overcoming linear economic lock-ins, particularly in nations with financing challenges and a high concentration of small businesses [EMF, 2012, 2021].

2.8.4. Value/Supply Chain

The value/supply chain factor is a crucial component that promotes the growth of circular innovation. It comprises all aspects of supply chain optimization, such as the availability of premium circular products, effective logistics, and cooperation across value chain enterprises. In the 2015 paper, the author D'heur stated *"The value chain consists of the product development and supply chain processes of an organization. It covers all stages of the life-cycle from idea/concept, raw material sourcing, production, and distribution, and end customers use to the point where the product goes back to a biological or technical cycle, thus closing the loop."*

One major impediment to the efficient movement of materials and resources in a circular economy is a lack of supply chain optimization. Furthermore, the value chain's resilience is critical since it enables the capacity to respond to and recover from disturbances. Another key part is the development of strong reverse logistics systems that allow for the collection, sorting, and processing of discarded or old items for recycling or re-manufacturing [Ritzén and Sandström, 2017; Kirchherr et al., 2018; Gedam et al., 2021]. Additionally, the financial viability of circular processes needs to be ensured at every level of the value chain. Successful circular innovation also demands cooperation and a commitment to work together among the many actors throughout the value chain, as it involves shared efforts and responsibilities [Hina et al., 2022].

A number of obstacles prevent a circular value/supply chain from being realized. These include a lack of supply chain design and optimization, disruptions in the supply chain, subpar quality in circular products, insufficient packaging and cold chain, and a lack of market cooperation among companies [Werning and Spinler, 2020; Eisenreich et al., 2022; Gedam et al., 2021; Kirchherr et al., 2018].

2.8.5. Structural/Operational services and products

The operational/structural component is related to market or industry-specific elements that could have a big impact on a company's performance. Although these elements are beyond of a company's direct control, they may significantly affect how they operate. The industry is characterized by structural forces that encourage cyclical innovation [Ranta et al., 2018].

This is a very significant building block as it is crucial for this to be compatible. As Kirchherr et al.; Gedam et al.; Ritzén and Sandström explain, this is often outside the locus of control for a firm itself and often is in connection to the nature of the industry itself. Several scholars emphasize the need of cooperation among industrial actors. This coordination entails not only real collaboration among players, but also a shared vision for technical innovation and the TIS that surrounds it. A shortage of actors, or a lack of cooperation among them, can prevent large-scale diffusion [Kirchherr et al., 2017; Ritzén and Sandström, 2017; Gedam et al., 2021; Ortt and Kamp, 2022].

2.8.6. Customer

The customer factor plays a critical role in the success of circular innovation. The three key customer drivers are social awareness, environmental literacy, and shifting consumer preferences. Social awareness refers to the increasing consciousness among customers about social issues such as sustainability. Environmental literacy is the knowledge and understanding of environmental issues, which has a significant impact on customer decisions. The shift towards service-based models, as opposed to asset ownership, is another driver of customer behavior. However, certain barriers can hinder the adoption of circular innovation by customers. These include a lack of consumer perception, limited involvement and support from consumers and suppliers, and rigidity in consumer behavior and business routines. Overcoming these barriers requires a deep understanding of customer behavior and effective communication strategies [Gedam et al., 2021; Kirchherr et al., 2018; Ritzén and Sandström, 2017; Hina et al., 2022].

2.8.7. Institutional/Regulatory Factor

The institutional/regulatory component is a critical aspect in whether or not circular innovation is possible. This comprises laws governing the environment, rules for waste disposal, and the existence of a supportive legal system. Circular Economy can be supported by the presence of certain restrictions, but their absence or misalignment might act as a severe impediment. The issue is further complicated by the limited use of circular procurement methods and the absence of a worldwide agreement on Circular Economy. Organizations wanting to engage in circular innovation face difficult obstacles include skewed incentives, a weak institutional structure, and a lack of laws and rules[De Jesus and Mendonça, 2018; Ritzén and Sandström, 2017; Hina et al., 2022; Kirchherr et al., 2018; Trevisan et al., 2023].

However, due to a lack of legal enforcement, the present complicated government structure and policy framework provide hurdles for the transition to a circular economy. Furthermore, mismatched incentives, a defective legal system, and a deficient institutional structure hamper progress toward a Circular Economy[Gedam et al., 2021].
2.8.8. Attitudinal and Organisational

Circular innovation is significantly influenced by social, cultural, and behavioral factors. Two major forces that might assist circular innovation are a rise in environmental awareness among people and a move toward sustainable lifestyles and consumption habits. The inclination of consumers for sharing and cooperative systems over asset ownership has recently increased. The development of circular innovation can, however, be hampered by a number of barrier factors, including a lack of knowledge of and/or willingness to participate in the circular economy, risk aversion, and a poor understanding of sustainability. A barrier to a more sustainable and circular economy might also be the lack of Key Performance Indicators (KPIs) and industry knowledge. To overcome these challenges and advance toward a more sustainable future, it is thus essential to raise awareness of and encourage engagement in circular innovation [Gedam et al., 2021; Kirchherr et al., 2018].

Consumers have not yet fully accepted items based on Circular Economy, despite its benefits for the economy and the environment. This might be as a result of Circular Economy-based business models not meeting the cultural, social, and psychological demands of customers, which acts as a barrier to Circular Economy's spread. Additionally, customers' unfavorable attitudes and actions toward circular items provide a barrier to Circular Economy acceptance. To fully adopt a Circular Economy, customers and suppliers must actively participate, yet both groups are reluctant owing to higher costs or problems with quality. These external stakeholders must be included and supported if the supply, usage, and procurement of sustainable goods and services are to be improved, which makes their involvement crucial to the success [Gedam et al., 2021; Kirchherr et al., 2018; Trevisan et al., 2023].

It is also important to mention that the success of a company's efforts to implement circular innovation is significantly influenced by its organizational structure. It covers elements that may influence the creation and provision of a successful circular good or service, such as culture, values, structure, and resources. The organizational drivers have the potential to either support or limit a company's capacity for value creation and innovation in a circular economy. However, a number of barriers may prevent circular innovation from being successful within a given firm. These include a lack of knowledge, teamwork, leadership, and training inside the organization. There could also be problems with the business model's scalability and replication, a lack of circular indicators, a reluctant corporate culture, and a lack of impact data [Kirchherr et al., 2018].

As Gedam et al. explained, for the circular economy to be successful, the firm's awareness, practice, collaboration, and leadership are essential. However, because to a lack of time, vision, and resources, companies disregard Circular Economy priorities, which results in detrimental behavior as well as a lack of awareness and leadership. The firm's interest in Circular Economy is impacted by the lack of training and expertise. Organizations often find it challenging to convey, report, and track the development of Circular Economy due to the disjointed and fragmented nature of Circular Economy indicators [Kirchherr et al., 2018; Gedam et al., 2021].

2.9. Barriers to Circular Innovation

This section lists out the factors that potentially cause barriers to Circular Innovation [De Jesus and Mendonça, 2018; Kirchherr et al., 2018; Ranta et al., 2018; Ritzén and Sandström, 2017;

Ranta et al., 2018; Hina et al., 2022; Gedam et al., 2021].

2.9.1. Technological Know-how

Technology know-how plays a crucial role in circular innovation. Furthermore, the scope of circular designs remains limited, preventing the full realization of their potential impact. Ritzén and Sandström talks about how it might be difficult to integrate a circular product into currently established production processes. Additionally, the establishment of more large-scale demonstration projects can serve as powerful showcases to inspire and accelerate the adoption of circular practices throughout various industries [Kirchherr et al., 2018; Ritzén and Sandström, 2017; Gedam et al., 2021; Hina et al., 2022; De Jesus and Mendonça, 2018].

2.9.2. Market, Industry and Competition

Market, Industry and Competition have shown to be vital for circular innovation [De Jesus and Mendonça, 2018; Ritzén and Sandström, 2017; Kirchherr et al., 2018; Gedam et al., 2021]. This involves understanding how the innovation can be applied and being aware of the market structure and key actors involved. However, challenges such as asymmetric information, uncertain returns, and lacking economic viability can impede this. These challenges hinder customer and supplier engagement in circular practices. Overcoming these obstacles is noted to be crucial in order to foster transparency, predictability, and economic viability, enabling the success of circular innovation. Realistically, there is competition between innovations based on old and new technologies, as well as among different versions of products utilizing new technology. This competition extends to various components, production systems, complementary products, and services. [Hina et al., 2022]. Additionally, competition influences other factors as well, including the relative price and performance of innovative solutions. Circular firms not only compete with conventional products and services but also face competition from other circular offerings, further shaping the success of the firm [De Jesus and Mendonça, 2018; Kirchherr et al., 2018; Ritzén and Sandström, 2017].

2.9.3. Resources

Several papers that study the barriers to circular economy mention Resource availability as a key factor that influences circular innovation. Firstly, natural resources are required for creating products, production systems, and complementary goods. These resources can be acquired individually or through collaborations between organizations. Secondly, mobilizing human resources with the necessary knowledge and skills is essential. This expertise can be obtained through education programs, training, or practical experience. Finally, financial resources are required for the development, application, and support of the innovation, production systems, and complementary products and services. These resources can come from various sources such as suppliers, investors, government institutions, or customers [De Jesus and Mendonça, 2018; Gedam et al., 2021; Ritzén and Sandström, 2017; Hina et al., 2022; Kirchherr et al., 2018; EMF, 2012].

2.9.4. Strategy, Economy and Institutions

Economic and strategic aspects are influential factors in the building blocks of the Transition Innovation System (TIS) [Ortt and Kamp, 2022]. The state of the economy, such as economic growth or recession, can either hinder or facilitate TIS formation. Economic growth provides resources and support for incubation activities and consultancy services, fostering the development of circular initiatives. Market structures and strategic policies adopted by countries also impact TIS formation. The European Union (EU) has taken a proactive role in promoting the circular economy through initiatives like the Circular Economy Action Plan and the European Green Deal [Kirchherr et al., 2018; EC, 2015; Commission, 2003; EC, 2016]. By aligning with the EU's circular economy vision, businesses can leverage these strategic policies to shape their TIS building blocks and contribute to a more sustainable future.

2.9.5. Social and Attitudinal

Socio-cultural aspects have shown to play a significant role in the context of circular innovation. These aspects encompass the norms, values, and beliefs held by potential customers and other key stakeholders within the socio-technical system. While more informal than institutional factors, socio-cultural aspects can greatly influence the behavior of actors within the market and industry. It is important to note that these aspects are not static and can evolve over time, potentially shifting from being supportive to becoming hindrances for circular innovation. [Ritzén and Sandström, 2017; Hina et al., 2022; Repo and Anttonen, 2017; Kirchherr et al., 2018; Gedam et al., 2021]. This is not just limited to customers, but also to other firms, investors and actors throughout the value/supply chain.

In the context of circular innovation, customer perception holds particular importance. Ritzén and Sandström talk about the risk appetite as well as the perception of sustainability. Recent environmental awareness has led to significant changes in ownership preferences and purchase decisions. Customers are increasingly conscious of the environmental impact of their choices and are more inclined towards sustainable alternatives. However, customers may still exhibit hesitancy towards embracing new approaches or circular products [Singh and Giacosa, 2019].

2.9.6. Accidents

From a company perspective, it is important to take into account unforeseen events and accidents [Ortt and Kamp, 2022]. In the context of circular innovation, accidents could have a significant influence. These incidents can happen internally, such as manufacturing errors or product failures, or they can happen externally, such as wars or natural catastrophes. Accidents show the unpredictability of innovation processes and emphasize the significance of resilience and flexibility in the circular innovation environment. Since supply chains are a crucial part of any circular economy, supply chain disruptions caused by any natural event or otherwise can have potentially big repercussions [Gedam et al., 2021].

2.9.7. Leadership and Organisational

Within the context of CI, leadership and the company as a whole are crucial factors. Adopting circular processes may be significantly hampered by a firm's lack of leadership, collaboration,

and awareness. Leadership is crucial in recognizing the value of Circular Economy principles and actively promoting them inside the company. The adoption and successful implementation of circular methods may also be hampered by the lack of training and expertise in circular economy principles. Companies may find it difficult to negotiate the complexity of circular business models without the requisite knowledge and skills. The circular business model's replication and scalability provide another difficulty. Gedam et al. do a great job at explaining what this entails in the 2021 paper "Circular economy practices in a developing economy: Barriers to be defeated".

Additionally, it is difficult for businesses to evaluate and convey their success in this specific context since there are no defined circular indicators. Progress is further hampered by a cautious corporate culture that opposes change and lacks a proactive approach to Circular Economy. Last but not least, making informed decisions and evaluating circular processes are made more difficult by the lack of comprehensive data, which includes knowledge on environmental and social impacts. Organizations may promote and quicken the shift to a circular economy by addressing these influencing factors and developing great leadership [Ritzén and Sandström, 2017; Gedam et al., 2021; Hina et al., 2022].

The literature review conducted in this chapter has shed light on the drivers and barriers of Circular Innovation, providing valuable insights into the factors that influence its implementation. These drivers and barriers have been loosely categorized, allowing us to understand the dynamics of Circular Innovation better. Additionally, the chapter explored the concept of Technological Innovation Systems (TIS) and its components, providing a comprehensive understanding of the framework's intent and structure. Furthermore, an operational definition of Circular Innovation was established, accompanied by critical reflections on its strengths and weaknesses. It is also to be noted that certain papers used in this literature review such as [Kirchherr et al., 2018; Ritzén and Sandström, 2017] would be of broader focus, across regions and industries. It is important to keep in mind the scope of the research in context moving forward.

Having completed the literature review, the subsequent chapter will delve into the conceptual model, elucidating the individual building blocks of Circular Innovation and highlighting their specific focus areas within the context of the study.

3

Conceptual Model

This chapter delves into the building blocks and influencing conditions of the Technological Innovation System (TIS) framework, with a specific focus on their significance within the context of circular innovation. Our objective is to gain insights into the specific key areas that hold particular importance in the context of circular innovation by understanding each component of the TIS framework. The TIS framework was originally designed as a tool to formulate niche strategies in cases where large-scale diffusion may not be feasible. In this thesis, we aim to apply the TIS framework to the context of circular innovation and explore whether niche strategies can effectively overcome the barriers to large-scale diffusion. In order to accomplish these objectives and advance the research, the upcoming phase of the study will involve a detailed exploration of specific focus areas within each component of the Technological Innovation Systems (TIS) framework, tailored to the context of Circular Innovation. This analysis will provide a comprehensive understanding of how each component contributes to the overall functioning of the TIS and its influence on Circular Innovation.

The tables D.1, D.2, D.3 and D.4 in Appendix D provide a summary of the factors and focus areas for each of the building blocks and influencing conditions of the Technological Innovation System (TIS). These keywords were identified through a review of the literature on circular innovation above. The tables are intended to be used as a tool for understanding the challenges and opportunities for circular innovation. The keywords were added to the TIS building blocks and influencing conditions to adapt it to be better for circular innovation. The TIS can be used to understand the factors that influence the adoption of new technologies and practices. By adapting this TIS this way, it can be used to better understand the specific challenges and opportunities for circular innovation."

3.1. Context specific key areas for Building Blocks

The following section provides an overview of the building blocks of the Technological Innovation Systems (TIS) framework, drawing insights from the literature review. It aims to identify the key areas of focus within each block and enhance the effectiveness of case studies by following a well-informed and structured approach. Understanding the drivers and barriers mentioned earlier will not only help in determining the relative importance of the building blocks but also guide the focus for each block and influencing condition, enabling a targeted exploration of niche strategies to overcome barriers to circular innovation.

3.1.1. Product Performance and Quality

As elucidated earlier, the concept of "Product performance and quality" takes on a distinctive dimension within the context of circular innovation. In addition to meeting conventional standards of performance and quality, circular high-tech products strive to align with circular principles. This entails going beyond traditional metrics to maximize resource efficiency, minimize waste generation, and foster long-term product use and reusability.

Circular high-tech innovation places a significant emphasis on not only delivering superior performance and quality but also integrating circular principles into every stage of product design and development. This entails reimagining the entire product lifecycle, from sourcing sustainable materials and employing eco-friendly manufacturing processes to designing for durability, reparability, and recyclability. By prioritizing circularity, high-tech companies can create products that not only excel in functionality but also embody sustainability, contributing to the transition towards a more resource-efficient and regenerative economy.

By incorporating strategies such as material recycling, remanufacturing, and product-asa-service models, circular high-tech products strive to optimize resource utilization, minimize environmental impact, and foster a more sustainable and circular economy [Gedam et al., 2021; Ritzén and Sandström, 2017; Ranta et al., 2018; Hina et al., 2022; Kirchherr et al., 2017]. Therefore, for Circular Innovation, factors such as Design for Circularity and resource optimization would be of focus under this building block.



Figure 3.1: Elements of Focus in Product Performance and Quality

3.1.2. Product price

In the context of circular innovation, the price aspect entails key distinguishing factors. Unlike conventional approaches, circular high-tech innovation considers not only the initial product cost but also the long-term feasibility and total cost of ownership This has been highlighted by several authors. While circular economy principles aim to create value and reduce waste, the implementation of circular practices may involve additional costs, such as incorporating recycled materials or implementing remanufacturing processes. Balancing the economic feasibility of circular products with their environmental benefits is crucial. It requires evaluating the life cycle costs, assessing the potential for cost savings through extended product lifetimes, and identifying opportunities for innovative business models such as leasing or sharing. By carefully considering the price factor and finding ways to align economic viability with circular principles, this building block can be completed[Kirchherr et al., 2017; Ritzén and Sandström, 2017; De Jesus et al., 2018; EC, 2015].

Product Price				
Long Term Feasibility	Total Cost of Ownership			

Figure 3.2: Elements of Focus in Product Price

3.1.3. Production system

In the context of circular innovation, the production system and technical know-how play a significant role in distinguishing factors. Circular high-tech innovation requires a shift in production processes towards resource optimization, waste reduction, and the integration of circular practices. Key factors include adopting advanced technologies that enable efficient use of resources, implementing remanufacturing and recycling processes, and fostering collaboration across the value chain. Technical know-how becomes crucial in designing products for disassembly, implementing reverse logistics systems, and ensuring the quality and performance of recycled materials. Moreover, the production system should be flexible and adaptable to accommodate changes in product design, materials, and processes, enabling the transition towards circularity. Emphasizing technical know-how and continuously improving production systems are essential for successful circular high-tech innovation [Ranta et al., 2018; Bicket et al., 2014; EMF, 2012, 2021]. Production system is known to be a critical component of a circular Innovation, particularly the 9R capabilities and Scalability.



