



CLOSING LOOPS, OPENING HORIZONS: NAVIGATING THE CIRCULAR ECONOMY JOURNEY IN NOORD-LIMBURG'S MANUFACTURING INDUSTRY

A qualitative study on external barriers and drivers and internal dynamics shaping circular economy (CE) integration within the manufacturing industry in Noord-Limburg, the Netherlands

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Colophon

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Preface

Dear reader,

In front of you lies the Master's Thesis named 'Closing loops, opening horizons: navigating the Circular Economy journey in Noord-Limburg's manufacturing industry'. With this Master's Thesis, I finalise my Master's degree in Environment and Society Studies with the specialisation 'Local Environmental Change and Sustainable Cities' at Radboud University Nijmegen, the Netherlands. The research was conducted from February 2024 to June 2025, as part of an internship at Volantis | Circular Design Group. The thesis concerns a qualitative study in the light of regional sustainable development into the external barriers and drivers and internal dynamics shaping circular economy (CE) integration within the manufacturing industry in Noord-Limburg, the Netherlands.

The process surrounding this Master's Thesis did not always go smooth sailing unluckily, as the time frame shows. Partly due to personal circumstances, the work in that respect was sometimes difficult to get off the ground. Motivation and discipline were therefore hard to find at times. During this long, sometimes dead-end looking period, there were many people who tried to support me, who therefore certainly deserve a thank you.

First and foremost my thesis supervisor, dr. Mark Wiering, for his continual patience and his useful feedback and extensive guidance throughout the entire research period. I also would like to thank my former colleagues at Volantis | Circular Design Group for making me feel at home and making my internship both educational and fun in many respects. And in particular I want to thank my internship supervisor, Jelle Kerstjens, for his day-to-day enthusiasm and commitment to my research, his experience as a former Master student and everything else he has done in the past year and more, even after the end of the internship period. I also want to thank all of my respondents that were prepared to share their experiences and contribute to this research. And finally, I would like to thank my family, my in-laws, my friends and my girlfriend, who all in their own way have supported me throughout this period of completing my Master's Thesis.

It may have taken a while, but I can now finally proudly say that the thesis for the completion of the MSc Environment and Society Studies program has been completed.

I wish you lots of reading pleasure.

Rowan van Kasteren

Venlo, 26th June 2025

Executive summary

In an effort to tackle climate change, resource depletion and environmental degradation, the Dutch government has set the target for achieving a circular economy by 2050. Therefore, there is an urgent societal need to transition away from traditional ‘take-make-dispose’ economic models to circular ones that prioritise resource efficiency, reduced environmental impact and long-term sustainability. The manufacturing industry plays a big role in this, since this particular industry is responsible for 12% of the Gross Domestic Product, while simultaneously being a very significant contributor to pollution, resource depletion and waste production. In the region of Noord-Limburg, the industry’s share (of the Gross Regional Product) exceeds 33%, making it a real heavyweight in the region. Therefore, it can play a crucial role in the circular economy transition regionally.

However, despite the increasing recognition and advocacy for circularity (particularly given the establishment of the Corporate Sustainable Reporting Directive), moving towards it has demonstrated to be very complex and multifaceted. Manufacturing companies face persistent barriers to circular economy integration, while the impact of those external influences remains underexplored. By investigating how external barriers and drivers influence the internal integration of circular economy principles within the manufacturing industry in Noord-Limburg, this study aims to inform both academic understanding and practical strategies for accelerating the circular transition in this key economic sector. The central research question, therefore, reads as follows:

HOW DO EXTERNAL FACTORS, SPECIFICALLY EXTERNAL BARRIERS AND DRIVERS TO CIRCULAR ECONOMY (CE), INTERNALLY INFLUENCE THE LEVEL OF CE INTEGRATION WITHIN MANUFACTURING COMPANIES IN NOORD-LIMBURG, THE NETHERLANDS?

In order to answer the research question, a qualitative case study was employed, consisting of eight semi-structured, in-depth interviews with different manufacturing companies in Noord-Limburg and the contextual document ‘Maakindustrie Noord-Limburg: Actieprogramma 2022-2024’ (Crossroads Limburg, 2022). Thematic analysis served as a cornerstone for identifying, analysing and documenting significant patterns within the data and consistently linking them back to the study’s theoretical framework and the broader literature on circular economy.

The analysis shows a unique regional landscape, shaped by a combination of internal practices and external influences captured through the lenses of circular economy integration, barriers and drivers. While many manufacturing companies increasingly engage in circular practices, these often remain fragmented, operational and informal. Therefore, they yet lack formalised policies and long-term strategic embeddedness company-wide as the CSRD implies. Nonetheless, increasing awareness (of such external requirements) is gradually nudging the practices toward more structured, formalised strategies, indicating a transitional phase of circular economy integration in Noord-Limburg, with companies advancing from awareness to action but remain in need of strategic cohesion and alignment.

Since bridging this gap is crucial for companies to mature in their circular ambitions, likewise are the external influences that hinder or foster this. The list barriers and drivers discovered in this study is extensive, ranging from cultural/social factors like customer interest to market/economic factors like price differences, and from regulatory/institutional factors like (lack of) policy alignment to technological factors like product design flexibility. The findings show that these external barriers and drivers have a substantial and complex influence on the degree to which circularity is internally perceived, prioritised, operationalised, and consequently integrated into manufacturing companies in Noord-Limburg. So internal circular economy integration is not simply a response to external factors

as isolated determinants, but rather it is co-shaped through an interaction between external factors and internal capacity/readiness. Manufacturing companies with a stronger internal sustainability culture, a more proactive leadership and the 'right' mindset are better positioned to convert external drivers into real opportunities. Conversely, manufacturing companies lacking internal awareness, knowledge or mindset are more vulnerable to the external barriers present, and are therefore less likely to benefit from similar supportive external factors and ultimately translating them into progress regarding circular economy integration. Therefore, while external factors are powerful determinants for circular economy integration, internal organisational characteristics help shape how these factors are interpreted and acted upon.

The findings open up several avenues for practice, policy and research. Companies that wish to advance their circular ambitions could invest in education, management and collaboration throughout their value chain, which could increase their capacity to perceive and act upon external factors. Policymakers could consider the role of perception in communication strategies, framing circularity as a journey to competitiveness, resilience and innovation (rather than solely compliance or obligatory), which may improve internal adoption and public engagement of the concept. And from a scientific perspective, the findings encourages a shift in the academic debate: from a technology/policy-driven perspective that reflects the necessity and complexity of the concept itself, towards one that considers the agential, governance and interpretive dimensions that ultimately determine its success, too.

Keywords: Circular Economy integration, barriers and drivers, CSRD, manufacturing industry Noord-Limburg, case study, in-depth interviews, thematic analysis

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1. Introduction

1.1. Problem statement

Climate change, resource depletion and environmental degradation stress the importance of sustainability in shaping future societies. Achieving sustainability requires collective actions of individuals, organisations and governments at all levels of society, making it a key topic on academic, political and industrial agendas (Leach et al., 2012; United Nations, 2015). In the Netherlands, it has become an important issue for policymakers and communities alike. The Dutch government has set multiple targets for achieving sustainability, including transitioning to a circular economy by 2050 (Government of the Netherlands, 2021). The circular economy (abbreviated to CE in the remainder of this thesis) is an economic system, designed to keep products, components and materials at their highest value/utility at all times (Ellen MacArthur Foundation, 2021). Globally, regions and companies are increasingly embracing CE principles to transition towards more sustainable and environmentally responsible ways-of-doing (Kirchherr, Reike & Hekkert, 2017), given the urgent societal need to transition away from the traditional linear 'take-make-dispose' economic model to a circular one prioritising resource efficiency, reduced environmental impact and long-term sustainability (Stahel, 2016). CE principles can reduce waste, decrease greenhouse gas emissions, generate green jobs and promote economic growth (European Commission, 2020). These possible advantages hold environmental importance and are essential for improving the well-being and life quality of present and future generations (Bocken, de Pauw, Bakker & van der Grinten, 2016), as well as for the reputation and durability/resilience of businesses and regions. However, despite this increasing recognition and advocacy for circularity, moving towards it has demonstrated to be very complex and multifaceted.

The manufacturing industry plays a large role in the global economy, but it is also a very significant contributor to pollution, resource depletion and waste production. Within this context, the manufacturing industry could play a central role in driving the CE principles. In fact, the manufacturing industry is often responsible for a very significant percentage of the gross regional/domestic product. In the Netherlands, this industry has a 12% share in the Gross Domestic Product (Crossroads Limburg, 2022). However, the integration of CE practices into manufacturing companies is loaded with barriers and challenges that withhold companies to become circular (Grafström & Aasma, 2021). Understanding these barriers, as well as driving forces allowing them to do so (Kirchherr et al., 2018), is of paramount importance to achieve those goals of guiding the transition to a CE; both in this particular industry and in society overall.

The region of Noord-Limburg, located in the Netherlands, is one of those regions that has shown commitment to endeavouring to move away from traditional linear business operations towards more circular products and production processes. With a huge share of 33% of the Gross Regional Product, the manufacturing industry is a heavyweight in the region (Crossroads Limburg, 2022). Therefore, it plays a crucial role in the CE transition in Noord-Limburg. Linear economic models, defined by resource depletion and high waste production, are no longer sustainable in light of diminishing resources and the pressing need to address environmental challenges (Korhonen, Nuur, Feldmann & Birkie, 2018). By embracing circular practices, manufacturing companies have the potential to minimise waste, reduce their dependence on virgin materials, and improve their environmental performance. While these companies are under increasing pressure to adopt CE principles, they face substantial barriers.

Concurrently, external incentives could be important levers to change. Yet, much of the existing research focuses on internal company practices, and often underemphasises how external influences like stakeholder expectations and regulatory pressures internally shape CE integration. This is particularly relevant given the recent establishment of the Corporate Sustainability Reporting Directive (CSRD), requiring companies to disclose their environmental performances, including progress related to circularity. Such an obligation/regulation could be seen as an external (institutional/regulatory) driving force to circularity, as it is being introduced to set the ball rolling for positive change (European Commission, 2023a).

In this context, this study addresses a clear problem: despite growing policy and market pressure to adopt circular practices, manufacturing companies face persistent barriers to CE integration, while the impact of those external influences remains underexplored. This research seeks to fill that gap, by investigating how external barriers and drivers influence the internal integration of CE principles within manufacturing companies in Noord-Limburg. The ultimate aim is to inspire and guide the industry in the region in transitioning to a CE. At the heart of this research lies the objective of analysing the barriers and drivers faced by manufacturing companies during their CE journey. The findings aim to inform both academic understanding and practical strategies for accelerating the circular transition in this key economic sector. Their experiences offer invaluable insights into the practicalities of transitioning to circularity, informing and inspiring not only manufacturing entities in the Noord-Limburg region but also counterparts in other parts of the world (Bocken et al., 2016).

1.2. Societal relevance

The transition to a CE within the manufacturing sector holds significant societal relevance, particularly within regions where manufacturing contributes a large share to the GRP. This research offers insight into the external barriers and drivers that shape CE integration internally within manufacturing companies in Noord-Limburg. Therefore, it has societal relevance in several ways. A central societal contribution is the enabling of knowledge dissemination. By documenting the real-world experiences, struggles and successes of companies transitioning toward circularity, this research fosters peer learning and the adoption of best practices (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). This promotes a culture of environmental responsibility and continuous improvement. Additionally, the findings offer insights for (regional) policymakers, industry associations and business leaders, seeking to formulate more targeted interventions based on empirical academic evidence (Bocken et al., 2016), supporting and accelerating the CE transition. Knowledge-sharing within the manufacturing industry also fosters community engagement and social cohesion. By encouraging local businesses to pull together and share experiences in networks, the research promotes a sense of shared responsibility/collaboration within Noord-Limburg (Geissdoerfer et al., 2017). By promoting collaborative approaches to overcome shared barriers and leverage common drivers in the region, this research could strengthen the bonds between local stakeholders and reinforce the collective, regionally embedded goal of transitioning to a CE.

The CE transition in Noord-Limburg's manufacturing industry has direct implications for economic development in the region. When companies successfully adopt circular practices, CE integration can support economic development regionally by enhancing business resilience, stimulating innovation, and creating new employment opportunities (Bocken et al., 2016). As companies seek innovative solutions to optimise resource use and reduce waste, this may lead to the development of new technologies/processes that can be applied in Noord-Limburg and beyond.

Overall, there lies societal relevance in this research, extending beyond the general benefits of a CE. It helps regional economic development, supports informed decision-making, fosters collaboration and innovation and enhances corporate responsibility, ultimately strengthening the region's efforts to transition to a CE.

1.3. Scientific relevance

This research is also significant scientifically relevant; it addresses critical knowledge gaps in the fields of CE theory, environmental studies, corporate social responsibility and organisational change. It contributes to the evolving field of CE theory by providing real-world case studies of manufacturing companies actively embracing circular practices. These offer practical insights into how CE principles are applied, thus enriching the theoretical frameworks with empirical evidence (Bocken et al., 2016). Scientifically, the research helps refining and expanding the understanding of CE dynamics, making it more applicable to industrial contexts. Besides, the examination of barriers and drivers that manufacturing companies face is scientifically valuable as it deepens our understanding of why certain businesses are successful in integrating circular principles, or not. This contributes to the academic discussions around organisational behaviour and corporate social responsibility, as the findings can inform further research on the barriers and drivers of businesses in making sustainability-driven decisions. (Korhonen et al., 2018).