Figure 3.3: Elements of Focus in Production System

3.1.4. Complementary products and services

In the context of circular innovation, the availability of complementary products and services plays a crucial role. It is essential for companies to have access to a supportive ecosystem that includes a range of complementary goods and services. This includes infrastructure, network support, and effective communication channels. Collaboration and cooperation among industrial actors are key factors in operationalizing circular innovation. Coordination among players, shared visions for technical innovation are indicated to be necessary for large-scale diffusion of circular practices. However, challenges may arise due to a lack of actors or insufficient cooperation among them. To overcome these barriers, fostering strong partnerships and establishing a shared understanding of circular principles within the industry are vital. Cooperation among actors and the availability of complementary products and services contribute significantly to the successful implementation and diffusion of circular innovation [Ritzén and Sandström, 2017; Gedam et al., 2021; Ranta et al., 2018; Kirchherr et al., 2017]. However, it must be noted that certain circular products/services do not require existing complementary

 Complementary Products and Services

 Collaboration
 Ecosystem of Products / Services
 Industry Specific Infrastructure

Figure 3.4: Elements of Focus in Complementary products and services

3.1.5. Network formation and coordination

Network formation and coordination are critical factors in the context of circular innovation. The successful implementation of circular practices requires effective collaboration and coordination among actors at all levels of the value chain. This entails building strong networks and fostering relationships between different stakeholders, including producers, suppliers, distributors, and customers. Effective coordination ensures smooth operations and seamless flow of materials and products within the circular economy. However, challenges may arise in terms of communication, division of responsibilities, and infrastructure. Overcoming these challenges requires proactive engagement, open communication channels, and a shared vision for achieving circular goals Hina et al. [2022]; Kirchherr et al. [2017]; Gedam et al. [2021]; Eisenreich et al. [2022]; Werning and Spinler [2020]. Just by the nature of Circular Innovation, this building block becomes crucial and factors such as Strong Network and the division of responsibility are highlighted.



Figure 3.5: Elements of Focus in Network Formation and coordination

3.1.6. Innovation-specific institutions

These institutions encompass regulatory frameworks, environmental laws, waste disposal regulations, and the overall legal system. Their effectiveness and alignment with circular economy principles significantly influence the feasibility and success of circular innovation endeavors. The absence or misalignment of supportive regulations, coupled with the limited adoption of circular procurement methods, creates formidable barriers. Moreover, the global perspective and coordination of innovation-specific institutions play a crucial role in circular innovation. The absence of a worldwide agreement on Circular Economy and the limited use of circular procurement methods pose significant challenges for circular innovation on a global scale. In contrast, conventional innovation may be less dependent on global coordination and agreements. Unfortunately, the lack of robust legal enforcement mechanisms, coupled with intricate government structures and policy frameworks, hinder the transition towards circularity. Inadequate alignment of incentives, deficiencies in the legal system, and institutional shortcomings

products and services, and a novel ecosystem would be required.

further impede progress towards realizing a truly circular economy. A critical evaluation and proactive remediation of these institutional factors are imperative to foster the transformative shift towards circular innovation[De Jesus and Mendonça, 2018; Ritzén and Sandström, 2017; Hina et al., 2022; Kirchherr et al., 2018; Trevisan et al., 2023; Gedam et al., 2021].

	Customers	
Awareness and	Ownership	Resistance to
Knowledge	Preferences	Change

Figure 3.6: Elements of Focus in Complementary products and services

3.1.7. Customers

Customers play a crucial role in driving the success of circular innovation. Research on cognitive sciences and preferences as indicated that increasing social awareness among customers about sustainability issues and their environmental literacy significantly impacts their decisionmaking process. Moreover, the shift towards service-based models and shared ownership also shapes customer preferences. However, there are certain barriers that can hinder the adoption of circular innovation by customers, such as limited consumer perception, lack of involvement and support from consumers and suppliers, and resistance to change in consumer behavior and business routines. Overcoming these barriers requires a deep understanding of customer behavior and effective communication strategies. It is crucial to identify potential customers who have a need for the innovation and ensure they are aware of its benefits compared to other products. Additionally, addressing barriers such as limited means, knowledge, and uncertainty about the product is vital to converting potential customers into actual customers [Gedam et al., 2021; Kirchherr et al., 2018; Ritzén and Sandström, 2017; Hina et al., 2022]. This block plays a pivotal role in the TIS. As literature has indicated that there is a perspective shift in the customers' mindset, this can quickly turn into a barrier for various reasons.

Innovation-Specific Institutions			
General Concensus	Standardisation	Emerging Robust Policies	

Figure 3.7: Elements of Focus in Customers

3.2. Context specific key areas for Influencing Conditions

As explained by Ortt and Kamp, it is important to have a clear understanding of the nature of barriers as well. Drawing insights from the literature review, it aims to identify and understand the key elements of each influencing conditions specific for Circular Innovation. By considering these influencing conditions, the study can provide valuable insights into the barriers and guide the formulation of effective strategies to overcome barriers to large scale diffusion.

3.2.1. Knowledge and awareness of Technology

When comparing the influencing condition of "Knowledge and awareness of technology" in circular innovation to other forms of innovation, several key differences emerge. In the context of circular innovation, technology know-how assumes a critical role within the Technological Innovation System (TIS). However, one notable distinction lies in the limited scope of circular designs, which hinders their full potential impact. As highlighted by Ritzén and Sandström, integrating a circular product into existing production processes can pose challenges. This suggests that circular innovation requires a deeper understanding of the intricacies involved in transforming traditional production systems to embrace circularity. By promoting knowledge and awareness of technology specific to circular innovation, these projects contribute to overcoming barriers and driving the transition towards a more circular economy [Hina et al., 2022; Gedam et al., 2021; Kirchherr et al., 2017, 2018; De Jesus et al., 2018; Ritzén and Sandström, 2017; Ranta et al., 2018].

Knowledge and Awareness of Technology				
Limited Scope of Circular Products	Large Scale Demonstration			

Figure 3.8: Elements of Focus of Knowledge and awareness of Technology

3.2.2. Knowledge and awareness of application and market

In circular innovation, understanding the application and market dynamics is crucial. Knowledge of how the innovation can be applied and awareness of the market structure and key actors are essential. However, challenges such as asymmetric information, uncertain returns, and economic viability can hinder progress. Overcoming these obstacles is vital for transparency, predictability, and economic success. Additionally, competition exists among different technologies and versions of products, influencing factors like price and performance. Thus, knowledge and awareness of application and market play a significant role in navigating these challenges and achieving success in circular innovation. Circular firms not only compete with conventional products and services but also face competition from other circular offerings, shaping the overall success of the firm [Hina et al., 2022; Ranta et al., 2018; Commission, 2003; EC, 2016; Vermunt et al., 2019].

Knowledge and Awareness of Application and Market			
Uncertain Returns	Linear Lock-ins	Assymteric Information	

Figure 3.9: Elements of Focus of Knowledge and awareness of application and market

3.2.3. Natural, human and financial resources

Literature has pointed out that Circular innovation requires a distinct approach to resource utilization. It involves optimizing resource efficiency, minimizing waste generation, and promoting resource regeneration. This necessitates a comprehensive understanding of the natural resources involved, their availability, and their sustainable use. Human resources play a vital role in circular innovation as well, requiring specialized knowledge and skills in circular design, resource management, and sustainable practices. Financial resources are also unique in circular innovation, as they need to support not only the development of innovative technologies and processes but also the establishment of infrastructure for resource recycling, remanufacturing, and the implementation of circular business models. Effective allocation and coordination of these resources are essential for successful circular innovation, distinguishing it from other forms of innovation that may have different resource requirements and management approaches EMF [2012]; Hina et al. [2022]; Kirchherr et al. [2017, 2018]; Ranta et al. [2018].



Figure 3.10: Elements of Focus on Resources

3.2.4. Macro-economic and strategic aspects

Macro-economic and strategic aspects are demonstrated to play a pivotal role as influencing conditions in the context of circular innovation. Uniquely, circular innovation necessitates a shift in macro-economic policies and strategic considerations. It requires a comprehensive understanding of the circular economy's potential impact on sectors, industries, and economies at large. Macro-economic factors such as resource availability, market demand, and regulatory frameworks need to align with circular principles and support the transition to a circular economy. Strategic considerations involve rethinking business models, supply chain configurations, and value propositions to align with circularity goals. Organizations must assess the economic viability and long-term sustainability of circular practices, considering potential costs, benefits, and returns on investment. This requires strategic foresight, innovative thinking, and collaboration across sectors to address systemic challenges and unlock the full potential of circular innovation [Kirchherr et al., 2018; Commission, 2003; EC, 2016; EMF, 2012; Hina et al., 2022].



Figure 3.11: Elements of Focus in terms of Economic Strategic Aspects

3.2.5. Socio-cultural aspects

Socio-cultural aspects play a significant role as influencing conditions in the context of circular innovation, presenting notable differences compared to other forms of innovation. The success of circular innovation relies heavily on the alignment of social and cultural norms, values, and beliefs with the principles of the circular economy. Environmental awareness and the growing interest in sustainable lifestyles and consumption patterns have emerged as driving forces for circular innovation. However, barriers such as limited knowledge, resistance to change, and cultural preferences for traditional ownership models can impede the widespread adoption of circular practices. Moreover, customer perception and attitudes towards circular products and business models can influence their acceptance and market penetration [Ritzén and Sandström, 2017; Hina et al., 2022; Repo and Anttonen, 2017; Kirchherr et al., 2018; Gedam et al., 2021; Singh and Giacosa, 2019].



Figure 3.12: Elements of Focus in terms of Socio-Cultural aspects

3.2.6. Competition

Competition is identified as a significant influencing condition in the context of circular innovation as it exhibits key differences. In circular innovation, competition extends beyond traditional product-based competition to include competition among different versions of products utilizing new technologies, various components, production systems, and complementary products and services. Circular firms not only compete with other circular offerings but also face fierce competition from conventional products and services. This unique competitive landscape shapes the success of circular innovation. Additionally, competition influences other factors such as relative price and performance of innovative solutions. Unlike in conventional innovation, circular firms need to navigate the competition between old and new technologies, as well as the competition among different circular solutions. This highlights the importance of differentiation, value proposition, and market positioning in the circular innovation space. Effectively addressing competition and positioning circular solutions in the market are key considerations for successful circular innovation [Ritzén and Sandström, 2017; Ranta et al., 2018; Chesbrough, 2010; Gedam et al., 2021].



Figure 3.13: Elements of Focus in terms of Competition

3.2.7. Accidents and Events

Accidents and events constitute an influencing condition in the context of circular innovation, showcasing key differences compared to other forms of innovation. The unpredictable nature of accidents, whether they occur internally within a company or externally as unforeseen events, can significantly impact circular innovation processes. Internal incidents such as manufacturing errors or product failures can disrupt the development and implementation of circular practices. External factors like wars or natural catastrophes can also disrupt supply chains, which are crucial in a circular economy, leading to significant repercussions. These incidents highlight the importance of resilience and flexibility in the circular innovation environment. The ability to effectively respond to and recover from accidents and events becomes essential for ensuring the smooth progression of circular innovation and mitigating potential disruptions [Gedam et al., 2021].



Figure 3.14: Elements of Focus Accidents and Events

3.3. Adapted TIS for Circular Innovation

Putting together all the key focus areas and adapting the TIS framework specifically to Circular Innovation, we get the following TIS. This model will be used moving forward in the Case Studies.

Knowledge and Awareness of Technology		Product Performance and Quality			
Limited Scope of Products	Circular Large Sca	le Demonstration	Design for Circularity	Resource Optimisation	Integrated PSS
Knowledge and	Awareness of Applic	ation and Market		Product Price	
Uncertain Returns	Linear Lock-ins	Assymteric Information	Long Term Feas	sibility Total Co	st of Ownership
Natural, H	uman and Financial	Resources		Production System	
Resource flow Optimisation	Leadership and Team Skills	Availability of Finances	9 R(s) Capabilities	Strong Reverse Logistics	Flexibility and Adaptability
Macro-Ec	onomic and Strategi	c Aspects	Compleme	entary Products and	Services
Systemic Perspective	Economic Conditions	Conducive Regulations	Collaboration	Ecosystem of Products / Services	Industry Specific Infrastructure
ç	Socio-Cultural Aspect	IS	Network	Formation and Cool	rdination
Literacy and Motivation	Informed Preferences	Limited Information and Knowledge	Strong Network	Division of Responsibility	Shared Goals
Competition			Innovation-Specific Institutions		itions
Market Positioning	Conventional Competition	Value Proposition	General Concensus	Standardisation	Emerging Robust Policies
Market Positioning	Conventional Competition	Value Proposition	General Concensus	Standardisation	Emerging Robust Policies

Figure 3.15: TIS Framework adapted for Circular Innovation

TIS Building Block / Influencing Condition / Focus Area is Incomplete/Incompatible/Unfavourable

Noted as a Driver in this TIS*

3.4. Expert Validation: HollandCircularHotspot

In the literature review chapter, we identified the key drivers and barriers of circular innovation, which informed the focal points within each component of the technological innovation system (TIS) and their influential conditions. Based on literature, these areas have been broadly categorized to help understand circular innovation's complexities. These focal points will be used to analyze interview-derived data in later chapters as we apply the TIS framework to case studies. This method will generate relevant codes and extract valuable insights from case studies, enabling a thorough circular innovation investigation.

This study's conceptual model was carefully adapted from the Technological Innovation System (TIS) framework. This well-established framework's core components and interconnections provide a holistic view of innovation dynamics in different contexts. We want to use this framework's essence and analytical power to tailor it to circular innovation research. BlueCity Rotterdam and HollandCircularHotspot, circular innovation leaders, were among our industry experts. These dialogues provided practical insights and supported the Technological Innovation System (TIS) framework's focal-point concentration approach.

The decision to avoid new blocks and conditions was based on the realization that circular innovation operates within the technological innovation system. Identifying focal points within the existing building blocks ensures a comprehensive exploration of circular innovation while maintaining the analytical robustness and applicability of the TIS framework. This method lets you examine how circular innovation fits into the TIS framework.

Visiting BlueCity Rotterdam and Holland Circular Hotspot experts provided firsthand knowledge of circular innovation implementation. These conversations stressed the importance of studying circular innovation within the TIS framework. The interactions showed that by highlighting specific focal points, we capture circular innovation's practical realities and challenges while using the TIS framework's analytical power.

In the following chapters, case studies will be conducted, examining real-world data on circular innovation in the market. These case studies would contribute to answering the remaining sub-questions and ultimately provide valuable insights to address the overarching research question.

4

Case Studies

In this chapter, we delve into a series of case studies focusing on circular high-tech companies in the Netherlands. These case studies serve as a valuable source of empirical evidence and insights into the practical application of circular innovation within the technological innovation system (TIS). The primary method employed in these case studies is semi-structured interviews conducted with employees of the selected companies. Through these interviews, we aim to gain a comprehensive understanding of the introduction of specific products and/or services to the market by the companies, along with the surrounding circumstances and events that influenced their implementation.

The guidelines, prompts, questions, and interview structure for the case studies can be found in Appendix E of this research. This includes an explanation of the guidelines presented to the interviewees, as well as the precise prompts and questions employed during the interviews. Additionally, the Appendix outlines the overarching structure of the interview process itself. This supplementary material plays a critical role in improving the scientific rigor of the study, as it offers a valuable resource for comprehending the applied methodology and approach utilized in the data collection phase.

The interview transcripts were carefully analyzed using a systematic coding process. Initially, the interviews were broken down into smaller fragments, and key concepts were highlighted without immediate categorization or grouping of codes. In the subsequent coding round, the codes were further examined and refined. This involved assigning codes to specific sections of the interviews, merging or splitting codes as necessary, and ultimately categorizing and grouping them to identify common themes and patterns. The outcomes of this analysis were in line with the research objectives, particularly in uncovering the key drivers of circular innovation within the case studies. The codes are pretty self-explanatory and the comprehensive list of codes can be found in Appendix F.

Company	Interviewee	Company Activities	Founded in	Interview Medium
MUDJeans	CSR Officer	MUDJeans is a sustainable fashion company that offers circular Denim Products	2012	Virtual - Zoom
КеуКед	Sustainability Engineer	KeyKeg specializes in manufactur- ing circular Kegs for the Beverage Industry	2006	Virtual - MS Teams
FliptheCity	Product Designer	FliptheCity manufactures circular tiles made from duckweed that can be used in urban spaces	2017	Virtual - MS Teams
Nature's Principles	СТО	Nature's Principles produces circu- lar biochemicals by repurposing low value byproducts.	2019	Virtual - MS Teams

Table 4.1: Information on the Companies included in the Case Studies

Through in-depth discussions during the interviews, we aim to uncover how these strategies were employed to navigate the unique challenges and opportunities associated with circular innovation. It was essential to choose companies that have demonstrated traction and a proven track record in successfully introducing circular innovations to the market. Moreover, the innovations considered align with the defined scope and definition of Circular Innovation discussed earlier.

4.1. Case 1: MUDJeans

MUD Jeans is a renowned sustainable fashion company based in the Netherlands that was founded in 2012. The company has gained recognition for its commitment to circular economy practices and aims to disrupt traditional linear fashion models by promoting a circular approach to production and consumption. MUD Jeans operates on an innovative business model centered around leasing their jeans to customers, providing them with a fashionable and sustainable alternative to traditional offerings. At the end of the lease period, customers have the option to return the product for recycling, ensuring that materials are reused in future production cycles and closing the loop [MUDJeans, 2023].

4.1.1. Driving Factors to Circular Innovation at MUDJeans:

1. **Emerging Regulations:** One of the key drivers identified in the case study is the influence of emerging regulations. As highlighted multiple times in the EU reports [EC, 2016; Commission, 2003] and by the work of Kirchherr et al.. MUD Jeans has been proactive in adapting to and leveraging new regulations that support circular economy practices. These emerging regulations have served as a significant driver, inspiring MUD Jeans to align their strategies with sustainability goals and stay ahead in the circular fashion landscape.



Figure 4.1: Example Quotation for Drivers of MUDJeans

2. Collaboration and Coordination with Like-minded Partners: The case study emphasizes the importance of collaboration and coordination with partners who share the same vision. MUD Jeans has successfully established partnerships with organizations and individuals who are aligned with their circular innovation goals. This collaborative approach has created a more conducive environment for bringing their sustainable products to the market. By leveraging shared visions and resources, MUD Jeans has been able to overcome barriers and strengthen their position in the industry.



Figure 4.2: Example Quotation for Drivers of MUDJeans

4.1.2. Building Blocks of MUDJean's TIS

To gain further insights into the drivers and barriers of circular innovation, the case study analyzes the applicability of the Technological Innovation System (TIS) framework. This was done by means of desk research from sources such as MUDJeans; MUDJeans; Coalition; **?** as well as based on the interview. The visualisation in its entirety can be found in Figure 4.6.

1. Product Performance and Quality:

· MUDJeans' products demonstrated excellent performance and quality, meeting

customer expectations and satisfaction. The company emphasized clarity in design, ensuring the optimization of resources to minimize waste and enhance circularity. Additionally, MUDJeans adopted an integrated service system to provide a holistic and sustainable experience to customers.

2. Product Price:

 MUDJeans successfully determined the appropriate pricing for their circular products. They carefully assessed the long-term feasibility and total cost of ownership, considering the environmental and social benefits offered by their sustainable denim. This approach ensured that their pricing strategy aligned with the circular innovation goals.

3. Production System:

 MUDJeans faced challenges related to scaling their production system and conducting large-scale demonstrations. They recognized the need for a flexible, adaptable, and resilient production system to support circular innovation. Addressing these challenges would enable them to optimize their operations and expand their reach while maintaining sustainability principles.

4. Complementary Products and Services:

 MUDJeans benefited from having a network of collaborators with shared goals in the circular economy. This collaboration extended beyond their immediate supply chain and involved partners who contributed complementary products and services. The availability of such a network facilitated the diffusion of circular innovation and strengthened MUDJeans' market presence.