Studying influential factors, strategies and practices of manufacturing companies in this transition provides insights into the operational aspects of implementing CE principles. This contributes to the fields of sustainable supply chain management and industrial ecology, since it informs how manufacturing companies can reconfigure processes, adopt sustainable sourcing, and optimise resource use within a circular context (Farooque, Zhang, Thürer, Qu & Huisingsh, 2019). Furthermore, understanding the challenges faced and the drivers companies employ to overshadow those is of scientific importance, as it deepens our knowledge of how companies interpret and respond to them. This research thereby contributes to discussions of organisational resilience, problem-solving and adaptability, in the context of sustainability-driven change (Farooque et al., 2019).

By focusing on external influences, this research extends the existing literature's scope, since most existing studies often focus on internal, organisational factors. By examining the internal impact of external barriers and drivers, this research gives a comprehensive understanding of those dynamics, both internal and external, shaping circular organisational practices and decision-making processes within manufacturing industries.

In conclusion, the scientific relevance of this research is multi-faceted. By addressing these aspects, this study contributes to the academic discourse on CE integration, sustainability, and industrial transformation.

1.4. Research aim and research question

Based on the research problem statement set up above, the following research aim has been formulated for this research:

The research aims to contribute to the knowledge around the concept of circular economy (CE) by providing a comprehensive understanding of the adoption of R-imperatives, the degree of alignment with the Corporate Sustainability Reporting Directive (CSRD) on 'resource use and circular economy', the internal barriers and drivers shaping circular economy (CE) integration, as well as the role of

external barriers and external drivers on CE integration among manufacturing companies in Noord-Limburg, the Netherlands.

In order to achieve the above stated research aim, a central research question has been formulated that reads as follows:

HOW DO EXTERNAL FACTORS, SPECIFICALLY EXTERNAL BARRIERS AND DRIVERS TO CIRCULAR ECONOMY (CE), INTERNALLY INFLUENCE THE LEVEL OF CE INTEGRATION WITHIN MANUFACTURING COMPANIES IN NOORD-LIMBURG, THE NETHERLANDS?

In addition, a number of sub-questions have been formulated that will try to contribute to answering the above-mentioned main research question:

1. *Which, and to what extent have, R-imperatives been adopted by manufacturing companies in Noord-Limburg?*
2. *What is the level of alignment between manufacturing companies in Noord-Limburg and the CSRD regarding 'resource use and circular economy'?*
3. *Which internal barriers and drivers play a role in shaping CE integration within manufacturing companies in Noord-Limburg?*
4. *How do external barriers hinder CE integration within manufacturing companies in Noord-Limburg?*
5. *How do external drivers positively influence CE integration among manufacturing companies in Noord-Limburg?*

The research question encapsulates the relationships/balance between 'External barriers and drivers', external to the companies in Noord-Limburg, on the one hand and 'Internal CE integration', internal to the companies in Noord-Limburg, on the other hand. This framing provides a coherent structure for exploring the influence of external factors on the internal processes of manufacturing companies in the context of CE integration.

1.5. Thesis outline

The research question as formulated above, accompanied by the five sub-questions, is leading in the remainder of this thesis. In the following chapter, Chapter 2, the most important concepts and theories from the existing literature that are relevant to this research are being discussed, and on this basis, a conceptual model is drawn up from where the central research question will be approached. Chapter 3 describes the methodology, motivating the way in which these concepts were addressed and investigated. The decisions made regarding the research strategy and design are being discussed, as well as the methods of data collection and analysis. In Chapter 4, the findings of the study are presented, analysed and thoroughly elaborated on. Finally, in Chapter 5, conclusions are presented and the research question is being answered. The chapter then pays attention to discussion and reflection, and concludes with recommendations based on the results and conclusions of the research.

2. Theoretical framework

2.1. Circular economy: an introduction

Over the years, the concept of CE has attracted considerable attention as a sustainable alternative to the conventional 'take-make-dispose' model and as a promising approach to tackle resource depletion, waste generation and environmental degradation. One frequently cited framework is Ellen MacArthur Foundation's definition, which identifies three key principles: designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen MacArthur Foundation, 2015). This emphasises the significance of product design, resource efficiency, value retention and closing material cycles. In greater detail, the CE can be characterised as an economic model focused on developing a regenerative system by decoupling economic growth from (scarce) resource utilisation, where resources are employed efficiently, waste is reduced/minimised, and materials are constantly reallocated, with the primary objective to tackle global challenges like climate change, biodiversity loss, waste and pollution (Bocken et al., 2016; Ellen MacArthur Foundation, 2015; Geissdoerfer et al., 2017). The CE transition is recognised as a crucial move towards attaining the Sustainable Development Goals and mitigating the environmental impacts of industrial production/consumption. This chapter provides an overview of the academic literature on CE, highlighting definitions, theoretical foundations, strategies, empirics and challenges.

Throughout the years, there have been many different definitions of the CE (Kirchherr, et al., 2017). After gathering 114 definitions of the CE, the authors discovered that CE is most frequently depicted as a combination of reuse, reduce and recycle activities, but other studies have argued that there is much more to it, leading to confusions and concerns conceptualising the CE: "With a view on its potential impact, a concern is that CE has been argued to lack conceptual clarity and an accepted definition" (Reike, Vermeulen & Witjes, 2018, p. 247). Although several attempts have been made to discern key conceptual elements of CE and its link to other sustainability related concepts (Geissdoerfer et al., 2017), "theoretical or paradigmatic clarity regarding the concept of CE has yet to emerge" (Blomsma & Brennan, 2017, cited in Reike et al., 2018, p. 247). This, until the start of the 2020's, when Nobre & Tavares (2021) proposed a final statement definition for a CE:

Circular Economy is an economic system that targets zero waste and pollution throughout materials lifecycles, from environment extraction to industrial transformation, and to final consumers, applying to all involved ecosystems. Upon its lifetime end, materials return to either an industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle. It operates creating value at the macro, meso and micro levels and exploits to the fullest the sustainability nested concept. Used energy sources are clean and renewable. Resources use and consumption are efficient. Government agencies and responsible consumers play an active role ensuring correct system long-term operation. (p. 10)

The theoretical foundations of CE draw from various disciplines. Industrial ecology, for instance, provides a systems-based approach focused on understanding and optimising resource flows within industrial systems (Graedel & Allenby, 2010). Diffusion of innovation theories provide understanding into the adoption and diffusion of CE practices, suggesting that embracing CE principles and adopted

practices are shaped by elements like relative advantage, compatibility, complexity, visibility, and testability (Rogers, 2003). Understanding these elements can guide approaches for promoting the widespread adoption of CE principles. Systems thinking highlights the interconnectedness of various components within a system and the need to consider the entire lifecycle of products (Arnold & Wade, 2015). Ultimately, economic theories such as product-service systems and cradle-to-cradle design have additionally impacted the development of CE concepts (Ünal & Shao, 2019).

Numerous strategies and approaches have been suggested and implemented to promote CE. These include product redesign for recyclability, remanufacturing, sharing economy platforms, waste-to-energy technologies and extended producer responsibility (Blomsma & Brennan, 2017; Stahel, 2016). Many studies have highlighted the significance of collaboration and network establishments among stakeholders, including businesses, governments and consumers, to enable the transition to a CE (Ghisellini, Cialani & Ulgiati, 2016; Bocken et al., 2016). Furthermore, digital technologies and data management have emerged as enablers of CE practices, facilitating the tracking and tracing of materials, optimising utilisation and resource distribution, along with supporting new business models (Korhonen et al., 2018). Technological advancements like Internet of Things, blockchain, and AI can support material flows optimisation, facilitate product sharing platforms, and enhance transparency in supply chains, thus contributing to the implementation of CE principles. The literature also highlights the importance of policy and governance frameworks in promoting the CE transition. Policy instruments such as extended producer responsibility, eco-design regulations and waste management policies have been identified as key factors for encouraging sustainable production and consumption practices, as effective create an enabling environment, providing economic incentives and promote collaboration between stakeholders to overcome barriers to CE implementation (Ghisellini et al., 2016; Kirchherr et al., 2017).

CE literature highlights its potential environmental and economic benefits. By minimising resource extraction, reducing waste, and promoting reuse and recycling, the CE has the potential to reduce greenhouse gas emissions, preserve natural resources and improve resource efficiency (Geng, Jia, Sarkis & Xue, 2012; Geissdoerfer et al., 2017). According to Ghisellini et al. (2016) and Kirchherr et al. (2017) CE can result in new business opportunities, job creation, and economic growth. Additionally, CE is an actual form of economy, building on value retention and business models. It holds the promise of being an interesting alternative for companies to the linear, less sustainable, economy (Ghisellini et al., 2016). However, the extent of these benefits and their distribution across different sectors and regions require further empirical evidence.

While the concept of CE holds promise, scholars have raised critical perspectives and identified potential challenges. One key challenge is the complexity of transitioning from a linear to a circular system, requiring changes in production processes, supply chains, and consumer behaviour (Ghisellini et al., 2016). The absence of appropriate recycling technologies or the limited availability of secondary raw materials, can also impede progress (Korhonen et al., 2018). Moreover, regulatory structures and policy support are crucial for creating an enabling environment for CE practices, yet their development and implementation can be challenging due to conflicting interests and limited institutional capacities (Rizos et al., 2016). Such challenges will be elaborated later on in this chapter.

2.2. The R-imperatives in CE

The CE paradigm seeks to redefine traditional linear models by prioritising sustainability, resource efficiency and waste reduction. Reike et al. (2018) have produced a synthesis of 10 R-imperatives, or value retention options, as key circular (design) principles for achieving this. These represent a comprehensive set of strategies for achieving value retention and minimising environmental impact, and can be broken down into three categories (Reike et al., 2018): short loops (the product remains close to its user and its function), medium long loops (the product is upgraded and producers could be involved again) and long loops (the product loses its original function). This study employs the framework coming from a policy report of the PBL Netherlands (Potting, Hekkert, Worrell & Hanemaaijer, 2017), which is the Netherlands' Environmental Assessment Agency, and is generally used the most when it comes to the literature on R-imperatives where the number of Rs is tenfold (Kirchherr et al., 2017; Morseletto, 2020; Kupfer et al., 2022). Moreover, it is being used by Circularise, a leading platform providing end-to-end traceability for complex industrial supply chains (Malooly & Daphne, 2023). Under the short loops, Potting et al. (2017) have gathered 'refuse', 'rethink' and 'reduce'. The medium long loops consist of 're-use', 'repair', 'refurbish', 'remanufacture' and 'repurpose', and the long loops consist of 'recycle' and 'recover'. Essentially, these R-imperatives collectively provide a robust framework for investigating how manufacturing companies in Noord-Limburg can transition effectively to a CE. Their relevance lies in that it addresses various facets of circularity, from promoting sustainable resource management to addressing implementation challenges specific to the manufacturing sector in the region.

As Potting et al. (2017) emphasise, "several circularity strategies exist to reduce the consumption of natural resources and materials, and minimise the production of waste." (p. 4) These strategies, or R-imperatives, fall under a hierarchy and can therefore be ordered by priority, as Figure 2.1 shows. The ten R-imperatives are classified into the three categories that indicate the scope of the loop, and they present a variety of strategies/imperatives, in ascending order of low circularity (high R-number) to high circularity (low R-number):

The shorter the loop, the more sustainable the strategy is. The higher they are on the ladder, the tighter the waste loop. This means the strategy requires fewer materials and is therefore more circular. Smaller numbers also indicate the beginning of the value chain, and larger numbers at the end. (Malooly & Daphne, 2023)

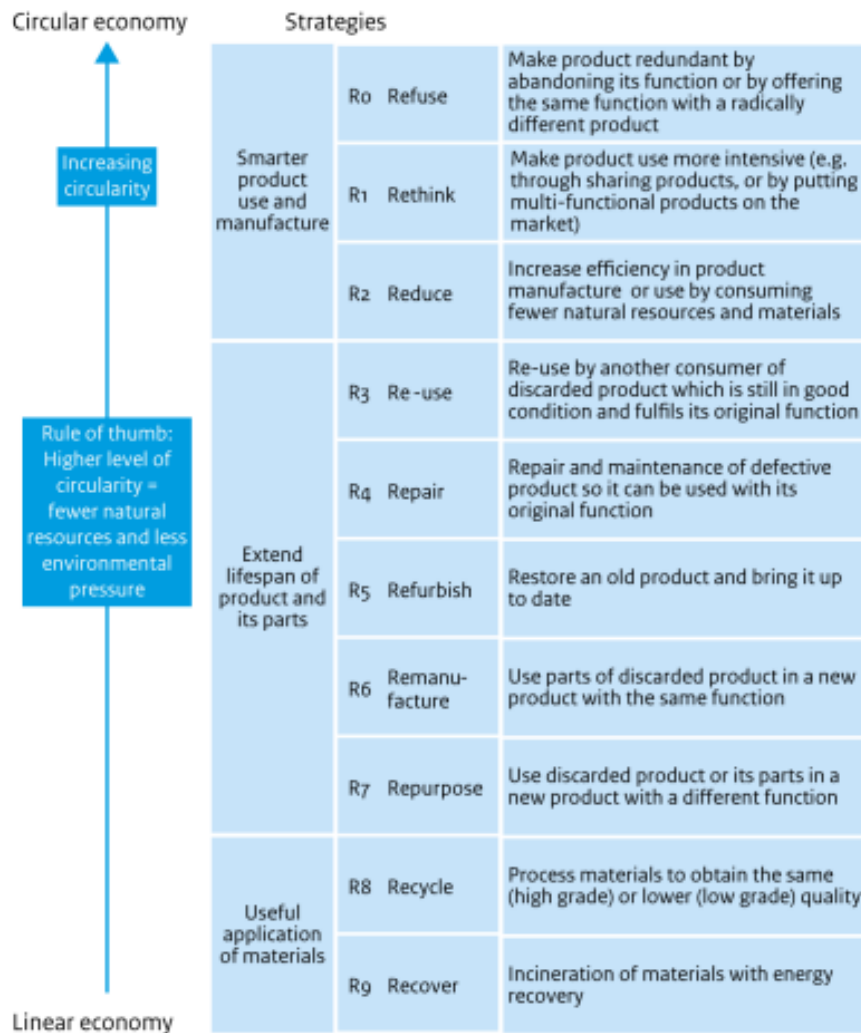


Figure 2.1 Mapping CE: R-imperatives, adopted from Potting et al. (2017)

2.2.1. Short loops: R0-R2

The elaboration of the short loops (R0-R2) has been moved to the Appendices section. See Appendix 1 for the motive for this.