5. Network Formation and Coordination:

 MUDJeans recognized the significance of establishing a strong network and ensuring effective coordination among suppliers and distributors. By fostering robust relationships within their supply chain and optimizing logistical operations, they achieved seamless material flow and efficient circular economy practices. Strong network formation and coordination were instrumental in implementing their circular innovation strategies.

6. Innovation-Specific Institutions:

 MUDJeans operates primarily from the Netherlands and having partners in Tunisia and Turkey. For the major part, regulations and legislation in the Netherlands and the European Union is applicable. As indicated earlier, these regulations have proven to be a driving factor for MUDJeans and therefore, it can be concluded that this building block is complete/compatible.

7. Customers:

 MUDJeans acknowledged the evolving customer preferences in favor of sustainable and eco-friendly products. They conducted research to understand customers' mindset and expectations, aligning their offerings with these changing trends. However, they faced challenges related to greenwashing and the perception of authenticity in the market. MUDJeans worked on addressing these concerns to enhance compatibility between their circular innovation and customer expectations.

4.1.3. Influencing Conditions for Circular Innovation:

1. Knowledge and Awareness of Technology:

 MUDJeans encountered challenges in their technology-related processes, particularly in scaling up their operations and conducting large-scale demonstrations. They recognized the need for continuous improvement and innovation in their technology to support the circular objectives effectively.



Figure 4.3: Quotations and Codes: Knowledge and awareness of Technology

2. Knowledge and Awareness of Application and Market:

 MUDJeans demonstrated a comprehensive understanding of their target market and the application of circular innovation. They proactively engaged with customers and the community, allowing them to adapt their offerings based on market demand. This awareness facilitated the alignment of their circular products with customer needs and preferences.

3. Natural, Human, and Financial Resources:

 MUDJeans faced resource limitations, particularly in terms of financial constraints for optimizing their processes and scaling up operations. However, they leveraged their available resources efficiently, seeking innovative solutions and partnerships to overcome these challenges.



Figure 4.4: Quotations and Codes: Natural, human and Financial resources

4. Macro-Economic and Strategic Aspects:

 The Netherlands' favorable economic conditions and supportive regulations played a significant role in enabling MUDJeans' operations and circular initiatives. The country's circularity plan and regulations favored firms with a good reputation for sustainability and circular practices, providing an enabling environment for MUD-Jeans to thrive.

5. Socio-Cultural Aspects:

 Social factors, customer preferences, and mindset played a significant role in shaping the landscape for circular innovation. MUDJeans encountered challenges related to customer expectations, greenwashing concerns, and the need to educate the market about the benefits of circular products. They actively worked on addressing these socio-cultural aspects to enhance compatibility and promote wider adoption of circular practices.



Figure 4.5: Quotations and Codes: Socio-Cultural Aspect

6. Competition:

 MUDJeans' offering intended to change the fast-fashion industry. MUDJeans was one of the first movers in the market they operate in. Since the aim was to be an alternate, competition from conventional offerings was not present. Their circular denim offerings differentiated them from traditional denim brands, allowing them to carve out a brand and following within the industry.

7. Accidents and Events:

• There were no particular issues, events or accidents that were noted which would explain and cause the barriers identified in the building blocks.



Figure 4.6: Status of MUDJeans's TIS

MUDJeans had barriers in terms of their Production System, which was influenced by their Knowledge and Awareness of Technology as well as Natural, Human and Financial Resources, particularly the availability of Finance. Another Barrier they faced was in terms of Customers. This was significantly influenced by Socio-Cultural Aspects, particularly, informed preferences, limited knowledge and information. In order to overcome these barriers, MUD-Jeans redesigned and developed their product and entire production process by collaborating with other partners who have the same shared goal. The Niche Strategy is further explained below.

4.1.4. Niche Strategies in Circular Innovation: Lessons from MUDJeans

MUDJeans has been strategically redesigning their products, services and processes and therefore adopting the **Redesign niche strategy** as their primary approach. This has allowed them to introduce their products into the market despite large scale diffusion not being possible. By leveraging this strategy, MUDJeans effectively addressed several barriers and challenges that hindered their circular innovation efforts. The company recognized the limitations in their technological expertise, resource availability, application knowledge, and sociocultural influences, all of which were well-suited for the Redesign niche strategy.



Figure 4.7: Quotations of Operations and Strategy

In response to the barrier of limited technological expertise, they recognized that their existing level of technological expertise was insufficient to support the availability and production of their jeans. As a result, they chose to simplify the design of their jeans, adopting a more straightforward approach that would require fewer technological complexities. By streamlining the design, MUDJeans aimed to make their jeans more accessible to a wider audience and reduce the resource requirements associated with production.

The introduction of the Lease-a-Jeans concept exemplified MUDJeans' application of the Redesign niche strategy. This innovative approach allowed customers to lease their jeans instead of purchasing them outright, providing a sustainable alternative to traditional ownership models [?]. The Lease-a-Jeans concept not only aligned with MUDJeans' circular economy principles but also served as a means to introduce their product in a more straightforward manner. By offering leasing options, MUDJeans aimed to overcome potential barriers related to cost and accessibility, making their jeans more affordable and appealing to a broader market.



Figure 4.8: TIS for MUDJeans

Furthermore, MUDJeans proactively focused on optimizing resource utilization and improv-

ing their materials through research and development projects. By investing in research and development, MUDJeans sought to enhance the performance and durability of their products while minimizing resource consumption. These efforts were in line with the principles of the Redesign niche strategy, which aims to optimize existing resources and materials in order to create more sustainable and environmentally friendly products. This was done with the intention of being the most cost-effective.

Additionally, MUDJeans recognized the importance of forming strategic alliances and collaborations with stakeholders who shared their circular economy goals. By engaging with partners who had a similar vision, MUDJeans sought to leverage collective expertise and resources to advance their circular innovation objectives. Collaborative efforts allowed them to address barriers more effectively and bring their products to the market with greater success.

Through their application of the Redesign niche strategy, MUDJeans overcame the barrier of limited technological expertise and addressed related challenges. By simplifying the design, adopting the Lease-a-Jeans concept, optimizing resource utilization, and forming strategic alliances, MUDJeans effectively redesigned their product and production processes. These strategic initiatives not only improved market acceptance but also aligned with their circular innovation objectives better.

4.2. Case 2: KeyKeg

KeyKeg is a Dutch manufacturer dedicated to sustainability and circularity. They offer a line of products known as KeyKegs, which are widely used by beverage manufacturers and other liquid product vendors, particularly in the food and beverage industry. KeyKeg also serves customers outside of the industry. This case study examines the TIS building blocks and influencing conditions related to KeyKeg's circular innovation efforts [KeyKeg, 2023]. By adopting a circular design approach, KeyKeg's product performance and quality align with sustainability principles. Their pricing strategy offers a compelling value proposition to customers, driving the adoption of circular innovation. KeyKeg also benefits from an efficient network formation and coordination with like-minded organizations, creating a conducive environment for circular innovation [BevIndustry, 2022].

4.2.1. Driving Factors to Circular Innovation at KeyKeg:

 Product Design and Value Proposition: KeyKeg's product design and value proposition are significant drivers of circular innovation. The company's focus on creating a product that is user-friendly, efficient, and optimized for resource utilization has attracted customers who appreciate its circularity. The KeyKeg's design allows customers to use the product without having to relearn or adjust their processes, making it a seamless transition. This strong product design and value proposition have been instrumental in driving KeyKeg's circular innovation journey.



Figure 4.9: Example Quotation for Drivers of KeyKeg

2. Local Collaboration: KeyKeg recognizes the importance of collaboration with local entities as a driver of circular innovation. By partnering with local governing bodies, such as the Amsterdam municipality, KeyKeg has been able to create visibility for their brand and gain support for their circular initiatives. Collaborative projects and programs have provided KeyKeg with opportunities to test and validate their innovation, build relationships, and drive value creation. Local collaboration has played a crucial role in promoting KeyKeg's circular innovation agenda and expanding their market presence.



Figure 4.10: Example Quotation for Drivers of KeyKeg

4.2.2. Building Blocks of KeyKeg's TIS

KeyKeg's TIS was analysed based on qualitative analysis of the interview as well as additional information from other relevant sources [KeyKeg, 2023, 2020; BevIndustry, 2022]. The visualisation in its entirety can be found in Figure 4.13.

1. Product Performance and Quality:

 KeyKeg's product performance and quality have been identified as key drivers in their circular innovation journey. Through research, sales analysis, and interviews, it has been established that KeyKeg's products perform well and are of good quality. This aligns with previous literature on circular innovation, highlighting the importance of delivering products that meet customer expectations while minimizing resource consumption and waste generation. The circular design of KeyKeg's products, coupled with optimized resource utilization, enhances their performance and reinforces their commitment to sustainability and circularity.

2. Product Price:

 Price plays a crucial role in the success of any product, and KeyKeg recognizes its significance in driving circular innovation. During discussions with KeyKeg representatives, it became evident that the company has put considerable thought into pricing their products. They have developed a pricing strategy that not only works for their customers but also offers a compelling value proposition. By finding the right balance between affordability and perceived value, KeyKeg has been able to attract customers and drive the adoption of their circular products.

3. Production System:

 KeyKeg's production system is a critical building block in their circular innovation journey. However, it has been identified as partially incompatible. The analysis reveals various reasons contributing to this incompatibility, particularly in the areas of technology, processes, and machinery. KeyKeg has faced challenges with their production technology, hindering their ability to achieve large-scale diffusion. Issues with machinery and processes have created barriers that need to be addressed to optimize their production system for widespread adoption of their circular solutions.

4. Complementary Products and Services:

 KeyKeg's products have garnered interest not only from beverage manufacturers and other liquid product vendors but also from small and medium enterprises and entrepreneurs. These stakeholders actively seek out KeyKeg products because they recognize the value and benefits they offer. The compatibility of KeyKeg's products with existing industry infrastructure and technical requirements has further facilitated their integration into the market. This compatibility ensures that the availability of complementary products and services does not pose a significant barrier, allowing KeyKeg to leverage existing industry ecosystems for their circular innovation.

5. Network Formation and Coordination:

 Network Formation and Coordination: KeyKeg's ability to form networks and coordinate with partners in the technological innovation system has been identified as an efficient and compatible building block. With operations across the European continent, KeyKeg has established partnerships with organizations that share similar interests and visions. This network formation and coordination contribute to a conducive environment for collaboration, knowledge sharing, and the exchange of best practices. It enhances KeyKeg's ability to navigate the complex landscape of circular innovation, fostering synergies and accelerating their progress.

6. Innovation-Specific Institutions:

 The building block of innovation-specific institutions has been found to be partially incompatible for KeyKeg. This incompatibility arises from various factors, including regulatory clarity and region-specific requirements. Circular innovation necessitates a shift in policies and strategic considerations, and the lack of standardized procedures and regulations enforcement poses challenges for KeyKeg. These barriers impact the company's production system and the establishment of consistent innovation-specific institutions across different regions. To overcome these barriers, KeyKeg needs to engage with relevant stakeholders and advocate for standardized regulations and policies that support circular innovation.

7. Customers:

 KeyKeg's ideal customers play a crucial role in driving their circular innovation journey. These customers understand the benefits and value of KeyKeg's products and are less likely to notice any degradation in performance compared to traditional alternatives. The customers' awareness and knowledge of the product ensure that they actively seek out KeyKeg's offerings, contributing to the demand and market acceptance of their circular solutions. KeyKeg's focus on meeting customer expectations and delivering sustainable and high-quality products results in a compatible building block.

4.2.3. Influencing Conditions for Circular Innovation:

1. Knowledge and Awareness of Technology:

 KeyKeg has encountered challenges related to their production technology, processes, and machinery. These challenges hinder large-scale diffusion and necessitate a deep understanding and awareness of the technological aspects involved in their circular innovation. By addressing these challenges and enhancing their knowledge and awareness of technology, KeyKeg can overcome barriers and optimize their production system.



Figure 4.11: Quotations and Codes: Knowledge and awareness of Technology

2. Knowledge and Awareness of Application and Market:

 KeyKeg has demonstrated good awareness and knowledge of the market in which they operate. This understanding enables them to effectively implement their circular innovation strategies and align their products with market needs and demands. By continuously monitoring and adapting to market trends, KeyKeg can stay ahead of the curve and drive the adoption of their circular solutions.

3. Natural, Human, and Financial Resources:

 KeyKeg has not faced notable barriers related to the availability of natural, human, and financial resources. They have successfully raised funds and have a clear proof of concept, indicating a favorable market size and investor interest. The availability of these resources supports KeyKeg's circular innovation journey, allowing them to focus on other areas of improvement without significant resource constraints.

4. Macro-Economic and Strategic Aspects:

The macro-economic and strategic aspects play a significant role in creating barriers for KeyKeg's circular innovation. Lack of standardization, unclear regulations, and region-specific considerations have impacted their production system and innovation-specific institutions. KeyKeg needs to navigate these macro-economic and strategic factors by advocating for standardized regulations, engaging with policymakers, and strategically positioning themselves in the market to overcome these barriers.



Figure 4.12: Quotations and Codes: Macro-Economic and Strategic Aspects

5. Socio-Cultural Aspects:

 Surprisingly, socio-cultural aspects did not have a significant impact on the identified barriers for KeyKeg. The effectiveness and usefulness of KeyKeg's circular product mitigated potential barriers related to socio-cultural factors. The market acceptance and positive customer feedback indicate that KeyKeg has successfully addressed socio-cultural aspects, enabling them to focus on other building blocks and conditions in their circular innovation journey.

6. Competition:

 Competition, in the context of KeyKeg's circular innovation journey, did not emerge as a notable influencing condition affecting the identified barriers. KeyKeg's product has a straightforward use case and offers distinct advantages in terms of sustainability and resource efficiency. These factors, coupled with the positive reception from customers, contribute to KeyKeg's competitive advantage and mitigate potential barriers arising from competition.

7. Accidents and Events:

 There were no particular issues, events or accidents that were noted which would explain and cause the barriers identified in the building blocks. Although it was noted that the covid-19 pandemic impacted the beverage industry. We can argue that KeyKeg does not have any particular influencing conditions under Accidents and events and it is complete or compatible.



Figure 4.13: Status of KeyKeg's TIS

KeyKeg faced barriers with respect to their production system. Reverse logistics proved to be a major challenge for them. Another Barrier they faced was in terms of innovation specific institutions. There was a sever misalignment in the regulations between regions and there was no standardization at all. These barriers were influenced by Macro-Economic and Strategic Aspects, the lack of a systemic perspective and overall conducive regulations. As a result of this, they were unable to do a large scale demonstration, further compounding and exaggerating the barriers in their productions system. In order to overcome these barriers, KeyKeg decided to decentralize their operations and thereby circumventing these mismatch in regulations and challenges with respect to logistics. The strategy is explained below.

4.2.4. Niche Strategies in Circular Innovation: Lessons from KeyKeg

KeyKeg has strategically embraced **Decentralization** as a key element of their niche strategy in circular innovation. Decentralization refers to the distribution of operations and resources across different locations, allowing KeyKeg to overcome barriers and enhance the effectiveness of their circular initiatives. Decentralization plays a crucial role in addressing several barriers and facilitating the successful implementation of KeyKeg's circular innovation.



Figure 4.14: Quotations of Operations and Strategy

One significant barrier to large-scale diffusion of circular innovations is the variation in regulations and standards across different regions and countries. KeyKeg encountered challenges related to regulatory compliance when expanding their operations into different markets. However, their decentralized approach provides a solution to this barrier. By localizing their operations and adapting to regional regulations, KeyKeg ensures compliance with specific

requirements in each market. Decentralization allows them to navigate the complexity of regulatory environments, reducing barriers and enabling smoother implementation of their circular innovation.

Circular innovation often involves the effective management of resources throughout the product life cycle, including recycling and reusing materials. KeyKeg's decentralized strategy facilitates the establishment of efficient reverse logistics systems. By localizing their operations and collaborating with regional partners, KeyKeg reduces the complexities and costs associated with transporting empty KeyKegs back to their production facilities. Instead, they can leverage local recycling facilities and strategic partnerships to ensure the proper disposal, collection, and recycling of their products. This decentralized approach streamlines resource management, making circularity more viable and scalable.

Decentralization enables KeyKeg to foster collaboration and engagement at the local level, overcoming barriers associated with coordination and alignment across diverse stakeholders. By establishing partnerships with local governing bodies, municipalities, and other organizations, KeyKeg can actively involve communities in their circular initiatives. This localized engagement creates awareness, generates support, and facilitates the adoption of KeyKeg's circular products within specific regions. Furthermore, local collaboration enhances KeyKeg's understanding of market needs and enables them to co-create solutions with customers and stakeholders, driving innovation and addressing specific challenges.

Decentralization aligns with KeyKeg's niche strategy by enabling them to cater to specific markets and customer segments. By localizing their operations, enhance customer satisfaction, as customers benefit from localized supply chains, reduced logistics costs, and products designed specifically for their requirements. Decentralization also supports localized customer service and support, further enhancing the overall customer experience.

Knowledge and Awareness of Technology	Product Performance and Quality	
Limited Scope of Circular Products Large Scale Demonstration	Design for Resource Circularity Optimisation Integrated PSS	
Knowledge and Awareness of Application and Market	Product Price	
Uncertain Returns Linear Lock-ins Asymmetric Information	Long Term Feasibility Total Cost of Ownership	
Natural, Human and Financial Resources	Production System	
Resource flow Leadership and Availability of Optimisation Team Skills Finances	9 R(s) Capabilities Strong Reverse Logistics Flexibility and Adaptability	
Macro-Economic and Strategic Aspects	Complementary Products and Services	Decentralize
Systemic Economic Conducive Perspective Conditions Regulations	Collaboration Ecosystem of Industry Specific Infrastructure	Niche Strategy
Socio-Cultural Aspects	Network Formation and Coordination	
Literacy and Informed Limited Information Motivation Preferences and Knowledge	Division of Strong Network Responsibility Shared Goals	
Competition	Innovation-Specific Institutions	
Market Positioning Conventional Competition Value Proposition	General Concensus Standardisation Emerging Robust Policies	
Accidents and Events	Customers	
Internal Disruption Cascading Effects Resilience	Awareness and Ownership Resistance to Knowledge Preferences Change	
Key • TIS Building Block / Influencing Condition / I • TIS Building Block / Influencing Condition / I • TIS Building Block / Influencing Condition / I • Noted as a Driver in this TIS*	Focus Area is Fully Complete / Compatible / Favourable Focus Area Partially Complete / Compatible / Favourable Focus Area is Incomplete/Incompatible/Unfavourable	

Figure 4.15: TIS for KeyKeg

4.3. Case 3: FliptheCity

Flip the City is a pioneering company dedicated to driving circular innovation in the Netherlands. Their innovative product, a circular tile made from the plant Duckweed, offers a sustainable alternative to conventional tiles. Operating in a region where Duckweed is recognized as an invasive species, Flip the City addresses environmental concerns by repurposing this abundant plant into a valuable resource. Flip the City strives to offer a seamless and environmentally-friendly solution to customers, while simultaneously contributing to the preservation of biodiversity and the environment in the Netherlands [FliptheCity, 2023].

4.3.1. Driving Factors to Circular Innovation at FliptheCity:

 Collaboration and Coordination with Like-minded Partners: Flip the City places a strong emphasis on collaboration and building partnerships with various stakeholders, including local municipalities, businesses, and community organizations. This collaborative approach has been instrumental in driving their circular innovation efforts. By working together with these stakeholders, Flip the City can leverage their expertise, resources, and networks to amplify the impact of their initiatives. This collaborative mindset fosters a shared vision of creating a more sustainable and resilient urban environment, where circularity is embraced and actively supported.



Figure 4.16: Example Quotation for Drivers of FliptheCity

2. Product Design and Value Proposition: Flip the City's value proposition lies in its innovative product offering that addresses a critical environmental challenge. By utilizing Duckweed, an invasive plant species, as a raw material for their circular tiles, Flip the City not only provides a sustainable alternative to conventional tiles but also helps tackle the problem of biodiversity damage caused by Duckweed. This unique value proposition resonates with environmentally conscious consumers, businesses, and municipalities seeking sustainable solutions. The compelling nature of Flip the City's value proposition drives their circular innovation journey and enables them to differentiate themselves in the market.



Figure 4.17: Example Quotation for Drivers of FliptheCity

4.3.2. Building Blocks of FliptheCity's TIS

In order to obtain additional understanding regarding the factors that stimulate and hinder circular innovation, the TIS framework was used. This was done by means of desk research from sources such as [FliptheCity, 2023; BlueCity, 2023; Village, 2023] as well as based on the interview. The visualisation in its entirety can be found in Figure 4.21.

1. Product Performance and Quality:

 The building block of product performance and quality was found to be compatible for Flip the City. After analyzing and discussing with company representatives, it was concluded that the product's performance did meet the requirements for largescale diffusion. While the innovation showed promise, there were no identified limitations that hindered its widespread adoption in this block.

2. Product Price:

 Offering the product at a reasonable price was not a significant barrier for Flip the City. The simplicity of their circular tile product, made from duckweed, and the availability of raw materials in nature allowed them to establish a pricing strategy that was feasible for customers. This made the product financially accessible, contributing to its potential for adoption.

3. Production System:

 The production system of Flip the City did not reveal any notable barriers. The abundance of raw materials, specifically duckweed, and the simplified manufacturing process developed by the company ensured a smooth and efficient production system. This factor facilitated the scalability and viability of the circular innovation.

4. Complementary Products and Services:

• Flip the City's offering was straightforward and did not require extensive complementary products or services. Therefore, the building block of complementary products and services was deemed compatible with their circular innovation. The sim-
plicity of their solution streamlined the implementation process, eliminating the need for complex ancillary offerings.

5. Network Formation and Coordination:

 Network formation and coordination posed challenges for Flip the City's circular innovation. In order for innovations to achieve widespread diffusion, it is crucial to have a well-functioning network of actors supporting the system. However, in Flip the City's case, there were difficulties in establishing effective network coordination. Responsibility sharing across the value chain and industry-specific infrastructures were not appropriately developed, leading to incompatible network formation and coordination.

6. Innovation-Specific Institutions:

 The analysis did not reveal any significant barriers in terms of innovation-specific institutions for Flip the City. In fact, regulations in the Netherlands were conducive to the business environment, supporting the company's circular innovation efforts. This compatibility with existing regulations provided a favorable context for Flip the City's operations and expansion.

7. Customers:

 The customer building block was found to be partially incompatible for Flip the City. Influencing conditions such as socio-cultural aspects and customer preferences contributed to this incompatibility. Social issues surrounding sustainability, including concerns about greenwashing, trust in eco-friendly products, and the unique preferences driving customer choices, impacted the compatibility of Flip the City's product with customer needs. This indicated a need for customer education and a shift in preferences to align with the circular offering.

4.3.3. Influencing Conditions for Circular Innovation:

1. Knowledge and Awareness of Technology:

• Flip the City demonstrated adequate knowledge and awareness of their technological innovation. This influencing condition did not contribute to the identified barriers, as the company exhibited a solid understanding of the technology behind their circular tile product.

2. Knowledge and Awareness of Application and Market:

• Flip the City showcased a good understanding of the market and potential users. Their knowledge and application of the market did not significantly impact the barriers identified. They had a clear understanding of their target audience and the market potential for their innovative solution.

3. Natural, Human, and Financial Resources:

 Flip the City did not face significant issues with natural resources, as their innovation utilized readily available and renewable resources like duckweed. However, financial resources posed a challenge for the company. Inability to demonstrate the innovation's impact on a large scale limited their ability to secure necessary financial resources. The nature of the field itself presented roadblocks in obtaining financial support.



Figure 4.18: Quotations and Codes: Knowledge and awareness of Technology

4. Macro-Economic and Strategic Aspects:

 Macro-economic and strategic aspects played a significant role in the formation of barriers for Flip the City. Stakeholder influence, lack of transparency, and responsibility sharing hindered coordination among actors in the network. These macroeconomic and strategic factors, when not effectively addressed, limited the scalability and diffusion of Flip the City's circular innovation.



Figure 4.19: Quotations and Codes: Macro-Economic and Strategic Aspects

5. Socio-Cultural Aspects:

Socio-cultural factors played a significant role in the compatibility of Flip the City's circular innovation. Issues such as greenwashing, where companies falsely claim to be sustainable, raised concerns and affected customer trust. Additionally, societal preferences and habits influenced customer choices, posing challenges in aligning customer needs with the circular offering. Addressing these socio-cultural aspects required targeted marketing, awareness campaigns, and consumer education initiatives.



Figure 4.20: Quotations and Codes: Socio-Cultural Aspects

6. Competition:

 The unique nature of Flip the City's product resulted in a lack of direct competition. Their circular tile made from duckweed presented a distinctive offering in the market. While this lack of competition may seem advantageous, it also meant that Flip the City had to navigate uncharted territory, create market demand, and educate potential customers about the benefits of their innovative solution.

7. Accidents and Events:

 No notable accidents or events were identified as influencing conditions contributing to the barriers faced by Flip the City. However, it is essential to remain vigilant and prepared for any unforeseen incidents that could impact the business and its operations.



Figure 4.21: Status of FliptheCity's TIS

FliptheCity faced barriers in Network formation and coordination. They were unable to establish a strong network with stakeholders who hold the same shared goals. The identi-

fied influencing conditions responsible for this were Natural, Human and Financial Resources – particularly, financial in nature and Macro-economic and Strategic Aspects – Overall conditions and undesirable stakeholder influence. Another Barrier for FliptheCity was the Customers Block. Customers were severely misinformed and did not posses adequate information therefore their preferences ended up being a challenge. This barrier was influenced by Socio-Cultural Aspects. In order to overcome these challenges, FliptheCity decided to provide offer Turnkey solutions, which in essence means to a product-service system that is delivered end to end. This helped them overcome barriers to finances, network formation and customer preferences by being involved from the project definition phase. This is further explained in the next section.

4.3.4. Niche Strategies in Circular Innovation: Lessons from FliptheCity

Flip the City employed a niche strategy to enhance their circular innovation efforts. One of their key approaches was the development of a **Turnkey Product-Service-System**. This strategy involves providing a comprehensive solution to their customers, encompassing analysis, customized solutions, and implementation. By offering a complete package that eliminates the hassle and complexity for customers, Flip the City simplifies the adoption of their circular product. This niche strategy aligns with the principles of circular economy by promoting resource efficiency, waste reduction, and sustainable consumption.



Figure 4.22: Quotations of Operations and Strategy

Flip the City's niche strategy of offering a comprehensive product-service system played a pivotal role in overcoming multiple barriers to circular innovation. One of the key barriers they faced was the lack of coordination and shared vision among stakeholders in the network. Col-

laborating with various actors in the urban ecosystem, such as municipalities and landscaping contractors, allowed Flip the City to establish shared goals and align their efforts towards a common vision of urban sustainability.

By providing a turnkey solution that encompassed every aspect of the process, including analysis, groundwork, customized solutions, and implementation, Flip the City effectively addressed the coordination challenge. Their comprehensive approach eliminated the need for extensive coordination and communication among different stakeholders, as they took full responsibility for the entire process. This streamlined approach ensured efficient execution, minimized delays, and maximized the impact of their circular innovation.



Figure 4.23: TIS for FliptheCity

Furthermore, the niche strategy of offering a complete product-service system allowed Flip the City to address the barrier of product performance and quality. By controlling the entire value chain, from sourcing the raw materials to delivering the final implemented output, they could closely monitor and maintain the highest standards of performance and quality. This end-to-end control ensured that their solution met or exceeded customer expectations, enhancing trust and confidence in their offering.

The comprehensive nature of Flip the City's niche strategy also had a positive impact on financial barriers. By bundling their services into a complete solution, they could demonstrate the cost-effectiveness and long-term value of their circular innovation to potential customers. This approach allowed them to overcome the skepticism or reluctance that might arise from fragmented or complex offerings. As a result, Flip the City was able to secure the necessary financial resources, both internally and externally, to scale their operations and expand the adoption of their circular solution.

In summary, Flip the City's niche strategy of offering a comprehensive product-service system not only facilitated coordination and shared vision among stakeholders but also ensured high product performance and quality while addressing financial barriers. This strategic approach enabled them to effectively overcome these challenges and accelerate the diffusion of their circular innovation in urban environments, making a significant contribution to the advancement of sustainable urban development.

4.4. Case 4: Nature's Principles

Nature's Principles is a Dutch company that develops and produces lactic acid in a circular way. Lactic acid is a versatile chemical compound with a wide range of applications, including food, cosmetics, and pharmaceuticals. The company's technology uses low-value by-products of other industries to produce lactic acid [Principles, 2023]. Besides, Nature's Principles' lactic acid is certified by the European Food Safety Authority (EFSA) as a safe food additive. The company's technology has been recognized by a number of awards, including the Circularity Award and the Climate Action Award.

4.4.1. Driving Factors to Circular Innovation at Nautre's Principles:

1. **Emerging Regulations:** Nature's Principles' circular innovation journey has been significantly catalyzed by the emergence of new regulations, particularly in the realm of soil sanitation. These evolving regulatory mandates have not only set the stage for the company's growth but have also strategically positioned them to capitalize on the shifting industry landscape. By proactively aligning their product offerings with these regulations, Nature's Principles has managed to secure a distinctive foothold in the market.



Figure 4.24: Example Quotation for Drivers of Nature's Principles

2. Product Design and Value Proposition: Operating in an industry characterized by resistance to change, Nature's Principles has leveraged its extensive market expertise and a shrewd pricing strategy to drive circular innovation. Their profound understanding of market dynamics, coupled with their value proposition, has enabled them to not just meet customer expectations. Insights gained from interviews with company representatives underscore the significance of their affordable and value-driven solutions in an industry traditionally resistant to transformative shifts.



Figure 4.25: Example Quotation for Drivers of Nature's Principles

3. Perception Shift and Intrinsic Motivation: An intriguing dimension of Nature's Principles' circular innovation journey is the role of perception shift and intrinsic motivation. These factors, often explored in the literature [Gedam et al., 2021; Trevisan et al., 2023], delve into the transformative impact of these motivators on both individuals and organizations. While the precise implications were clarified during discussions with the co-founder, the intrinsic motivation within the team and the organization was explicitly acknowledged. The availability of specialized talent within this distinct field, coupled with

the recognition of how the right human resources can drive innovation and overall business growth, has been clearly noted.



Figure 4.26: Example Quotation for Drivers of Nature's Principles

4.4.2. Building Block of Nature's Principles's TIS

Nature's Principles is the youngest of all the cases analysed. In depth interview provided insights, which, combined with desk research [Principles, 2023; BioBizzHub, 2023; Invest, 2023] resulted in the following analysis of it's TIS. The network in its entirety can be found in Figure 4.29.

1. Product Performance and Quality:

 Nature's Principles' journey of circular innovation gains impetus from their product's exceptional performance and quality. Comprehensive research, sales analysis, and insightful interviews have highlighted the remarkable performance and quality of their lactic acid and derivative-based offerings. These attributes resonate with circular innovation's core principles, as they use low-value byproducts from other industries, extending their lifecycle and reusing resources.

2. Product Price:

 The strategic aspect of pricing is a pivotal driver in the context of circular innovation. Nature's Principles displays a deep understanding of their market and its dynamics. Their pricing strategy strikes a balance between current expenses, long-term viability, and total cost of ownership. This thoughtful approach, backed by an extensive knowledge base, resonates well with customers, making their pricing strategy a powerful driver of adoption.

3. Production System:

 The compatibility and scalability of the production system are crucial for achieving large-scale diffusion of circular innovation. Nature's Principles demonstrates an advantageous position in this domain. Their patented production process exemplifies compatibility and scalability, underscoring their commitment to efficient resource utilization and circularity.

4. Complementary Products and Services:

Collaboration and ecosystem development are the cornerstones of successful circular innovation. While Nature's Principles has leveraged coordination in their journey, they currently navigate barriers in establishing compatible complementary products and services making this building block partially incompatible. This critical juncture underscores the importance of a cohesive system that supports product development, distribution, adoption, maintenance, and responsible disposal—an ecosystem indispensable for circular innovation's largescale diffusion. This as will be explained later, is primarily caused due to the linear lock-in of the industry and competition.

5. Network Formation and Coordination:

Building robust networks and fostering collaboration within an industry often resistant to change holds paramount importance for circular innovation. Nature's Principles acknowledges the significance of stakeholder coordination, but challenges persist due to the absence of industry-specific infrastructure and shared goals. This was explicitly highlighted by the lack of urgency and interest in the novel solution by incumbent industry players. The resistance to change in the industry was observed by Nature's Principles, presenting various challenges. It can be concluded that this building block is partially incompatible.

6. Innovation-Specific Institutions:

Regulatory frameworks and institutions form the bedrock upon which circular innovation can flourish. For Nature's Principles, these institutions have been largely supportive and compatible, aligning favorably with their circular innovation aspirations. Their ability to navigate emerging regulations and leverage compliance as a catalyst for success demonstrates the pivotal role that innovation-specific institutions play within their journey.

7. Customers:

 At the heart of any circular innovation endeavor lies the customer factor. Nature's Principles acknowledges the potential resistance to change that customers within their industry may exhibit. This building block was found to be partially incompatible in the TIS. Their success hinges on the reception and adoption of their solutions by the target market. Operating within an industry where traditional practices might hold sway, Nature's Principles acknowledges that the embrace of innovative approaches can be met with resistance. The nature of circular innovation, in certain sectors, if not all, demands a thorough understanding of the customers' mindset, preferences, and pain points. The challenge here lies in conveying the value proposition effectively, especially when the benefits might not be immediately obvious.

4.4.3. Influencing Conditions for Circular Innovation:

1. Knowledge and Awareness of Technology:

 A fundamental and significant influencing condition within the TIS framework, this aspect centers on technological comprehension. In the context of circular innovation, limited product scope and the challenge of demonstrating scalability can impede progress. Remarkably, Nature's Principles defies these obstacles with a profound understanding of their technology and its practical application. Their comprehensive knowledge and awareness of their product's potential in diverse contexts underpins their ability to drive innovation.

2. Knowledge and Awareness of Application and Market:

Another crucial influencing condition lies in understanding how their innovation applies within the market. This proficiency in application and market dynamics ensures functional relevance. Nature's Principles not only recognizes the importance of this but has actively displayed adeptness in discerning their technology's application and aligning it with market requirements. Their awareness of both application and market nuances allows them to navigate the complexities of market integration.

3. Natural, Human, and Financial Resources:

 The availability of proficient human resources is a pivotal determinant of successful circular innovation. Nature's Principles has identified a significant challenge stemming from the scarcity of specialized skills in their domain. This scarcity has been further exacerbated by the high demand for these skills across industries. Conventional enterprises, vying for similar expertise, often resort to overpayment, making it difficult for Nature's Principles to secure these essential human resources. This paucity of skilled personnel hampers their capacity to effectively execute their innovation initiatives. The lack of available and suitably skilled human resources has a cascading effect, influencing not only the execution of innovation but also their ability to secure necessary financial resources. The absence of skilled personnel impacts their capability to develop and demonstrate their circular innovation effectively, which subsequently affects their appeal to potential investors and funders. This dual challenge highlights the intricate interdependence between human resources and financial support in the context of circular innovation, showcasing the complexity of resource allocation and its implications for Nature's Principles' innovative journey.



Figure 4.27: Quotations and Codes: Natural, Human and Financial Resources

4. Macro-Economic and Strategic Aspects:

In the broader socio-economic landscape, macro-economic and strategic considerations play an influential role. Economic downturns and systemic factors can challenge the viability of innovative endeavors. However, Nature's Principles has navigated these aspects adeptly. Despite operating within a fluctuating economic environment, accelerated by the ever-changing landscape of regulations, the strategic tenacity of Nature's Principles has enabled them to thrive, underscoring their resilience and adaptability within the larger economic context.

5. Socio-Cultural Aspects:

 The socio-cultural dimension adds an intricate layer to circular innovation. Factors such as knowledge dissemination, awareness, and sociopolitical preferences can determine the trajectory of innovation. Nature's Principles adeptly acknowledges this facet, although with nuanced challenges. While their innovation aligns well with the emerging regulatory landscape, certain socio-cultural aspects pose contemplative points for consideration. However, their proclivity to tailor their approach for the evolving market indicates their recognition of these influencing factors.

6. Competition:

 A key driver for innovation is the competitive landscape, often marked by the clash between new and established technologies. In the case of circular innovation, the uniqueness lies in positioning within the market and countering existing linear models. Nature's Principles faces this challenge head-on. The coexistence of conventional offerings and competing circular solutions necessitates strategic positioning. This has been one of the major influencing factors that has caused the barriers to large-scale diffusion. The Linear Lock-in and the sheer scale of conventional offerings have been identified as influencing the building blocks of Nature's Principles TIS.



Figure 4.28: Quotations and Codes: Competition

7. Accidents and Events:

 In the context of innovation, the unpredictable nature of accidents and events can significantly impact progress. These unexpected occurrences, ranging from internal mishaps to external disruptions, have the potential to interrupt the innovation process. Within the context of circular innovation, the intricate interplay of components and the openness to collaboration bring both opportunities and vulnerabilities. Nature's Principles, although facing a challenging period due to a stakeholder exit, has displayed remarkable resilience. This was clear and acknowledged during the interview as well. However, it must be noted that this, in no way, influenced the state of any of the Building Blocks, instead highlighting the importance of resilience demonstrated by the team at Nature's Principles.



Figure 4.29: Status of Nature's Principles' TIS

Nature's Principles faced barriers in terms of their Complementary Products and Services block. This was primarily because of the nature of the industry. Nature's Principles further

faced challenges with regards to availability of Natural, Human and Financial Resources, particularly with regards to the availability of skilled talent. Competition, besides influencing the above, also influenced Network formation and Coordination, primarily fueled by the conventional offerings in this particular industry. This further went on to influence the Customers, raising challenges with respect to that block as well. In order to overcome these barriers, as regulations surrounding soil sanitation were emerging, a new market opportunity is created for Nature's Principles. Their technology is aptly suitable for this purpose and the company leverages this emerging customer based to introduce their products to market. The Strategy is explained below.

4.4.4. Niche Strategies in Circular Innovation: Lessons from Nature's Principles

Nature's Principles has embraced a distinctive niche strategy with a strong focus on compliance, strategically positioning themselves in the circular innovation landscape. This compliance driven **Stepping-Stone Strategy** approach aligns with their overarching goal of addressing emerging regulatory requirements, a crucial driving factor for their business. Notably, the intersection of regulatory changes and their target market's needs has guided their path. Their strategy is particularly intriguing when observed through the lens of the TIS building blocks, where challenges in complementary products and services as well as customer engagement have surfaced.