2.2.2. Medium long loops: R3-R7

The elaboration of the short loops (R3-R7) has been moved to the Appendices section. See Appendix 1 for the motive for this.

2.2.3. Long loops: R8-R9

The elaboration of the short loops (R8-R9) has been moved to the Appendices section. See Appendix 1 for the motive for this.

2.3. The Corporate Sustainability Reporting Directive (CSRD)

Corporate Sustainability Reporting (CSR) has become integral to modern business practices. It transcends traditional financial disclosures to include a portrayal of an organisation's environmental, social, and governance (ESG) performance, with roots lying in an expanding awareness of the societal and environmental impacts of business activities. It is a dynamic and evolving process through which organisations communicate their commitment to sustainable business practices, emphasising transparency and accountability (Herzig & Schaltegger, 2011). It entails the disclosure of information

that goes beyond profit margins, as CSR reports capture the broader impact of business operations on the ESG structure. Evolved over time, driven by changing societal expectations, regulatory developments and corporate responses to emerging challenges, sustainability reports enable organisations to transparently communicate their environmental and social performances. Beyond regulatory compliance, CSR offers a platform for businesses to showcase their commitment to sustainability. Such reports enable investors, customers and the wider community to evaluate an organisation's ethical stance, environmental impact, and social contributions (Gray & Milne, 2007). As businesses increasingly embrace sustainability as a core value, CSR reports could become powerful instruments for fostering transparency and accountability, which opens avenues for demonstrating commitment to ESG values, contributing to broader societal goals and securing a competitive edge in an increasingly (environmentally) conscious market (Koskela, 2023). Formerly, these CSR reports were not standardised, which made it difficult to compare companies with each other, which is the reason for the EU to implement the Corporate Sustainability Reporting Directive (CSRD).

In November 2022, the EU adopted the CSRD, after which it came officially into effect on January 5, 2023 (SER, 2023). This guideline, central to the EU's Green Deal, states that from 2024 onwards, companies will be (gradually) required to report on the impact of their activities on people and the environment. The directive's main objective, therefore, is to enhance transparency and to elevate the quality of sustainability performance information, enabling investors, consumers and other stakeholders to make informed decisions when investing in activities and organisations, all through one standard for reporting.

Formerly, companies in the EU were only required to report on their financial performances. The CSRD directive obliges companies to report on their sustainability performance using various sustainability criteria, and it addresses the three pillars of sustainability: Environment, Social and Governance, each consisting of one or more 'topical standards'. Topical standards (ESRS's) contain the disclosure requirements for the ESG areas, as can be seen in Figure 2.2. Each topical ESRS requires reporting on policy, targets, action plans and measuring points/metrics, ensuring that a standard methodology can be drawn up to elaborate on each theme. CSRD requires companies to report on sustainability both in their own organisation and their value chain (European Commission, 2023b). This necessity will have major effects on many companies, including those that are not (yet) directly affected by the entry into force of the directive. Large companies will most likely request detailed information from their suppliers and customers, since CSRD obliges to report on their entire value chain. Therefore, smaller companies, too, will eventually receive the relevant questions from within their specific value chain, highlighting the urgency and relevancy of contemplating the CSRD by SMEs.

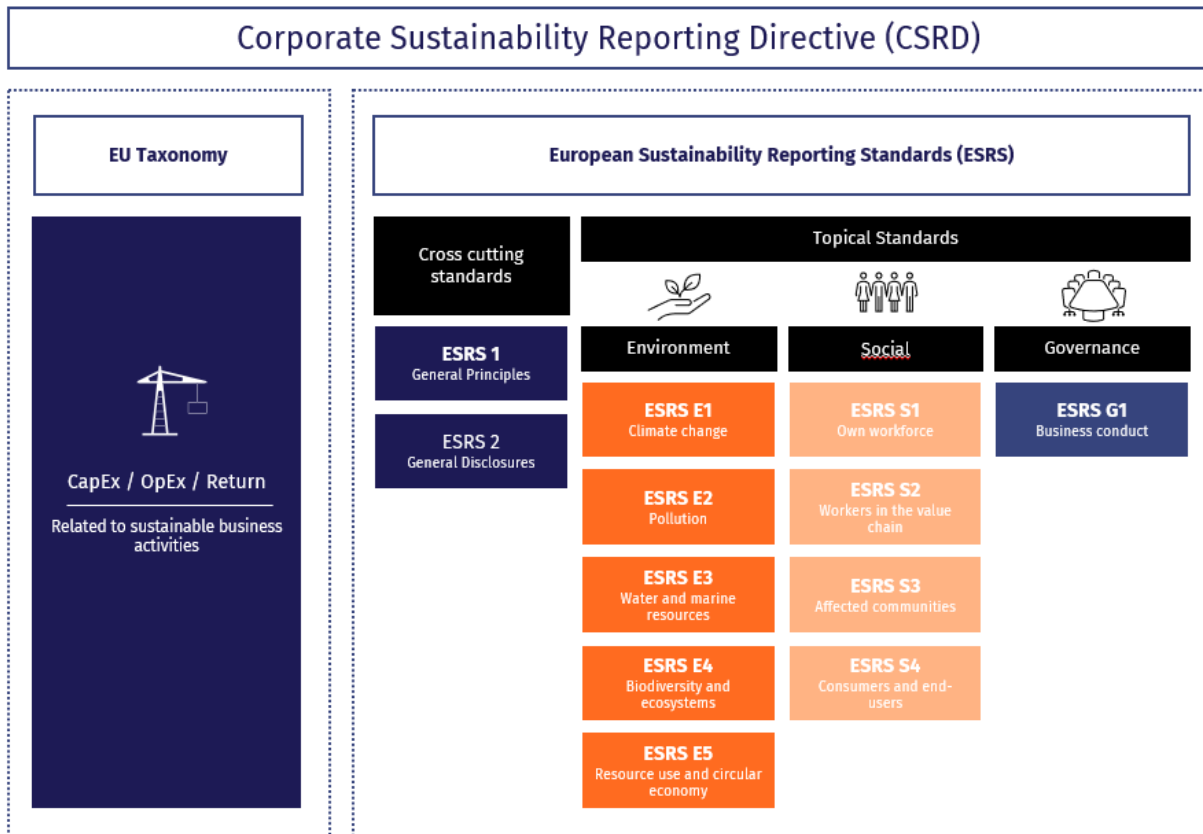


Figure 2.2 The Corporate Sustainability Reporting Directive, adopted from Volantis (2024)

2.3.1. ESRS E5: Resource use and circular economy

One topical standard in the CSRD is ESRS E5 on ‘Resource use and circular economy’, as can be seen in Figure 2.2. This shows that particular attention is given to CE and related practices, since the directive obliges companies to explicitly report on initiatives, policies, targets, action plans and measuring points/metrics related to circularity (SER, 2023). Therefore, the CSRD and ESRS E5 serve as a guiding framework that aligns reporting practices with the principles and goals of CE. By mandating disclosures related to resource inflows, resource outflows and waste (European Commission, 2023b), ESRS E5 requires companies to transparently communicate their strategies, performance and impacts concerning resource efficiency, waste management and other circular practices.