Figure 4.30: Quotations of Operations and Strategy

To tackle these challenges, Nature's Principles has chosen to leverage compliance as a

powerful driver. Compliance, in this context, entails aligning their innovation with the emerging regulations, especially in fields such as soil sanitation. By doing so, they not only demonstrate their commitment to sustainability but also actively respond to the regulatory landscape. This approach facilitates the integration of their products into markets where these regulations are becoming increasingly significant.

This strategy helps resolve the conflict between the building blocks. Through this, Nature's Principles is strategically maneuvering around potential barriers, such as market resistance due to lack of awareness or existing conventional solutions. By aligning their offering with regulatory mandates, they establish a value proposition that transcends perceived challenges.

Furthermore, their approach emphasizes the significance of understanding the broader context in which their circular innovation operates. By choosing a niche strategy rooted in compliance, Nature's Principles demonstrates a proactive response to a dynamic regulatory environment. This approach showcases their agility and adaptability, ensuring that their innovation aligns with market shifts and regulatory developments.

In summary, Nature's Principles' niche strategy of compliance-driven approach capitalizes on the interplay of regulatory changes and market demand, enabling them to introduce their product to market while navigating potential barriers and positioning themselves as a key player in the industry.

Knowledge and Awareness of Technology		Product Performance and Quality				
Limited Scope of Circular Products Large Scale Demonstration			Design for Circularity	Design for Resource Circularity Optimisation Integrated PSS		
Knowledge and Awareness of Application and Market		Product Price				
Uncertain Returns	Linear Lock-ins	Asymmetric Information	Long Term Fea	asibility Total Co	ost of Ownership	
Natural, Hu	ıman and Financial F	Resources		Production System		
Resource flow Optimisation	Leadership and Team Skills	Availability of Finances	9 R(s) Capabilities	Strong Reverse Logistics	Flexibility and Adaptability	
Macro-Economic and Strategic Aspects		Complementary Products and Services			Stepping	
Systemic Perspective	Economic Conditions	Conducive Regulations	Collaboration	Ecosystem of Products \ Services	Industry Specific Infrastructure	Strategy
Socio-Cultural Aspects		Network Formation and Coordination				
Literacy and Motivation	Informed Preferences	Limited Information and Knowledge	Strong Network	Division of Responsibility	Shared Goals	
	Competition		Inno	vation-Specific Institu	itions	
Market Positioning	Conventional Competition	Value Proposition	General Concensus	Standardisation	Emerging Robust Policies	
A	ccidents and Events			Customers		
Internal Disruption	Cascading Effects	Resilience	Awareness and Knowledge	Ownership Preferences	Resistance to Change	
Key TIS TIS TIS No	S Building Block / Influenci S Building Block / Influenci S Building Block / Influenci ted as a Driver in this TIS	ng Condition / Focus Area i: ng Condition / Focus Area F ng Condition / Focus Area i:	s Fully Complete / Compatible artially Complete / Compatibl s Incomplete/Incompatible/Unfa	/ Favourable e / Favourable avourable		

Figure 4.31: TIS for Nature's Principles

4.5. Cross Case Analysis

Looking at the four illuminating cases of circular high-tech startups, we can observe a few commonalities. First, emerging regulations are a recurring driver in three of the cases and are relevant in all four. MUDJeans, FliptheCity, and Nature's Principles all stated that emerging regulations have created a better and more conducive environment for their respective products or services. However, it is also important to note that this is a very important factor for KeyKeg, as it has allowed them to pursue a niche strategy. KeyKeg's case highlights the lack of consensus and standardization across countries or even industries.

Emerging regulations and policies have been a significant driver for all of the circular companies in this research. Perhaps these emerging regulations have created the change and set up a conducive environment for these businesses to flourish. Another driver identified was collaboration. This has been an interesting observation. Collaboration with partners definitely helped MUDJeans overcome some barriers. At the same time, KeyKeg's collaboration with their partners helped them roll out their products, circumventing a few challenges, albeit in a different capacity. MUDJeans collaborated with partners with similar goals, which helped them build out their entire value chain. KeyKeg, on the other hand, partnered with several organizations within a country in order to set up their production system. This again highlights the stark differences in how emerging regulations affect companies differently and the misalignment and lack of generalization.

Another driver that was identified was product design and value proposition. This was a very interesting driver to observe and perhaps very pertinent to the context. A circular firm's product design and value proposition need to be spot-on for it to have a satisfactory level of performance and quality. Particularly, in terms of being circular, certain design elements are considered and the overall value proposition of the product/service is important. This is important and indicated for all four of our cases. However, if we look at KeyKeg, it is evident that a superior product design and value proposition is indeed a driving factor in their success. The fact that the product is designed to be circular yet work with the current infrastructure and set up without any extra effort for its customer proves to be a solid value proposition. However, on the other end of this, we find FliptheCity, who have a straightforward product design. However, their value proposition is what makes their product desirable. This also goes to show how the same driver can affect companies in different ways. However, it can be extrapolated that design for circularity is an important factor to be considered here.

Driver	Associated Codes	Description of Driver	Case Study Companies	Observations
Emerging regulations	Regulations: Regional Specific Drivers: Emerging Regulations Regulations: Visibility from Regulations Regulations: Government Regulation & Legislation	New regulations that support circular economy practices, such as the EU Action Plans and various Directives. These regulations are driving innovation in the circular economy by requiring businesses to reduce their environmental impact.	MUDJeans & Nature's Principles	Emerging Regulations was noted to be an important driver for MUDJeans and Nature's Principles, for the other two cases, they end up providing an overall conducive set of circumstances for its business.
Collaboration	Drivers: Local Local Pilot programs Drivers: Collaboration & Value Chain Coordiniation	Partnerships with like-minded partners, who often, collabratively work together. This can also include municipalities, government, other organisations etc., These partnerships are helping businesses to share knowledge and resources, to develop new technologies, and to scale their circular initiatives.	MUDJeans, KeyKeg & FliptheCity	Collaboration has been a very important driver for MUDJeans, Keykeg and FliptheCity, however, in contrast, Nature's Principles did not have the same experience, instead facing challenges in this regard.
Product Design and Value Proposition	Design Market Knowledge Technological Prowess Cost Effective Alternative Circular By Design & Valued Solution	Circular and sustainable product design that minimizes waste and maximizes the lifespan of products. This includes using recycled materials, designing products for disassembly and repair, and offering take-back and recycling programs. This also includes valur proposition of the product, its performance, in comparison to circular and conventional offerings.	KeyKeg & FliptheCity	It must be noted that product quality and service is implicitly assumed to be quite important, all cases showcase this behaviour. It also must be highlighted that Nature's Principles has good technology, however, during the analysis, it did not reveal to explicitly drive its diffusion.
Intrinsic Motivation	Attitude Attitude: Culture Attitude: Leadership Attitude: Environmental Literacy Attitude: Intrinsic Motivation Customers: Awareness	Passionate about creating a more sustainable future. This motivation drives businesses to adopt circular economy practices, even in the absence of regulations or market demand.	All four Cases	The desire to create value and solve problems is a powerful motivator that drives technological development. Intrinsic motivation is perhaps the most pivotal driver of innovation.

Figure 4.32: Cross Case Analysis, Drivers

All four companies, in some way or the other, need to ensure that their products/services are designed to be circular and boost their value proposition. The final driver that was identified was intrinsic motivation. This is what we could classify as a soft driver, similar to the findings of [De Jesus et al., 2018; De Jesus and Mendonça, 2018; De Jesus et al., 2019; Hina et al., 2022]. Nature's Principles explicitly displayed this, however, all the cases, to some extent, show the intrinsic motivation as well. This goes on to show how important leadership is, and more importantly, the specific skillset and thought processes that go behind operationalizing circular innovation.

The cross-case analysis offers complex insights into how various obstacles and building blocks interact in the context of circular high-tech startups. In the production system building block, there is a notable difference between MUDJeans and KeyKeg in that their particular technologies create production system barriers, whereas the other cases show a lack of challenges because of their more straightforward technologies. This difference emphasizes how technology complexity affects the dynamics of the production system.

Building Block - Barrier	Associated Codes	Case Study Companies	Influencing Conditions	Observations	
Production System	Challenges: Scalability Technological Prowess Challenges: Production	MUDJeans & KeyKeg	Knowledge and Awareness of Technology Natural, Human and Financial Resources	MUDJeans and KeyKeg seem to face barriers in their production system as a result of their technology being too specific. The	
	Challenges: Processes Challenges: Large Scale Demonstration Challenges: Technology, Processes & Machines	KeyKeg	Knowledge and Awareness of Technology Macro - Economic and Strategic Aspects	other two companies in the case studies did not face challenges related to this as their technology is very simple.	
Complementary Products and Services	Industry Specific Attitude: Leadership Availability of Talent Challenges: Scalability Challenges: Linear Lock-in	Nature's Principles	Natural Human and Financial Resources Competition	As mentioned, certain industries are more reluctant to change than other making the diffusion of new innovation even more difficult. Nature's Principles presents as an excellend example of this instance.	
Network Formation and Coordination	Industry Specific Challenges: Scalability Challenges: Linear Lock-in Attitude: Stakeholder Influence	FliptheCity	Natural Human and Financial Resources Macro Economic and Strategic Aspects	FliptheCity illustrates an example of how Newtork formation is affected due t undesirable stakeholder	
	Challenges: Logistics & Supply Chain Challenges: Large Scale Demonstration Attitude: Lack of Transparency and Responsibility	Nature's Principles	Competition	time, Nature's Principles can be seen facing challenges induced by industry lock-in.	
Innovation Specific Institution	Regulations: Mismatch Trust and Transparency Regulations: Not Enforced Regulations: Regional Specific Regulations: Lack of Standardization & Clarity	KeyKeg	Macro-Economic and Strategic Aspects	This observation remains to be the most suprising and yet the most informative perhaps. Despite being recogonised as a driving factor for Circular Innovation, there seems to be a significant gap in concensus and the standardisation. This could perhaps be the barrier with the most cascading effects.	
Customer	Attitude: Culture Customers: Mindset	MUDJeans	Socio - Cultural Aspects	All companies touched up on their experiences with their respective customers, these three cases faced some form of challenges regarding their customers. This just goes on to show how important the compatibility of this building block is for a business, particularly a circular one. There are a lot of hard and soft factors behind this, and any circular company would come across these at one point or the other. Besides the technical aspect, a lot of societal and cognitic factors also important as well.	
	Attitude: Social Issues Customers: Awareness Customers: Knowledge Challenges: Customers Attitude: Greenwashing Customers: Different types Attitude: Environmental Literacy	FliptheCity	Socio - Cultural Aspects		
	Attitude: Lack of Transparency and Responsibility	Nature's Principles	Competition		

The analysis emphasizes how industry characteristics have a nuanced impact on the spread of new innovations in the area of Complementary Products and Services. The seam-less adoption of innovative practices is hampered by certain industries, which exhibit a higher level of change resistance. FliptheCity serves as an example of how stakeholder influences can prevent efficient network formation, placing network formation and coordination in the spotlight. On the other hand, Nature's Principles deals with industry lock-in, highlighting the complex role of stakeholders in influencing network dynamics.

The most interesting finding is focused on Innovation-Specific Institutions. Although acknowledged as a strong force for driving circular innovation, a glaring lack of agreement and standardization shows up, exposing a significant gap with potentially cascading effects. This finding emphasizes the need for stronger framework coherence and alignment across the circular innovation landscape.

The difficulties faced by three of the cases in their interactions with customers highlight the crucial role of the Customer building block. This highlights the necessity of client compatibility, especially in the context of circular businesses. The significance of effective customer engagement strategies is further highlighted by the complexity of these challenges, which include both technical and socio-cognitive factors.

The successful implementation of circular innovation within high-tech companies necessitates navigating a complex landscape of challenges. These niche introduction strategies, tailored to each company's unique context, were instrumental in addressing the identified challenges.

MUDJeans embraced a redesign strategy, reimagining their production system with circular design principles, recycling materials, leasing models, and efficient return, repair, and recycling systems. This resolved production and customer challenges, establishing them as a sustainable fashion brand. KeyKeg adopted a decentralization approach, forging local partnerships to optimize production and supply chains, align with regulations, and create a network for their circular kegs.

FliptheCity pursued a turnkey product-service system (PSS) strategy, integrating technology, data management, and collaborations to optimize urban waste and resources. This unique approach attracted stakeholders and highlighted their value proposition. Nature's Principles leveraged compliance-driven Stepping-Stone strategy, aligning with emerging regulations. This agility positioned them as a compliance solution, overcoming product-service challenges and customer engagement barriers.

The Expanded version of the table along with the excel file with all the relevant information can be found in Appendix F.

The following chapter will discuss the results as well as draw insights from all the cases and henceforth build up to answer the research question and it's sub-questions.

5

Discussions

In this discussion chapter, we delve into a comprehensive analysis and interpretation of the research findings. The preceding chapters have laid the foundation by reviewing the relevant literature, presenting the conceptual model, and conducting in-depth case studies. By synthesizing the findings and connecting them to the broader context, this discussion chapter aims to provide valuable insights and pave the way for future research and practical implementation of circular innovation strategies.

5.1. Drivers to Circular Innovation in the Netherlands

Section 4.5 illustrates the common drivers of Circular Innovation in the Netherlands. Emerging regulations, strategic collaborations, product quality and service, and intrinsic motivation are all drivers of circular innovation in the Netherlands. Emerging regulations, especially for MUDJeans and Nature's Principles, have provided a conducive set of circumstances for their businesses. Strategic collaborations have helped all four companies to overcome barriers, accelerate their initiatives, and reach new markets. However, for FliptheCity and KeyKeg, they benefited from a conducive regulatory environment that did not require them to make significant changes to their business models. Product quality and service are implicitly assumed to be quite important for all of the companies in the study, as customers are more likely to adopt circular products and services if they are high quality and meet their needs. However, it is important to note that product quality and service are also important factors, as all four cases showcased this behavior. Finally, intrinsic motivation is perhaps the most pivotal driver of innovation, as the desire to create value and solve problems is a powerful motivator that drives technological development. All of the companies in the study have been motivated by a desire to make a difference and create a more sustainable future. This intrinsic motivation has been a key driver of their innovation.

5.2. Barriers to Circular Innovation

The journey toward achieving circular innovation within high-tech companies is marked by a complex array of challenges that necessitate insightful exploration. This section delves deeply into the barriers encountered across multiple case studies, including MUDJeans, KeyKeg,

FliptheCity, and Nature's Principles, all of which are examined through the lens of the Technological Innovation System (TIS) framework.

The MUDJeans case presents complex issues. New circular production processes required significant technological, resource, and expertise investments. Changing consumer consumption patterns and educating them about circular products were difficult. These barriers were shaped by technology knowledge, resource availability, and socio-cultural factors. KeyKeg faced production system and innovation-specific institution barriers. Manufacturing with circular design required major changes to production methods, materials, and supply chains. The company faced institutional obstacles due to non-circular frameworks and regulations. These barriers were interconnected with technological knowledge, macroeconomic conditions, and regulatory dynamics' strategic environment.

The FliptheCity case showed network coordination and customer engagement challenges. Performance and quality were crucial to ensuring circular solutions outperformed conventional ones. The complex stakeholder network made network formation and coordination difficult. Customer engagement required awareness and behavior change despite resistance and skepticism. These barriers were intertwined with resource availability, market conditions, and so-ciocultural influences. Nature's Principles, another case study, revealed network coordination, complementary product and service, and customer engagement issues. Coordinating a complex stakeholder network mirrored the high-tech ecosystem's challenges. Challenges in creating supportive ecosystems for complementary products and services compounded. Engaging customers and changing behaviors in a resistant industry was another challenge. These challenges were exacerbated by resource availability, competition, linear lock-in, and industry-wide change resistance.

5.3. Overcoming Barriers to Circular Innovation: Niche Introduction Strategies

The analysis across the four illuminating case studies underscores the multifaceted panorama of circular innovation strategies, their intrinsic barriers, and the ingenious niche introduction strategies they harnessed. Further look into the strategies also reveal parallels and similarities to the Niche Strategies identified by Ortt et al., which can be found in Appendix C. By following a "Redesign Niche Strategy" and honing their product to align with existing knowledge and a leaner resource palette, MUDJeans resonate with the core principles of innovation within a well-defined niche. Similarly, the "Decentralization Niche Strategy" employed by KeyKeg mirrors Ortt et al.'s "Dedicated System or Stand-Alone Niche Strategy." KeyKeg's emphasis on collaborative partnerships when infrastructure is scarce finds similarity in the dedicated system approach.

Moreover, FliptheCity's "Turnkey PSS Niche Strategy" presents a comprehensive, integrated solution. The innovative aspects of their approach align with the essence of carving out a niche within a unique service system. Nature's Principles, in their Compliance driven "Stepping-Stone Strategy," forms intricate parallels with multiple strategies outlined by Ortt et al.: the "Subsidized Niche Strategy," "Geographic Niche Strategy," and "Explore Multiple Markets Niche Strategy." The intersections lie in capitalizing on emerging regulations to bolster their relevance, selectively targeting geographic markets aligned with regulations, and subsequently diversifying across markets as expertise is garnered.

5.4. Reflection on TIS for Circular Innovation

The Technological Innovation System (TIS) framework emerges as a useful and all-encompassing analytical tool for examining the complex world of circular innovation drivers in the cases at hand. The TIS framework categorizes and analyzes key building blocks and influencing conditions to help understand circular innovation dynamics' contextual complexities. This framework goes beyond simple assessment by highlighting the complex interplay between factors, which helps us understand how these drivers work synergistically to promote innovation.

The adaptation of the TIS framework to circular innovation marked a turning point in this study. This contextual adaptation, developed after a thorough literature review and consultations with Holland Circular Hotspot specialists, has been very helpful in identifying circular innovation focal points. Such contextual alignment has given the research a perceptive lens to examine Circular Innovation's many facets. This tactical adjustment has deepened and specialized cross-case analysis, which is essential for understanding circular innovation.

Visiting BlueCity Rotterdam and Holland Circular Hotspot experts provided firsthand knowledge of circular innovation implementation. These conversations stressed the importance of studying circular innovation within the TIS framework. The interactions showed that by highlighting specific focal points, we capture circular innovators' practical realities and challenges while using the TIS framework's analytical power.

These interviews have two practical applications. Their real-world examples helped us understand operational circular innovation. These insights revealed BlueCity Rotterdam and Holland Circular Hotspot's circular innovation strategies, initiatives, and collaborative networks. These tangible examples show academia and industry effective methods and potential solutions for circular innovation hurdles.

Second, the interviews confirmed that our adapted conceptual model matches industry practitioners' perspectives. The BlueCity Rotterdam and Holland Circular Hotspot consultant's agreement strengthens our approach's relevance and practicality. Their input strengthens our research and ensures that our conceptual model accurately captures circular innovation within the TIS framework.

The findings retained the essence of the TIS framework and its intended application while being carefully shaped to suit the specific factors of circular innovation. This approach not only anchored the analysis within the established framework but also acknowledged the nuanced requirements of circular innovation within the Dutch context. By incorporating this refined perspective, the analysis seamlessly integrated the robustness of the TIS framework with the unique contours of the domain of circular innovation.