The implications of this ESRS could be profound. As it could foster a paradigm shift in corporate behaviour, it could contribute to the advancement of CE principles and to a growth in financing circular business models. Another potential is the growing awareness and accountability that ESRS E5 injects in companies. By necessitating detailed reporting on resource use and circularity-related practices, CSRD allows businesses to critically evaluate their operations. This bolsters a culture of responsibility, pushing companies to adopt more circular approaches in material sourcing, production and waste management. ESRS E5 thus not only acts as a mandatory reporting mechanism, but as a catalyst for innovation, too. The directive enables and encourages companies to explore and implement CE strategies, knowing that such policies, targets and action plans not only align with CSRD requirements, but also enhance their competitiveness through transparency and ambitious goals. This transparency and measurability could increase the access to sustainable financing and procurement, which creates a positive feedback loop where regulatory compliance intertwines with access to sustainable financing,

encouraging circular business innovation and eventually driving the broader adoption of circular principles.

As businesses navigate through the CE journey, the CSRD and ESRS E5 on 'Resource use and circular economy' can serve, in a similar manner as the ten R-imperatives do, as a framework for assessing CE integration. Much like the R-imperatives offer a structured approach to assessing CE performances (Reike et al., 2018), the degree of (early) compliance with/adherence to ESRS E5 provides a comprehensive means to gauge a company's commitment, maturity, progress and sophistication in CE integration. Many of the R-imperatives are in fact even included in ESRS E5 to assess the circular performances of organisations, offering more concrete metrics and KPIs, which according to Martinetti & Havas (2021) are crucial for monitoring and steering circular progress. So where the R-imperatives mainly link to design and business models, ESRS E5 looks at the broader business operations. Together, they offer a meaningful assessment framework for CE integration.

2.4. Barriers to CE

The adoption of a CE framework in the manufacturing industry represents a transformative shift towards sustainable and regenerative practices. The CE transition is a rather complex journey. It faces multiple challenges along the way, as the manufacturing industry grapples with a diverse range of barriers that hamper the integration of circular principles. This section delves into the versatile nature of these barriers, spanning from technological, regulatory, organisational, socio-political, economic, environmental and measurement domains. These barriers, as identified in the academic literature, shed light on the multifaceted nature of the CE paradigm.

Within the academic literature, there are various categorisations existent of barriers to CE. Kumar et al. (2019) summarise the key barriers within the manufacturing sector specifically into three categories: Socio-political barriers, economic barriers and environmental barriers. Jaeger & Upadhyah (2020) do not make use of categorisations, but rather identify seven main barriers to CE as faced by manufacturers. Their literature review and case study on ten manufacturing companies, proved that the following seven barriers to CE were the most prominent (Jaeger & Upadhyah, 2020): high start-up costs, complex supply chains, challenging business-to-business cooperation, lack of information on product design and production, lack of technical skills, quality compromise and disassembly of products being time-consuming and expensive. Specified to the built environment, Hart, Adams, Giesekam, Tingley & Pomponi (2019) in turn make a distinction between cultural, regulatory, financial and sectoral barriers. And for the logistics industry, which is "strongly interwoven with various activities in production and distribution chains" (van Buren, Demmers, van der Heijden & Witlox, 2016, p. 10), the barriers that impede the transition to a CE are categorised into institutional, economic, social and people-related, and professional barriers. But the classification that is used the most in the academic literature is the classification by the framework of CE barriers coming from De Jesus & Mendonca (2018), and which was further studied in the first large-N-study conducted by Kirchherr et al. (2018). Here, a distinction is made between cultural barriers, regulatory barriers, market barriers, and technological barriers. The theorisation of these CE barriers offers a clear overview, as Figure 2.3 shows, and will be further elaborated on in the remainder of this paragraph, based on the works of Kirchherr et al. (2018), Grafström & Aasma (2021) and other authors using the same categorisation.

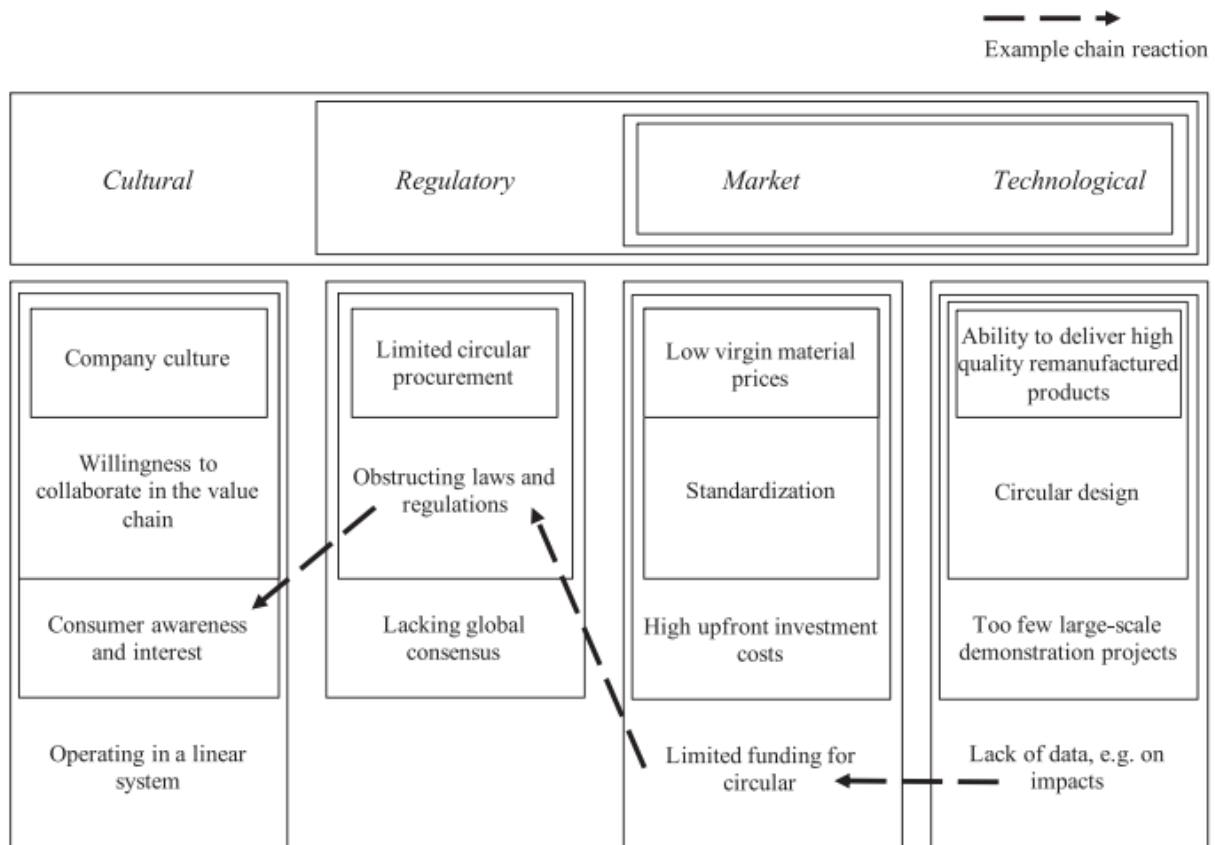


Figure 2.3 Theorising CE barriers, adopted from Kirchherr et al. (2018)