6

Conclusion

In this concluding chapter, we bring together the key findings, insights, and implications obtained from our comprehensive investigation into circular innovation within the high-tech landscape of the Netherlands. Throughout this thesis, we have explored the drivers and barriers that influence the adoption and implementation of circular practices in high-tech companies. By leveraging the Technological Innovation System (TIS) framework and conducting in-depth case studies, we have gained valuable firsthand perspectives on the challenges and opportunities that characterize the transition towards circularity. As we reflect on the research question and its implications, we aim to draw a holistic picture of the circular innovation ecosystem while shedding light on the practical relevance and potential for sustainable transformation. With a deep understanding of the complexities surrounding circular innovation, this chapter provides a critical synthesis of the research journey, underlining the significance of our work in advancing sustainable practices and paving the way for a more resilient and circular future in the high-tech sector.

6.1. Summary of Findings

SQ1. What are the key driving factors to circular innovation by high-tech companies?

The study found that emerging regulations can be a powerful driver of circular innovation, especially for businesses that are already aligned with these regulations. This is because regulations can create a favorable environment for circular businesses to operate in, such as by providing financial incentives or reducing the cost of compliance. This finding suggests that governments can play a significant role in promoting circular innovation by developing and implementing supportive regulations. The study also found that strategic collaborations can help businesses to overcome barriers, accelerate their initiatives, and reach new markets. This is because collaborations can bring together different skills, resources, and expertise, which can be essential for the development and implementation of circular solutions. This finding suggests that businesses should consider collaborating with other businesses, organizations, and governments to accelerate the transition to a circular economy. Furthermore product quality and service are important factors for the adoption of circular products and services. This is because customers are more likely to adopt products and services that meet their needs

and expectations. This finding suggests that businesses should focus on developing highquality circular products and services that meet the needs of their customers. Finally, intrinsic motivation is a key driver of innovation. This is because people are more likely to innovate when they are motivated by a desire to make a difference and create a more sustainable future. This finding suggests that businesses should create a culture of innovation that is driven by a desire to do good.

SQ2. What are the barriers to the introduction of circular innovation by high-tech companies in the Netherlands?

The analysis identified several barriers that high-tech companies face when introducing circular innovation. These barriers can be categorized based on the Technological Innovation System (TIS) framework. They include factors such as incompatible production systems, innovation-specific institutions, complementary products and services, network formation and coordination, and customer-related challenges.

These barriers were found to be influenced by factors such as limited knowledge and awareness of circular technologies. High-tech companies often struggle to understand and adopt circular technologies and practices due to the lack of accessible information and expertise. Resource constraints, both in terms of natural resources and financial resources, also pose significant influencing conditions. Additionally, socio-cultural aspects, such as consumer behavior and societal norms, influence the adoption and acceptance of circular innovations. Macro-economic and strategic conditions, such as market dynamics and industry structures, also impact the feasibility and scalability of circular business models.

SQ3. What specific niche strategies have been successful in introducing circular innovation in the Netherlands?

The case studies showcased the effectiveness of niche strategies in overcoming barriers and driving circular innovation. MUDJeans successfully utilized the redesign strategy to address challenges related to incompatible production systems. KeyKeg's decentralization approach enabled them to overcome barriers related to innovation-specific institutions. FliptheCity's adoption of a turnkey product-service system allowed them to tackle product performance and quality issues. Nature's Principles, on the other hand, embraced a Compliancedriven Stepping Stone strategy, strategically aligning their innovation with emerging regulatory requirements. This approach enabled them to integrate their products into markets where regulatory changes were significant.

The analysis of the case studies highlighted the effectiveness of the Redesign Niche Strategy in promoting circular innovation, as demonstrated by MUDJeans. This strategy, which focuses on rethinking and redesigning production processes and materials, offers a valuable approach to address barriers in the implementation of circular practices. However, it is important to note that the Decentralize Niche Strategy and Turnkey Product-Service System (PSS) may be more specific and unique to circular innovation itself. These strategies, exemplified by KeyKeg and FliptheCity, provide innovative solutions to overcome barriers related to innovation-specific institutions and product lifecycle challenges.

The compliance-driven Stepping-Stone strategy adopted by Nature's Principles aligns with the broader concept of a Subsidized Niche Strategy. Both strategies involve leveraging external factors, in this case, emerging regulations. While Nature's Principles focuses on compliance with regulatory mandates, the Subsidized Niche Strategy involves subsidizing a product due to its societal relevance. These strategies share the goal of utilizing external factors to enhance the viability and adoption of circular innovation.

6.2. Limitations and Future Work

Limitations of this study reveal its scope and generalizability. The limited case studies may not fully represent the diversity of high-tech companies.

Interviews and consultations for qualitative data collection may introduce biases and overlook certain viewpoints. Self-reported data from case study companies may introduce social desirability bias. The study also focused on Dutch high-tech companies, limiting its applicability. Cultural, institutional, and regulatory contexts in different countries greatly impact circular innovation. Thus, applying the findings to other regions requires caution.

The lack of successful Dutch circular innovation companies that have introduced circular products to the market made it difficult to obtain enough case studies. This limits the applicability of the findings to all high-tech circular companies. Participation willingness among eligible companies was another issue in the study. Many companies expressed interest, but logistical or contextual constraints prevented them from participating. This trend in several high-potential cases illuminates the complex challenges these companies face in transitioning to circular innovation. This limitation shows the complexity of the circular innovation landscape, where companies face many challenges beyond innovation.

This study opens scientific avenues for studying drivers and barriers across sectors and regions. Comparative studies across countries illuminate cultural, institutional, and regulatory influences. The long-term impact and scalability of niche strategies and the role of technology and digitalization in circular innovation are also research topics. Comparative country studies could also illuminate how cultural, institutional, and regulatory factors affect circular innovation. Future studies could assess niche strategies' long-term impact and scalability in promoting circular innovation. This could involve longitudinal studies of niche companies that overcame barriers. By studying the financial, environmental, and social impacts of circular innovation initiatives, statistical research could supplement this study's qualitative findings.

6.3. Contribution and Academic Relevance

This study contributes to both theoretical and practical understandings of circular innovation in the high-tech sector and an addition to the works of Kirchherr et al.; Hina et al.; Geissdoerfer et al.; Gedam et al.. The insights gained from the analysis of case studies provide empirical evidence and valuable guidance for practitioners. By showcasing real-life examples, this research offers practical strategies and approaches that can be adapted and implemented by high-tech companies seeking to embrace circular practices. The experiences of MUDJeans, KeyKeg, FliptheCity, and Nature's Principles demonstrate the relevance and effectiveness of niche introduction strategies. This is an extension of the work done by Ortt et al. [2013]; Geissdoerfer et al. [2020]

Moreover, the discussions and consultations with industry experts from BlueCity Rotter-

dam and Holland Circular Hotspot add depth and practical relevance to the research findings. These circular innovation hubs serve as valuable resources for entrepreneurs and startups, facilitating knowledge exchange, networking, and access to expertise. The insights gained from these consultations underscore the importance of collaborative platforms and knowledge sharing initiatives in driving circular innovation forward.

6.3.1. Practical Relevance

From a practical perspective, this thesis offers valuable implications for high-tech companies, policymakers, and practitioners seeking to embrace circular practices. The identified drivers and niche strategies provide practical guidance for companies aiming to adopt and scale circular innovations. By understanding the barriers and employing appropriate strategies, companies can navigate the challenges associated with circular innovation and leverage its potential for sustainable growth and competitive advantage. Moreover, policymakers can draw upon the insights gained from this research to create enabling environments and supportive frameworks that facilitate the widespread adoption of circular practices. The practical implications of this thesis contribute to the practical implementation of circular innovation strategies and pave the way for a more sustainable and resilient high-tech sector.

6.3.2. Relevance to Management of Technology

The Master's Program in Management of Technology offers a curriculum that provides a holistic understanding of technology from a strategic perspective. This thesis holds great relevance to the program as it aligns with the core courses' focus on technology management and strategy. First, we explore the driving factors of Circular Innovation in the Netherlands. This is important from a management point of view, emphasizing the relevance of the MoT Program. The course "Emerging and Breakthrough Technologies" by Professor Ortt introduced the Technological Innovation System (TIS) framework, which forms the basis of this thesis. By utilizing the TIS framework, this research examines the drivers and barriers of circular innovation in high-tech companies and explores the strategies employed to overcome these challenges. The program's emphasis on the comprehensibility of novel concepts is crucial in an environment where innovation is constantly evolving. This thesis contributes to that objective by exploring the strategies used by high-tech companies to drive circular innovation. It provides insights into innovative approaches, collaborative networks, and regulatory considerations. It aligns with the program's objective of developing strategic thinkers and technology leaders who can shape the future of innovation in a sustainable and responsible manner.

6.4. Conclusion

In conclusion, this study has provided valuable insights into the drivers, barriers, and niche strategies associated with circular innovation in high-tech companies in the Netherlands. By examining the experiences of MUDJeans, KeyKeg, FliptheCity, and Nature's Principles and engaging in consultations with industry experts, we have gained a deeper understanding of the dynamics involved in circular innovation and have identified practical approaches to overcome barriers. These findings contribute to the existing knowledge on circular innovation and offer actionable recommendations for stakeholders in the high-tech sector. In addition, the adapted TIS framework served as a very crucial analytical tool in understanding the dynamics

behind Circular innovation. This was pivotal in performing the case studies to understand the drivers and barriers to circular innovation by Dutch High-Tech Companies. As the global focus on sustainability continues to grow, the adoption of circular innovation becomes increasingly important, and the insights from this study can contribute to a more sustainable and resource-efficient future. At the same time, it is essential to recognize the limitations of this study and the need for further research to explore different contexts and expand our understanding of circular innovation in diverse industries and regions.

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Appendix A

A.1. Circular Business Models

Research by Geissdoerfer et al. indicates that circular business models serve as a critical lever for the successful implementation of a circular economy. Industrial practitioners recognize that business model innovation is instrumental in driving the transition to a circular economy at the organizational level. By enabling a systemic shift in the core logic of businesses and aligning the incentives of various stakeholder groups, these innovative business models facilitate the adoption of circular economy principles [Rashid et al., 2013; Schulte, 2013].

However, there is a notable lack of clarity regarding their theoretical conceptualization. Many definitions of circular business models emphasize value creation and are aligned with existing value logic frameworks or the business model definition. These definitions often integrate circular economy principles and translate them into specific strategies, such as recycling measures, efficiency improvements, use phase extensions, intensified use phase, and the substitution of product utility with service and software solutions [Geissdoerfer et al., 2017, 2018a,b, 2020].

A.2. Innovation for Circular Economy contd.

With favorable effects on the environment and society, eco-innovation has been recognized as a specific route for boosting productivity and competitiveness. A socio-economic system based on the idea of Circular Economy can be created by applying this type of innovation as a transformative process to break away from the status quo. This shift toward Circular Economy is unstable and uneven (as certain activities or sectors will change more quickly than others) (as pro-circular factors and actors will encourage others to change too). To put it another way, such innovations have the ability to set off a chain of events and generate localized pressures, which would subsequently inspire complementary adaptations elsewhere, resulting in the formation of a new techno-economic system [Reid and Miedzinski, 2010; De Jesus and Mendonça, 2018]. It is conceivable that ("transformative") innovation may now serve as the catalyst for stimulating a new, "green" transition, just as innovation facilitated the growth of an industrial, carbon-intensive economy [Schot and Kanger, 2018].
De Jesus and Mendonças highlight a few key points from "The Oxford Handbook of Innovation", Reconfiguration and adaptability during a transition are intrinsically innovative processes. Innovation is more than just the "introduction of a novelty;" it is a component of a larger social and economic system that is rooted in a particular historical and geographical setting [Fagerberg et al., 2005]. This link can be found at least as far back as the early 1990s. However, as the authors clearly explain, even after more than two decades, there is still a lack of developed relevant literature that relates innovation to the environment. Several perspectives on transition, sustainability, and Circular Economy exist in the subject of innovation studies[De Jesus and Mendonça, 2018]. In the framework of this thesis, *"Circular Innovation"* will be utilized as an operational definition of innovation carried out explicitly with the purpose of ecological, social, and economic issues, ultimately a drive towards Circular Economy. These innovations are seen to be more than merely "green technology" (i.e., tools that have a positive impact on the environment, including end-of-line interventions like fume exhaust catalysers), but rather as a tactical enabler of value-chain reforms as a whole [Andersen, 2008; Kemp, 2010].



Figure A.1: The Value Hill, Visualisation

A.3. Systemic Perspective towards Circular Economy, contd.

As Kirchherr et al.; De Jesus and Mendonça note in their respective work, it is already evident how important a "systemic" innovation approach is to a Circular economy, especially in EU reports. In order to achieve circular transition, it is necessary to "adopt a systemic approach to eco-innovation that encompasses value and supply chains in their entirety and engages all actors in such chains". In fact, the EU has taken a leading role in the creation of a Circular economy by reshaping its environmental agenda to include more circular considerations. The EU's agenda towards being circular is now a part of broader initiatives to strengthen the EU's competitiveness, foster business opportunities, generate jobs, and foster social cohesion and integration while also enhancing the European economy's sustainability. The EU's commitment is emphasized in the 2015 Circular Economy Action Plan, which also acknowledges the connections between implementing a Circular Economy and (eco)innovation [EC, 2016, 2015]. De Jesus et al. in a paper the following year, 2019, which explored pathways to a circular economy through a Delphi Approach presented similar findings(concensus) on the systemic innovation approach to Circular Economy. It also stated that, in particular, Circular Economy development over the following 20 years involves more than just solving technological and financial issues [De Jesus et al., 2019].

Corporate boundaries



Figure A.2: Four types of circular business model innovation, as illustrated by [Geissdoerfer et al., 2020]

	6		¢ ⁸	ŝ
		Value proposition	Value creation & delivery	Value capture
		 Main products/services Customer segments/markets Customer needs/problems How do you address them? 	 Key value chain elements Core competencies Resources and capabilities 	 Revenue streams Cost drivers Revenue model, like leasing, razor & blade, platform fees, etc
9	Cycling • Reuse • Repair • Remanufacturing/ refurbishing • Recycling • Design for X/Modularity • Reverse logistics • Incentives to return cores	 Used, repaired, remanufactured, refurbished or recycled products/ materials/organic feedstock (Ludeke- Freund et al., 2019) Segment of existing or new customers in need for affordable and green products/ materials/ processes or end-of-life/waste management solutions (Ludeke-Freund et al., 2019) Taking back products/ materials/ organic feedstock and transforming them in new resources (e.g. products, materials) (Ludeke-Freund et al., 2019) 	 Repair, remanufacture, refurbish, recycling products operations; reprocessing or industrial symbiosis operations (Bocken et al., 2016; Ludeke-Freund et al., 2019) Suppliers outsourcing and collaborations to close the loop (e.g., gap exploiters – collectors, retailers or recommerces, reprocessors) (Den Hollander and Bakker, 2016) Access to cores/end-of-life products; proper incentives/awareness to take back products from customers/end-users Reverse supply chain (Bocken et al., 2016; Ludeke-Freund et al., 2019) 	 Additional revenues (potential new business lines) from residual values of products/ materials/ organic feedstock (Bocken et al., 2016; Ludeke-Freund et al., 2019) Savings with reduced costs for resource input (e.g. recycled or exchanged materials, parts) (Bocken et al., 2016) Revenue model based on direct sales or trade of resources (Bocken et al., 2016; Ludeke-Freund et al., 2019)
0	Extending - Long-lasting products - Upgradability - Timeless design - Marketing/consume r education encouraging long product life - Maintenance/produ ct support	 Long-lasting products, products with time-less design, upgrading, warrantees and support, maintenance/repair/control, refurbishment/retrofit services (Ludeke-Freund et al., 2019) Segment of existing or new customers in need for reliability, savings with extending use of capital intensive products, lower downtime risks (Ludeke-Freund et al., 2019) Providing premium/superior-quality products and high service levels (Bocken et al., 2016) 	 Services operations (e.g. maintenance, repair, upgrade, refurbishing/ retrofitting) (Ludeke-Freund et al., 2019) Durable/repairable product design (Bocken et al., 2016) Digital capabilities (e.g. predictive maintenance) (Bocken et al., 2016) Service network collaboration (Bocken et al., 2016; Ludeke-Freund et al., 2019) Marketing/consumer education encouraging long product life (Bocken et al., 2016) Long-term customer relationship (Bocken et al., 2016) 	 Revenues from high-quality products (premium margins) or high-level servicing, customer loyalty (Bocken et al., 2016) Revenue model based on service packages or tailored contracts (payment for functions or results), payment per service transactions (e.g. upgradability and repairs). (Bocken et al., 2016; Ludeke-Freund et al., 2019)
	Intensifying • Sharing models • Rental/leasing models • User cooperatives • Open elements/ creative commons • Pooling models	 Products as service, collaborative consumption services (Bocken et al., 2016) Segment of existing or new customers in need of lower total cost of ownership and/or lower up-front investments, convenience (e.g. hassle free solutions) (Bocken et al., 2016) Providing functionality or the temporary availability of products instead of ownership (Bocken et al., 2016) 	 Capacity management (demand and supply of products) Digital capabilities (e.g. tracking) Transportation and logistics Reselling or redistributing products Slow and Close-the-loop' capabilities or collaborations (e.g. repair, maintenance, remanufacture, refurbishment products) Product-service systems design Orchestration of suppliers (e.g. service providers) Contract and customer relationship management (Bocken et al., 2016) 	 Recurrent revenues from service temporary contracts, long-term customer relationships (lock-in) (Bocken et al., 2016) Increased long-term profit margins due to savings from using products for longer (i.e. multiple cycles and users) and potential efficiency gains in operations (e.g. energy) (Bocken et al., 2016) Pricing per unit of service (e.g. time, number of uses), rental or leasing fees (Bocken et al., 2016)
	Dematerialising • Software instead of hardware • Service instead of product • Consumer education rationalising demand	 Services substituting or reducing the need for hardware Segment of existing or new customers in need of expertise in certain non-core activities, convenience, lower total cost of ownership (Bocken et al., 2016) Providing turn-key solutions or the results for customers needs (Bocken et al., 2016) 	 Technology design for digitalization Product-service systems design 'Slow and Close-the-loop' capabilities or collaborations (e.g. repair, maintenance, remanufacture, refurbishment products) Consumer education rationalising demand ("do you really need that?") 	 Recurrent revenues from services subscriptions or contracts, long-term customer relationships (Bocken et al., 2016) Increased profit margins due to additional value from uniqueness and savings from using products for longer and efficiency gains in operations (e.g. energy consumptions, transportation, less products as possible) (Bocken et al., 2016) Pricing per agreed results (e.g. pay- per-light) (Bocken et al., 2016)

Figure A.3: Key business model considerations for the circular economy, framework developed by Geissdoerfer et al.