2.4.1. Cultural/social barriers

Transitioning to a CE heavily relies on overcoming and navigating through cultural, social and organisational barriers. Scholars and researchers have discussed many cultural barriers across various contributions around CE barriers, both within and beyond organisational boundaries (Kirchherr et al., 2018). Within the organisational culture and structure, a rigid organisational structure can prevent innovation and opportunities for a CE coming from lower levels of the firm to get to the top of the organisation (Pheifer, 2017; Agyemang et al., 2019). This creates a lack of awareness and support (Tura et al., 2019) and goes in hand with a lack of understanding of the concept of CE (Geng & Doberstein, 2008; Mahpour, 2018), as well as a lack of knowledge about the implementation of CE policies (Vanner et al., 2014) and its benefits (Rizos et al., 2015; Mangla et al., 2018). Furthermore, risk aversion within an organisation as well as the perception of sustainability (Ritzèn & Sandström, 2017) can be a hindrance in the transition towards a CE. This collective of barriers can be attributed to the 'company culture' sub-barrier (Kirchherr et al., 2018), as Figure 2.2 shows.

Another sub-barrier within the framework is the limited willingness to collaborate/cooperate throughout the value chain (Preston, 2012; Vanner et al., 2014; Kirchherr et al., 2018). Ritzèn & Sandström (2017) mention a lack of (clear) responsibility within the firm and throughout the value chain as a possible barrier. Another barrier identified in the literature has to do with the fact that within the supply chain of a certain company, a sense of competition can prevail, instead of a sense of cooperation (Masi et al., 2018), which can hamper that particular company's intentions to transition to a CE. It can also occur that other parties within the same supply chain have a negative attitude

towards “green businesses” (Rizos et al., 2015, p. 10), or that there is a lack of awareness or long termism among stakeholders (Masi et al., 2018).

A third sub-barrier within the cultural/social barriers is consumer awareness and interest (Vanner et al., 2014; Kirchherr et al., 2018). Various authors have pointed out that customers often prefer new products and materials (Mahpour, 2018; Ranta et al., 2018; Milios et al., 2019). Furthermore, customers often give rather low priority to circular or environmentally superior products in comparison to the ones that feel familiar to them (Rizos et al., 2015; Ritzèn & Sandström, 2017; Mangla et al., 2018), which emphasises the lack of consumer enthusiasm (Preston, 2012). This lack of enthusiasm could go hand in hand with uncertainty among consumers and customers about the quality of recycled or other circularly designed goods or products (Kinnunen & Kaksonen, 2019). A final barrier that has to do with consumers and customers, is the possibility that there is effort needed from the consumer (Milios et al., 2018), for example to separate parts of the product after use, perhaps emphasising the inertia in consumer behaviour (de Jesus & Mendonca, 2018).

In certain occasions, it is likely that the industrial focus is still on linear models (Tura et al., 2019). Reasons for this linear focus could be assigned to a lock-in to non-recyclable goods, or to the fact that certain projects/products are simply not designed for a CE (Mahpour, 2018). Kinnunen & Kaksonen (2019) mention the mindset to focus on maximising extraction as a barrier to CE, while Ritzèn & Sandström (2017) notice the inertia within companies towards new CE business models. This collective of barriers can be assigned to the (lock-in of) operating in a linear system (Kirchherr et al., 2018; Grafström & Aasma, 2021).

2.4.2. Regulatory/institutional barriers

In addition to cultural and social barriers, it has been investigated that companies often have to deal with regulatory and institutional barriers as well when transitioning to a CE. The first sub-category has to do with limited circular procurement. Rizos et al. (2015) and Mangla et al. (2018) pose that a lack of training of HR and supply-chain managers in CE can act as a barrier, and De Jesus & Mendonca (2018) and Tura et al. (2019) add to that by stating that insufficient R&D within the company creates a knowledge gap for implementation of CE policies, hampering the transition. Next to that, no (investment in the) monitoring of waste management (Mahpour, 2018), for example, can pose as a barrier, meaning that ultimately, it is difficult to identify consumers/customers of recycled materials (Milios et al., 2018) and to have capacity for reversed logistics (Masi et al., 2018). This path dependent infrastructure favours a CE (Grafström & Aasma, 2021).

Next to procurement issues, the transition to a CE can be delayed by obstructing laws and regulation (Kirchherr et al., 2018; Tura et al., 2019). Firstly, a lack of regulatory pressures and taxation for CE promotion can prove to be a barrier (Mangla et al., 2018), and so can too strict or complex regulations on, for example, dangerous waste that could be reused (Kinnunen & Kaksonen, 2019; Tura et al., 2019). But also insufficient recycling policies for optimal use (and quality of) recyclables and the fact that the government incentivises parts of a linear economy can hamper the transition (Masi et al., 2018). Ranta et al. (2018) name a low level of enforcement of legislation as an institutional barrier, and Preston (2012) notices this with political obstacles to putting an optimal price on resource use. Materials that are classified as waste when they can actually still be reused (de Jesus & Mendonca, 2018) pose a final regulatory barrier to CE.

According to Kirchherr et al. (2018), ‘lacking global consensus’ is the third and final sub-barrier in the framework, and poor institutional cooperation across international supply-chains can be a testament to this (Preston, 2012). Regulations regarding CE also may vary across countries (Ranta et al., 2018; Kinnunen & Kaksonen, 2019), and often goes hand in hand with a weak degree of policy coherence (Vanner et al., 2014) and supply chain integration and networks (Agyemang et al., 2019; Tura et al., 2019). Finally, a lack of a (globally recognised) accreditation system is named among the regulatory/institutional barriers to CE (Ranta et al., 2018).

2.4.3. Market/economic barriers

For companies, economic considerations and market dynamics also contribute significantly to challenges in transitioning to a CE. They are classified as barriers to CE adoption due to “non-existent or ill-functioning of markets and (...) financial arguments for why a circular economy is not adopted” (Grafström & Aasma, 2021, p. 9). The first market-related barrier are the relatively low prices of raw and virgin materials (Geng & Doberstein, 2008; Vanner et al., 2014; Masi et al., 2018; Kinnunen & Kaksonen, 2019), which could translate into linear products outcompeting their circular equivalents (Kirchherr et al., 2018). Preston (2012) adds to this by stating that “the recycling of many materials does not occur because it is uneconomical relative to the production of virgin material” (p. 10).