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Appendix B

Building Blocks	Description
Product performance and quality	A product (with all subsystems including hard- ware and software components) is required with a sufficiently good performance and quality (ab- solutely or relatively compared to other compet- itive products). Lacking performance or quality can hamper large-scale diffusion.
Product price	A product (with all subsystems) is required with a reasonable price (absolutely or relatively com- pared to other competitive products). The price of a product involves financial and non-financial (e.g., time and effort) investments to acquire and use the product. A prohibitively high price can hamper large-scale diffusion.
Production system	A production system that can produce large quantities of products with sufficiently good per- formance and quality (absolutely or relatively compared to competitive products), is required for large-scale diffusion. A lack of production system can hamper large-scale diffusion.
Complementary products and services	Complementary products and services for the development, production, distribution, adoption, use, repair, maintenance, and disposal of an innovation are required. Unavailable, incompatible, or too expensive complementary products and services can hamper large-scale diffusion.

Table B.1: Building Blocks

Building Blocks	Description		
Network formation and coordi-	Required actors and sufficient coordination of		
nation	their activities to develop, produce, distribute, repair, maintain, and dispose of products are required for large-scale diffusion. Coordination can be emergent and implicit (e.g., the market mechanism) or can be formal and explicit (e.g., an industry association). Coordination can in- volve actual collaboration and a shared vision regarding the innovation and the TIS around it. If types of actors and coordination amongst these actors are needed yet missing, large- scale diffusion can be hampered		
Customers	Customer segments are required for large-scale diffusion. Potential customers with a need for the innovation should be identified. To become actual customers, they should be aware of the product, see its benefits relative to other inno- vations, and have the knowledge, means, and willingness to acquire and use it. If actual cus- tomers are lacking, large-scale diffusion can be hampered.		
Innovation-specific institu- tions	These institutions refer to formal policies, laws, and regulations either describing norms and re- quirements regarding the product, production facilities, and complementary products and ser- vices or describing how actors (on the supply and demand side of the market) should deal with the product and system around it. Specific institutions can stimulate or hamper large-scale diffusion.		

Table B.2: Influencing Conditions

Influencing Conditions	Description
Knowledge and awareness of	This involves both fundamental and applied
technology	technological knowledge. Fundamental knowl-
	edge refers to the technological principles in-
	volved in components of the TIS, like the prod-
	uct, production, and complementary products
	and services. Applied technological knowledge
	refers to the knowledge required to develop, pro-
	duce, repair, maintain, and improve these com-
	ponents. When relevant actors lack knowledge
	and awareness of technology for their role, this
	can affect the formation of several TIS building
	blocks.

Influencing Conditions	Description
Knowledge and awareness of	This refers to knowledge of (1) potential appli-
application and market	cations, (2) knowledge of the market (structure)
	and the actors involved in these applications.
	This knowledge is required for all actors includ-
	ing customers to formulate strategies, articulate
	product requirements and find or target other
	actors. When actors lack such knowledge re-
	quired for their role, this can affect the formation
Natural human and financial	Resources can refer to natural human and fi-
resources	nancial resources Natural resources refer to
	raw materials that can be acquired by each or-
	ganization separately or by associations of or-
	ganizations. Human resources refer to individu-
	als with the right knowledge and competences.
	Increasing human resources may involve edu-
	cation programs, courses, and training on the
	job. Financial resources can come from various
	sources. Lack of natural, human, or financial re-
	sources can affect the formation of TIS building
O a mar a fittion	blocks.
Competition	competition can refer to competition between
	but may also refer to competition between dif
	ferent product versions with a new technol-
	ogy Since different product versions often
	require different production systems and com-
	plementary products and services, competition
	arises between networks of companies. The
	combined complex patterns of competition may
	hamper the formation of TIS building blocks.
Macro-economic and strate-	Macro-economic aspects refer to the overrid-
gic aspects	ing economic situation, such as a recession or
	terests of countries which are often reflected
	in generic institutions and government policies
	Macro-economic and strategic aspects can in-
	fluence the formation of TIS building blocks.
Socio-cultural aspects	Socio-cultural aspects refer to the norms and
	values in a particular culture or socio-technical
	system. These conditions might be less formal-
	ized than the laws and rules in the innovation-
	specific institutions. They include methods
	and nabits, norms and values ("the way to do
	unings) and may become visible in interest
	cultural aspects can influence the formation of
	different TIS building blocks.

Influencing Conditions	Description
Accidents and events	Accidents and events may emerge both out- side a TIS (e.g., wars, political turmoil or natural disasters) or from within a TIS (e.g., accidents with products or in production, emergence of new technologies). Accidents and events can influence the formation of several TIS building blocks.

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Appendix C

C.1. Niche Strategies

As mentioned by Kamp et al., a product can be launched in a niche market—a small segment of the market—first as a way to overcome the barriers to large-scale diffusion. Since evidence suggests that there are barriers to product introduction in the current market, products are frequently not introduced directly into the large market. A niche strategy can be used to first launch the new product in a small market, or a niche market, in order to overcome these obstacles. Additionally, this might entail further developing the product through both subtle and significant innovations [Kamp et al., 2018; Ortt and Kamp, 2022; Hultink et al., 1997].

High-tech entrepreneurs encounter various challenges when it comes to commercializing their groundbreaking innovations within the highly competitive business environment. This is particularly true for emerging technologies that have not yet gained widespread commercial adoption. The utilization of niche marketing strategies can significantly facilitate the effective commercialization of new products by high-tech companies in such circumstances [Ortt et al., 2013].

It is however important to note that the applicability and effectiveness of these niche strategies may vary depending on the specific context, industry dynamics, and market conditions. Further research and empirical validation are necessary to comprehensively assess the impact and potential of niche strategies in the domain of circular innovation for high-tech startups. Research by Blomsma et al. also indicated that circular strategies work synergistically when combined with Product-Service Systems (PSS) This was highlighted with the example case of Riversimple [Blomsma et al., 2018].

C.2. Generic Niche Strategies as listed out by Ortt et al.

1. Demo, experiment and develop niche strategy

- Knowledge of the technology is lacking and that affects the availability of the product itself because the functionality is not provided with sufficient quality.
- A niche strategy can be adopted to demonstrate the product in public in a controlled

way so the limited quality of performance is not a problem. As part of the strategy, experimenting with the product is important to develop the product further, for example in a research environment.

2. Top niche strategy

- Knowledge of the technology is lacking and that affects the availability of the product for a reasonable price.
- Knowledge of the technology is lacking and that affects the production system with which controlled production of products with a constant and good enough quality and reasonable price is possible.
- Resources for the product or the production are lacking or very expensive and that affects the product's price.
- A niche strategy can be adopted where hand-made products can be made to order, in small numbers, for a specific top-end niche of the market.
- A skimming strategy can be adopted in which the top niche of customers is supplied first with a special product.

3. Subsidized niche strategy

- Knowledge of the technology is lacking and that affects the availability of the product or the production system and that in turn affects the availability of the product for a reasonable price.
- Resources for the product or the production are lacking or very expensive and that affects the product's price.
- A niche strategy can be adopted where the product is subsidized if the use of the product by a particular segment of users is considered as societally relevant or important.

4. Redesign niche strategy

- Knowledge of the technology is lacking and that affects the availability of the product or the production system and that in turn affects the availability of the product for a reasonable price.
- Resources for the product or the production are lacking or very expensive and that affects the product's price.
- Knowledge of the application of the product is missing or socio-cultural aspects affect the availability of appropriate institutional aspects (laws, rules and standards) and thereby hamper diffusion.
- Socio-cultural aspects affect the availability of suppliers or customers.
- A niche strategy can be adopted where the product is introduced in a simpler version that can be produced with the existing knowledge, less use of resources, and therefore for a lower price.
- A niche strategy can be to explore an application where institutional aspects are more favorable. Mostly leads to redesign.
- A niche strategy can be to explore an application where suppliers or customers have no resistance to produce and use it. Mostly leads to redesign.

5. Dedicated system or stand- alone niche strategy

• Knowledge of the technology is lacking and that affects the availability of complementary products and services. • A niche strategy can be adopted where the product is used in stand-alone mode or a dedicated system of complementary products and services is designed (e.g., a local network when an infrastructure is not available on a wider scale).

6. Hybridization or adaptor niche strategy

- Knowledge of the technology is lacking and that affects the availability of complementary products and services.
- Resources are lacking and that affects the availability of complementary products and services.
- A niche strategy can be adopted by which the new product is used in combination with the old product and thereby all existing complementary products and services can be re-used. Or an adaptor/convertor is provided to make the product compatible with existing complementary products and services.

7. Educate niche strategy

- Knowledge of the technology is lacking and that affects the availability of suppliers or customers
- A niche strategy can be adopted aimed at transferring the knowledge to suppliers.
- An educate and experiment (pilot) niche strategy can be adopted aimed at increasing customer knowledge.

8. Geographic niche strategy

- Knowledge of the technology or its application is lacking and that affect the availability of appropriate institutional aspects (laws, rules and standards)
- Resources are lacking affecting the availability of the product or complementary products and services.
- Socio-cultural aspects or macro- economic aspects affect the availability of suppliers, customers and appropriate institutional aspects.
- Accidents and unexpected events affect the availability appropriate institutional aspects.
- A niche strategy can be adopted where institutions (laws and rules) are relatively easy to arrange or are less strict.
- A niche strategy can be adopted in another geographic area where resources, suppliers or customers are available.
- A niche strategy can be adopted in another geographic area where suppliers are available and not hampered by these unexpected events or accidents.

9. Lead user niche strategy

- Knowledge of the application of the product is missing and that affects a clear view on customer applications, specific product requirements and customer segments by suppliers.
- Socio-cultural aspects, Macro- Economic aspects or accidents and unexpected events affect the availability of suppliers or customers.
- A niche strategy can be adopted finding innovators or lead users. These lead users can co-develop the product and innovators are willing to experiment with the product.

10. Explore multiple markets niche strategy

- Knowledge of the application of the product is missing and that affects the availability of a clear view on applications, usage patterns and product benefits by customers.
- A niche strategy can be adopted in which multiple customer applications can be explored. Visibility of the first applications might stimulate explorative use in new applications.

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Appendix D

Factors	Keywords/Focus Areas	References
Product / Services	Design for Circularity, Resource Op- timization, Integrated PSS	[De Jesus et al., 2018; Gedam et al., 2021; Ritzén and Sandström, 2017; Hina et al., 2022; Kirchherr et al., 2018]
Technical Prowess and Capabilities	9 R(s) Capabilities, Strong Reverse Logistics, Flexibility and Adaptabil- ity	[De Jesus et al., 2018; Bicket et al., 2014; EMF, 2021, 2012]
Economic / Financial / Market	Long Term Feasibility, Total Cost of Ownership	[Ritzén and Sandström, 2017; De Jesus et al., 2018; Kirch- herr et al., 2018; EC, 2015; EMF, 2012, 2021]
Value / Supply Chain	Strong Network, Division of Re- sponsibility, Shared Goals	[D'heur, 2015; Ritzén and Sandström, 2017; Kirchherr et al., 2018; Gedam et al., 2021; Hina et al., 2022]
Structural / Operational services and products and Organisational	Collaboration, Ecosystem of Prod- ucts / Services, Industry Specific In- frastructure	[Ranta et al., 2018; Kirchherr et al., 2017; Gedam et al., 2021; Ritzén and Sandström, 2017]
Institutional / Regula- tory Factor	General Consensus, Standardiza- tion, Emerging Robust Policies	[De Jesus and Mendonça, 2018; Ritzén and Sandström, 2017; Hina et al., 2022; Kirch- herr et al., 2018; Trevisan et al., 2023; Gedam et al., 2021].

Factors			Keywords/Focus Areas	References
Attitudinal tomers	and	Cus-	Awareness and Knowledge, Own- ership Preferences, Resistance to Change	[Singh and Giacosa, 2019; Gedam et al., 2021; Kirchherr et al., 2018; Ritzén and Sand- ström, 2017; Hina et al., 2022; Trevisan et al., 2023]

Table D.1 continued from previous page

 Table D.1: Keywords and Focus Areas for Circular Innovation relevant for Technological Innovation System, Building Blocks

Focus Area	Description
Design for Circularity	The design of products and services that are designed to be reused, repaired, or recycled at the end of their life. This can be done by us- ing durable materials, designing for disassem- bly, and making it easy to repair products.
Resource Optimization	The efficient use of resources throughout the product life cycle. This can be done by using recycled materials, reducing waste, and minimizing energy consumption.
Integrated PSS	Product-service systems that combine products and services in a way that minimizes waste and environmental impact. For example, a product- service system could include a product that is rented and then returned to the manufacturer for reuse or remanufacture.
9 R(s) Capabilities	This refers to the nine principles of waste hier- archy. Businesses that have strong 9 R(s) ca- pabilities can minimize waste and maximize the value of resources.
Strong Reverse Logistics	The efficient collection and disposal of end of life products / materials. Businesses with strong re- verse logistics capabilities are able to recover valuable materials and minimize the environ- mental impact of waste disposal.
Flexibility and Adaptability	The ability to change and adapt to new tech- nologies and market conditions. Businesses that are flexible and adaptable are better able to adopt circular practices and remain competi- tive in the long term.

Focus Area	Description		
Long Term Feasibility	The need to ensure that circular innovation is economically viable in the long term. This in- cludes factors such as the cost of developing and implementing new technologies, the avail- ability of financing, and the potential for market demand.		
Total Cost of Ownership	The need to consider the total cost of ownership of circular products and services, including the cost of materials, manufacturing, and disposal. This can help to ensure that circular solutions are actually more sustainable than traditional ones.		
Strong Network	The need for strong collaboration between dif- ferent actors in the value chain, such as man- ufacturers, suppliers, and distributors. This can help to ensure that circular products and services are available and accessible to con- sumers.		
Division of Responsibility	The need to clearly define the roles and respon- sibilities of different actors in the circular econ- omy. This can help to avoid conflict and en- sure that everyone is working towards the same goals.		
Shared Goals	The need for all actors in the circular economy to share the same goals. This can help to en- sure that everyone is working towards a com- mon vision and that progress is made.		
Collaboration	The need for collaboration between different in- dustries and sectors. This can help to share knowledge and resources and to develop new circular solutions.		
Ecosystem of Products / Ser- vices	The need to create an ecosystem of products and services that are designed to be circular. This can help to ensure that there is a market for circular products and services and that they are accessible to consumers.		
Industry Specific Infrastruc- ture	The need for industry-specific infrastructure that supports circular practices. This is relevant for highly specific industries, where compatibility is key.		
General Consensus	The need for a general consensus on the prin- ciples of the circular economy. This can help to create a supportive environment for circular in- novation and to overcome barriers to adoption.		

Table D.2 continued from previous page

Focus Area	Description
Standardization	The need for standardization of circular prod- ucts and services and their indicators. This can help to ensure that they are compatible with each other and that they can be easily recycled or reused.
Emerging Robust Policies	The need for emerging robust policies that sup- port the circular economy. This can include things like supportive regulations to subsidies for circular businesses.
Awareness and Knowledge	The need to raise awareness of the circular economy and its benefits. This can help to cre- ate demand for circular products and services and to overcome barriers to adoption.
Ownership Preferences	The need to change consumer preferences away from ownership and towards sharing and leasing. This can help to reduce waste and to make circular products and services more ac- cessible to consumers.
Resistance to Change	The need to overcome resistance to change from businesses and consumers. This can be a challenge, but it is essential for the successful transition to a circular economy.

Table D.2 continued from previous page

Table D.2:	Focus Area	a for Circular	Innovation.	explained

Factors	Keywords/Focus Areas	References
Technological Know- how	Limited Scope of Circular Products, Large Scale Demonstration	[Kirchherr et al., 2018; Ritzén and Sandström, 2017; Gedam et al., 2021; Hina et al., 2022; De Jesus and Mendonça, 2018]
Market, Industry and Competition	Market Positioning, Conventional Competition, Value Proposition, Un- certain Returns, Linear Lock-ins, Asymmetric Information	[De Jesus and Mendonça, 2018; Ritzén and Sandström, 2017; Kirchherr et al., 2018; Gedam et al., 2021; Hina et al., 2022]
Resources	Resource flow Optimisation, Avail- ability of Finances	[De Jesus and Mendonça, 2018; Gedam et al., 2021; Ritzén and Sandström, 2017; Hina et al., 2022; Kirchherr et al., 2018; EMF, 2012]
Strategy, Economy and Institutions	Systemic Perspective, Economic Conditions, Conducive Regulations	[Kirchherr et al., 2018; EC, 2015; Commission, 2003; EC, 2016]

Factors	Keywords/Focus Areas	References
Social and Attitudinal	Literacy and Motivation, Informed Preferences, Limited Information and Knowledge	[Ritzén and Sandström, 2017; Hina et al., 2022; Repo and Anttonen, 2017; Kirchherr et al., 2018; Gedam et al., 2021; Singh and Giacosa, 2019]
Accidents	Internal Disruption, Cascading Effects, Resilience	[Gedam et al., 2021; Ortt and Kamp, 2022]
Leadership and Organi- sational	Leadership and Team Skills	Gedam et al. [2021]; Hina et al. [2022]; Ritzén and Sand- ström [2017]

Table D.3 continued from previous page

 Table D.3: Keywords and Focus Areas for Circular Innovation relevant for Technological Innovation System, Causal Factors

Focus Area	Description		
Limited Scope of Circular Products	The scope of circular designs remains limited, preventing the full realization of their potential impact. This can be due to a lack of techno- logical know-how, market demand, or regulatory support.		
Large Scale Demonstration	The establishment of more large-scale demon- stration projects can serve as powerful show- cases to inspire and accelerate the adoption of circular practices throughout various industries. This can help to overcome barriers such as un- certainty about the viability of circular solutions and a lack of awareness of the benefits of circu- larity.		
Market Positioning	The market positioning of circular products and services is critical for their success. This in- cludes understanding the needs of target cus- tomers, developing a clear value proposition, and effectively communicating the benefits of circularity.		
Conventional Competition	Circular businesses face competition from con- ventional businesses that are not yet adopting circular practices. This can make it difficult to gain market share and achieve profitability.		

Focus Area	Description
Value Proposition	The value proposition of circular products and services needs to be clear and compelling in order to attract customers. This includes high- lighting the environmental and economic bene- fits of circularity, as well as the quality and per- formance of circular products.
Uncertain Returns	The returns on investment for circular busi- nesses can be uncertain, due to the novelty of circular products and services and the lack of clear market demand. This can make it difficult to attract investors and secure financing.
Linear Lock-ins	Linear economic systems are characterized by a "take, make, dispose" approach to resources. This can make it difficult to adopt circular prac- tices, as businesses and consumers are often locked into linear systems.
Asymmetric Information	Asymmetric information exists when one party to a transaction has more information than the other party. This can be a barrier to the adop- tion of circular practices, as consumers may be unaware of the benefits of circular products and services.
Resource flow Optimisation	Resource flow optimization is the efficient use of resources throughout the product life cycle. This covers all resources, materials and fiscal resources.
Leadership and Team Skills	Leadership and team skills are essential for the successful implementation of circular inno- vation. This includes the ability to develop and execute a clear vision for circularity, as well as the ability to build and manage a team of skilled and motivated individuals.
Availability of Finances	The availability of finances is essential for the development and implementation of circular in- novation. This can be obtained through a vari- ety of sources, such as government grants, pri- vate investment, and crowdfunding.
Systemic Perspective	The circular economy is a complex system that requires a systemic perspective to be success- ful. This means taking into account the intercon- nectedness of different actors and factors, and the need for collaboration and cooperation.

Table D.4 continued from previous page

Focus Area	Description
Economic Conditions	The economic conditions can have a significant impact on the development and adoption of cir- cular innovation. For example, periods of eco- nomic growth can provide opportunities for in- vestment and innovation, while periods of reces- sion can make it more difficult to secure financ- ing.
Conducive Regulations	Conducive regulations can create a supportive environment for the development and adoption of circular innovation. This includes regulations such as corporate responsibility directives and EU Action Plans.
Literacy and Motivation	The level of literacy and motivation among con- sumers and businesses can also affect the de- velopment and adoption of circular innovation. Consumers who are aware of the benefits of cir- cularity and are motivated to make sustainable choices are more likely to support circular busi- nesses and products. Businesses that are com- mitted to circularity and are willing to invest in the necessary resources are also more likely to be successful.
Informed Preferences	Consumers who have access to accurate infor- mation about the environmental and social im- pacts of their choices are more likely to make informed decisions about the products and ser- vices they purchase. This can help to drive de- mand for circular products and services.
Limited Information and Knowledge	The lack of information and knowledge about cir- cularity can be a barrier to its adoption. This in- cludes information about the benefits of circular- ity, as well as the challenges and opportunities associated with it.
Internal Disruption	Accidents that occur within a company can dis- rupt production, supply chains, and other opera- tions. This can have a significant impact on the ability of a company to adopt circular practices.
Cascading Effects	Accidents can have cascading effects, affecting other companies and organizations. This can make it difficult to coordinate efforts to adopt cir- cular practices.

Table D.4 continued from previous page

Focus Area	Description
Resilience	Resilience is the ability to recover from shocks and stresses. This is important for compa- nies and organizations that are adopting circular practices, as they will be more likely to be able to withstand disruptions.

Table D.4 continued from previous page

Table D.4: Focus Area for Circular Innovation contd., explained

E

Appendix E

E.1. Interview Guidelines

1. Introduction

- (a) Introduce yourself and explain the purpose of the interview.
- (b) Assure confidentiality and ethical use of the interview data.
- 2. Background Information
 - (a) Gather information about the interviewee's role and experience with circular innovation.
 - (b) Assess their familiarity with circular economy principles and involvement in implementing circular practices.
- 3. Key Drivers and Barriers
 - (a) Explore the interviewee's perspective on the key drivers that facilitate circular innovation.
 - (b) Ask about successful initiatives, strategies, or collaborations promoting circular practices.
 - (c) Inquire about the main barriers and challenges faced during the implementation of circular innovation.
 - (d) Keep the questions open-ended and exploratory to allow for comprehensive responses.
- 4. Niche Strategies
 - (a) Discuss the interviewee's knowledge and experience with niche strategies in circular innovation.
 - (b) Inquire about specific niche strategies employed or considered to overcome barriers.
 - (c) Explore the effectiveness and impact of these niche strategies in promoting circular practices.
 - (d) Keep the questions open-ended and exploratory to elicit detailed and insightful answers.

- 5. Contextual Factors
 - (a) Inquire about the role of regulations, industry landscape, and market dynamics in shaping circular innovation.
 - (b) Discuss the influence of policies, incentives, and supportive frameworks.
 - (c) Ask about challenges and opportunities arising from the company's industry context.
 - (d) Keep the questions open-ended and exploratory to capture the interviewee's unique perspectives.
- 6. Future Directions and Recommendations
 - (a) Seek insights and opinions on future trends and developments in circular innovation.
 - (b) Inquire about areas for improvement, innovation, and collaboration.
 - (c) Ask for recommendations or suggestions for policymakers and industry stakeholders.
 - (d) Keep the questions open-ended and exploratory to encourage innovative and forwardthinking responses.
- 7. Conclusion
 - (a) Thank the interviewee for their participation.
 - (b) Provide an opportunity for additional comments or insights.
 - (c) Reiterate the confidentiality and ethical use of the interview data.

E.2. Questions

- 1. Demography
 - (a) Which industry does your company operate in?
 - (b) How many employees are there in your company?
 - (c) Where is your company located?
- 2. Basics of Circular Economy
 - (a) Are you familiar with the concept of the circular economy?
 - (b) What is your understanding of the circular economy?
 - (c) Can you identify the three Rs of the circular economy?
 - (d) Which circular economy practices does your company currently implement?
- 3. Benefits of the Circular Economy
 - (a) How aware is your organization of the benefits of the circular economy?
 - (b) What specific benefits do you expect to achieve through the implementation of the circular economy?
 - (c) What factors motivate your intention to implement the circular economy?
 - (d) What social benefits do you anticipate from implementing the circular economy?(Social, Economic, environmental, technological, legislative)
 - (e) What drivers attract you to implement the circular economy?
- 4. Barriers to the Circular Innovation

- (a) What external barriers has your organization faced or might face while implementing the circular Innovation?
- (b) What factors prevent or hinder your organization from implementing the circular Innovation?
- (c) What are the main social barriers you perceive against the implementation of the circular Innovation?
- (d) What is the primary economic barrier inhibiting the implementation of the circular Innovation?
- (e) What is the primary environmental barrier inhibiting the implementation of the circular Innovation?
- (f) What is the main technological barrier inhibiting the implementation of the circular Innovation?
- (g) What is the main institutional barrier inhibiting the implementation of the circular Innovation?
- 5. Product/Service
 - (a) What specific product/service does your company offer?
 - (b) How does your product/service contribute to the circular economy?
 - (c) What unique features or functionalities does your product/service have compared to traditional offerings?
 - (d) How do you ensure the durability and longevity of your product/service?
 - (e) What steps have you taken to optimize the use of resources in the production of your product/service?
- 6. Business Model
 - (a) What is your current business model?
 - (b) Have you made any modifications to your business model to align with the principles of the circular economy?
 - (c) How do you generate revenue and create value within your business model?
 - (d) What partnerships or collaborations have you established to support your circular business model?
 - (e) How do you measure the success or impact of your circular business model?
- 7. Niche Strategies
 - (a) Have you implemented any niche strategies to overcome barriers to the adoption of your product/service?
 - (b) How do you identify and target specific niche markets for your offering?
 - (c) What unique value propositions or tailored features do you provide to meet the specific needs of niche market segments?
 - (d) How do you position your product/service within the niche market to differentiate it from competitors?
 - (e) Have you observed any effects between niche strategies and the operationalization of your business model?

F

Appendix F

F.1. Cross-Case Analysis Data

The following has the expanded tables from section 4.5. The tables include all the relevant codes, along with example quotations and the frequency of the code family within each of the interviews. The table also shows some additional information along with observations.

Driver	Associated Codes	Description of Driver	Case Study Companies	Quotation Examples	Code Frequency in Case	Driver for Cases	Observations	
Emoraina	Regulations: Regional Specific New regulations MUDJeans "And then you also have the EPR regulations. So that's of them is EU wide. And in the Netherlands, like I said, that into force in July now Yeah, I think overall, to summarize around taking more responsibility throughout your sup throughout the end of life of the product for the design of Also things such as guaranteeing repair in some s Plans and various Plans and various 4:33 ¶ 101 in MUDJeans Full transcript	"And then you also have the EPR regulations. So that's once one of them is EU wide. And in the Netherlands, like I said, that's coming into force in July now Yeah, I think overall, to summarize, it's kind of around taking more responsibility throughout your supply chain throughout the end of life of the product for the design of the product. Also things such as guaranteeing repair in some sense." <u>4:33 ¶ 101 in MUDJeans Full transcript</u>	18		Emerging Regulations was noted to be an important driver for MUDJeans and Nature's			
regulations	Regulations: Visionity mont Regulations Regulations: Government Regulation & Legislation	regulations are driving innovation in the circular economy by requiring businesses to reduce their environmental impact.	Nature's Principles	"I think regulations are very important. So for any industry, any industry is affected by regulations. But for our customers, for example, so this soil sanitation case, it's driven primarily by regulations. So governments and like European Union, you know, United States of America, they, they say, Okay, we need to have certain soil and water quality. And this is where the business comes from." <u>8:18 ¶ 63 in Nature's Principles Meeting-20230713 112719-</u> Meeting Recording	15	2	Principles, for the other two cases, they end up providing an overall conducive set of circumstances for its business.	
	Drivers: Local	Partnerships with like- minded partners, who often, collabratively work together. This can also include municipalities,	MUDJeans	"Um, yeah, I think we were very lucky with the suppliers that we have because Well, we essentially we consciously chose them because they have a similar vision, right? It's a partner of ours that invented this, that we of course, helped, you know, test and develop this method. But in the end, they are the ones that drove this development. So for us, it's definitely been a huge driver. And we we love working with partners that kind of, yeah, drive this circular ambition and not be a barrier to it. Thank you. Yeah. All right. Sophie, I think you said you didn't have any questions anymore. Nobody have any last question." 4:49 ¶ 191 in MUDJeans Full transcript	13		Collaboration has been a very important driver for MUDJeans, Keykeg and	
Collaboration	Local Pilot programs Drivers: Collaboration & Value Chain Coordiniation	government, other organisations etc., These partnerships are helping businesses to share knowledge and resources, to develop new technologies, and	KeyKeg	"So we are having we have collection partners that work for us, we buy the materials back for them, then we are renting a recycling facility in Germany to process all the materials are sorted to wash it off. But from from the moment that has become becoming waste from that point, we are already involved, again, to make sure that that circular economy is actually in place." 5:20 ¶ 74 in KeyKeg Transcript	5	3	FliptheCity, however, in contrast, Nature's Principles did not have the same experience, instead facing	
		to scale their circular initiatives. <i>FliptheCi</i>		FliptheCity	"Looking also for projects now with municipalities where we can deliver service. We gained a lot of knowledge on seed selection for biodiversity on going up changed locally. So we have a chain now in Rotterdam for retrieving duckweed. Dry drying duckweed storing duckweed using it. So in that way, I think that is our that will be our sort of new business model. So not only delivering not only delivering a product is" 7:8 ¶ 50 in FliptheCity Transcript	15		challenges in this regard.

Figure F.1: Cross Case Analysis, Drivers

Building Block - Barrier	Associated Codes	Case Study Companies	Quotation Examples	Influencing Conditions	Code Frequency in Case	Barrier in Cases	Observations
Innovation Specific Institution	Regulations: Mismatch Trust and Transparency Regulations: Not Enforced Regulations: Regional Specific Regulations: Lack of Standardization & Clarity	КеуКед	"Oh, one of the challenges that we face for collection point of view, for instance, is that we are living in a one Europe, but the problem is that all the countries have their own rights still to well make up law and legislation for on the way they see it, or they've still some freedom to interpretate, the legislation coming from the European Union or European Commission. And therefore we see, even within the countries where on regional level, we see different laws and lead legislation. So one of the challenges are, laws and legislation, and especially the delta so on that looking at specific regions specific, you know, the lack of standardization." 5:16 ¶ 53-56 in KeyKeg Transcript	Macro-Economic and Strategic Aspects	18	1	This observation remains to be the most suprising and yet the most informative perhaps. Despite being recogonised as a driving factor for Circular Innovation, there seems to be a significant gap in concensus and the standardisation. This could perhaps be the barrier with the most cascading effects.
	Attitude: Culture	MUDJeans	"But of course, if you're looking at overall population, there is a shift happening, but it's still in early stages, looking at that, of course, it can still be a barrier because the problem of paying monthly, making sure that you pay that or Well, it's automatic in our case, but making sure you have that money for that every month, sending the product back when you no longer want them of course there's a certain extra element to it that if you're not typically spending a lot of time on these topics. And of course it also becomes a barrier." 4:10 ¶ 65 in MUD.Leans Full transcrint	Socio - Cultural Aspects	22	All up v cu: cas of o thei gr 3 bu circ cor circ cor Bu as and	All companies touched up on their experiences with their respective customers, these three cases faced some form
Customer	Customers: Mindset Attitude: Social Issues Customers: Awareness Customers: Knowledge Challenges: Customers Attitude: Greenwashing Customers: Different types Attitude: Environmental Literacy Customers: Ownership Preferences Attitude: Lack of Transparency and Responsibility	FliptheCity	"I mean, the story most people get, but in first, the first instance, they, some people don't get our product, what it actually does, because the tile, people think, oh, I can drive with my bike over this tile, or I can walk over this tile, because it doesn't contain any pre grown plans. And that's also where we find it difficult with customers. They're not very used to this way in the garden center. And also, they just don't, they want to pay a significant like two, three times more money, if there would be plans in the time." 7:11 ¶ 68 in FliptheCity Transcript	Socio - Cultural Aspects	7		their customers. This just goes on to show how important the compatibility of this building block is for a business, particularly a circular one. There are a lot of hard and soft factors behind this, and any circular company would
	Feaponaiding	Nature's Principles	"the first two or three years, we were not focused enough on customers. We were assuming the customers would be there. And we had talks like we talked to the to the industry about licenses, for example, or how our valuable signals Yes, we started at some point, talking to real customers for Boeing lactic acid, for example. And the feedback was brutal. It was not so let's say good, as I thought it would be okay" <u>8:11 ¶ 51 in Nature's Principles Meeting- 20230713 112719-Meeting Recording</u>	Competition	5		come across these at one point or the other. Besides the technical aspect, a lot of societal and cognitic factors also important as well.

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Figure F.2: Cross Case Analysis contd., Drivers

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Building Block - Barrier	Associated Codes	Case Study Companies	Quotation Examples	Influencing Conditions	Code Frequency in Case	Barrier in Cases	Observations
Production System Ch	Challenges: Scalability Technological Prowess Challenges: Production Challenges: Processes Challenges: Large Scale Demonstration Challenges: Technology, Processes & Machines	MUDJeans	"So I think that's probably the biggest barrier for them, kind of this existing system that was quite hard to completely shift." <u>4:19 ¶ 83 in MUDJeans Full transcript</u>	Knowledge and Awareness of Technology Natural, Human and Financial Resources	20		MUDJeans and KeyKeg seem to face barriers in their production system as a result of their technology being too specific. The other two companies in the case studies did not face challenges related to this as their technology is very
		KeyKeg	"a lot of the recyclers are we're not all did not have the machinery in place to to process it to recycle it. Or the willingness wasn't there" <u>5:9 ¶ 53 in KeyKeg Transcript</u>	Knowledge and Awareness of Technology Macro - Economic and Strategic Aspects	15	2	
Complementary Products and Services	Industry Specific Attitude: Leadership Availability of Talent Challenges: Scalability Challenges: Linear Lock-in	Nature's Principles	"But the whole process is just a machine. So everything is completely optimized, nothing can be changed, okay. But there's all these markets customers, they can be very specific. Like if we're selling to fertilizer markets." 8:16 [159 in Nature's Principles Meeting- 20230713 112719-Meeting Recording	Natural Human and Financial Resources Competition	15	1	As mentioned, certain industries are more reluctant to change than other making the diffusion of new innovation even more difficult
Network Formation and	Industry Specific Challenges: Scalability Challenges: Linear Lock-in Attitude: Stakeholder Influence Challenges: Logistics & Supply Chain Challenges: Largo Scale	FliptheCity	"What are the barriers As a company you're facing? Money. All right. All right. There you go" <u>7:13 ¶ 32 in FliptheCity Transcript</u> "investors. We just find it very difficult to that they wouldn't really want to control the direction of where the company would go." <u>7:16 ¶ 92 in FliptheCity Transcript</u>	Natural Human and Financial Resources Macro Economic and Strategic Aspects	4	2	FliptheCity illustrates an example of how Newtork formation is affected due to undesirable stakeholder influences at the same time, Nature's
Coordination	Chailenges: Large Scale Demonstration Attitude: Lack of Transparency and Responsibility	Nature's Principles	"the feedback was relatively mixed. There was some urgency, but there are established companies, they don't always like to innovate, they have operational process" 8:9 ¶ 43 in Nature's Principles Meeting- 20230713, 112719. Meeting Recording.	Competition	7		Principles can be seen facing challenges induced by industry lock- in.

Figure F.3: Building Blocks turned Barriers, across all cases

Building Block - Barrier	Associated Codes	Case Study Companies	Quotation Examples	Influencing Conditions	Code Frequency in Case	Barrier in Cases	Observations			
Innovation Specific Institution	Regulations: Mismatch Trust and Transparency Regulations: Not Enforced Regulations: Regional Specific Regulations: Lack of Standardization & Clarity	КеуКеg	"Oh, one of the challenges that we face for collection point of view, for instance, is that we are living in a one Europe, but the problem is that all the countries have their own rights still to well make up law and legislation for on the way they see it, or they've still some freedom to interpretate, the legislation coming from the European Union or European Commission. And therefore we see, even within the countries where on regional level, we see different laws and lead legislation. So one of the challenges are, laws and legislation, and especially the delta so on that looking at specific regions specific, you know, the lack of standardization." <u>5:16 ¶ 53 – 56 in KeyKeg Transcript</u>	Macro-Economic and Strategic Aspects	18	1	This observation remains to be the most suprising and yet the most informative perhaps. Despite being recogonised as a driving factor for Circular Innovation, there seems to be a significant gap in concensus and the standardisation. This could perhaps be the barrier with the most cascading effects.			
	Attitude: Culture	MUDJeans	"But of course, if you're looking at overall population, there is a shift happening, but it's still in early stages, looking at that, of course, it can still be a barrier because the problem of paying monthly, making sure that you pay that or Well, it's automatic in our case, but making sure you have that money for that every month, sending the product back when you no longer want them of course there's a certain extra element to it that if you're not typically spending a lot of time on these topics. And of course it also becomes a barrier." <u>4:10 ¶ 65 in MUDJeans Full transcript</u>	Socio - Cultural Aspects	22	3	All companies touched up on their experiences with their respective customers, these three cases faced some form of challenges			
Customer	Customers: Mindset Attitude: Social Issues Customers: Awareness Customers: Knowledge Challenges: Customers Attitude: Greenwashing Customers: Different types Attitude: Environmental Literacy Customers: Ownership Preferences Attitude: Lack of Transparency and Responsibility	FliptheCity	"I mean, the story most people get, but in first, the first instance, they, some people don't get our product, what it actually does, because the tile, people think, oh, I can drive with my bike over this tile, or I can walk over this tile, because it doesn't contain any pre grown plans. And that's also where we find it difficult with customers. They're not very used to this way in the garden center. And also, they just don't, they want to pay a significant like two, three times more money, if there would be plans in the time." <u>7:11 ¶ 68 in FliptheCity Transcript</u>	Socio - Cultural Aspects	7		3	3	3	regarding their customers This just goes on to show how important the compatibility of this building block is for a business, particularly a circular one. There are a l of hard and soft factors behind this, and any circular company would come across these at on
		Nature's Principles	"the first two or three years, we were not focused enough on customers. We were assuming the customers would be there. And we had talks like we talked to the to the industry about licenses, for example, or how our valuable signals Yes, we started at some point, talking to real customers for Boeing lactic acid, for example. And the feedback was brutal. It was not so let's say good, as I thought it would be okay" <u>8:11 % 151 in Nature's Principles Meeting- 20230713 112719-Meeting Recording</u>	Competition	5			point or the other. Beside the technical aspect, a lo of societal and cognitic factors also important as well.		

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Figure F.4: Building Blocks turned Barriers contd., across all cases

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F.2. Links to Excel files of Data

- F.2.1. Case Studies Code Manager
- F.2.2. Case Studies Quotation Manager
- F.2.3. Cross-Case Analysis File