Another sub-barrier has to do with lacking of limited standardisation (Kirchherr et al., 2018), particularly regarding a lack of market mechanisms for reverse logistics and the reverse supply chain, which goes closely together with institutional barriers from the previous sub-paragraph (Tura et al., 2019) and the internalisation of externalities (Vanner et al., 2014). The absence of accreditation systems (Ranta et al., 2018), for example, could result in the fact that the benefits of CE efforts become unmeasurable and the profitability of those efforts uncertain (Ritzèn & Sandström, 2017; de Jesus & Mendonca, 2018), creating a certain lack of incentives for CE adoption (Mangla et al., 2018; Tura et al., 2019).

A third market and economic sub-barrier, which is mentioned by the majority of scholars that have written about barriers to CE (Preston, 2012; Rizos et al., 2015; de Jesus & Mendonca, 2018; Kirchherr et al., 2018; Masi et al., 2018; Kinnunen & Kaksonen, 2019) is related to high up-front (investment) costs, since the shift to a CE is rather complex and new investments within the whole business are mandatory. Often, there prevails a certain level of market uncertainty, demanding high capital requirement (de Jesus & Mendonca, 2018), resulting in a lack of short-term rewards (Mangla et al., 2018). This could make a certain company hesitant to take the first step, as “the first one that will invest (...) will probably lose money and only the second mover will earn a fortune” (Kirchherr et al., 2018, p. 269). Adopting a CE thus may not seem profitable at first glance (Ritzèn & Sandström, 2017; Ranta et al., 2018).

Therefore, to make CE initiatives economically viable, financial injections are often needed (Ranta et al., 2018). And even if a certain company is willing to innovate and transition to circular practices, they often run into challenges in obtaining finance for CE investment (Vanner et al., 2014; Dewick et al., 2020). This has very much proven to be the case for SMEs in particular (Rizos et al., 2015; de Jesus & Mendonca, 2018), since business models of this nature have rather long payback-periods (Kinnunen & Kaksonen, 2019). This collective of barriers can be assigned to the limited funding for circular business models from the framework by Kirchherr et al. (2018).

2.4.4. Technological barriers

Lastly, companies have proven to be faced with various technological barriers that prevent them from transitioning towards a CE, which are categorised into: the quality of (recycled) products, circular product design, too few large-scale demonstration projects, and lack of data on impacts (Kirchherr et al., 2018). Thus, they do not only include the (lacking) presence of technology that enhances the implementation of CE, but also the gaps regarding the means to design and use these technologies (de Jesus & Mendonca, 2018). A lack of skill, training and support regarding the technical capacities has influence on the quality of recycled (or other circular) products (Geng & Doberstein, 2008; Agyemang et al., 2019; de Jesus & Mendonca, 2018). Rizos et al. (2015) also found a lack of know-how and technical skill to implement CE practices. Recycled products have also shown to be less flexible and difficult to separate in some cases, impacting the quality of the good, too (Kinnunen & Kaksonen, 2019; Milios et al., 2019).

Research has also shown that there could be a lag between the design and the diffusion of the product (de Jesus & Mendonca, 2018), and that companies face a lack of know-how in product design, too (Vanner et al., 2014). And on top of that, it could occur that a certain product is believed to only 'work' through linear design (Ritzèn & Sandström, 2017) and that there is thus limited attention to end-of-life-design (Masi et al., 2018). This set of barriers are covered by 'circular product design' from the framework by Kirchherr et al. (2018). Kinnunen & Kaksonen (2019) found that businesses faced difficulties in scaling up the use of recycled materials, and Ritzèn & Sandström (2017) mention a low level of integration of CE technologies into the production processes. These barriers are testimonial to the sub-barrier 'too few large-scale demonstration projects (Kirchherr et al., 2018). This sub-barrier closely relates to the final technological sub-barrier adopted by Kirchherr et al. (2018), this being a lack of data (on impacts). Ritzèn & Sandström (2017) mention high uncertainty about the price and quality of recycled material as an important barrier. Geng & Doberstein (2008) and Mahpour (2018) identify little accessible data as a final technological barrier to the implementation of CE practices.

2.5. Drivers to CE

The integration of CE principles is conditional to a dynamic interplay between cultural, regulatory, economic and technological factors. As the previous paragraph proved, a multitude of challenges can be encountered along the way, as the manufacturing industry grapples with a diverse range of barriers that impede the integration of circular principles within organisations. But where these barriers seemingly obstruct progress, it also becomes evident that within these challenges/barriers lie powerful drivers propelling the transition towards circularity. Cultural transformations, driven by an increasing awareness of environmental issues, may not only mirror consumer preferences for sustainable goods, but also act as significant motivators encouraging businesses to embrace eco-friendly practices (Bocken et al., 2016). Regulatory frameworks, once seen as obstacles, may develop into essential support systems, offering the required structure for companies to adopt circular practices (Grafström & Aasma, 2021). Amidst economic challenges, the allure of cost savings and the strategic advantages of circular business models motivate organisations to transition (Kirchherr et al., 2017). And simultaneously, technological advancements could become catalysts for innovative solutions, fostering the development of circular processes and enhancing material traceability progress (Geng et al., 2012). This nuanced perspective underscores that within those barriers lie untapped potential, transforming barriers into driving forces that could steer the journey towards a circular and sustainable future.

But, in contrast to barriers, drivers to CE tend to be less clearly defined in the literature, according to Hart et al. (2019): "... authors can frequently see and evidence a barrier, but be unable to articulate what is needed to address it and unable to provide evidence that such action will promote circularity." (p. 621) Nonetheless, this study will use the same categorisation as has been used for the barriers to CE. Using the same categories for CE drivers as those used for barriers creates a coherent and organised analytical framework. The dynamic interaction of cultural changes, regulatory progress, economic motivations and technological innovations collectively transforms recognised barriers into opportunities, and employing the same categories for both barriers and drivers yields numerous advantages. Using the same categories allows for a straightforward and precise comparison between the elements obstructing CE integration and those promoting it. This uniformity allows researchers, policymakers and practitioners to recognise patterns, correlations and interactions among drivers and barriers, providing a thorough insight into the circular transition. By classifying both drivers and barriers into the same dimensions, a comprehensive and balanced representation of the circular landscape will emerge. This method recognises the complex aspects of the transition, making sure that every dimension is considered and none is unduly highlighted (Kirchherr et al., 2018). Moreover, a cohesive structure simplifies the processes of research design, data collection and analysis processes. Hereby, researchers can adopt a standardised methodology when investigating barriers and drivers, facilitating a coherent and systematic exploration of the circular ecosystem (Geissdoerfer, Santa-Maria, Kirchherr & Pelzeter, 2022). For policymakers and businesses, employing the same categories guarantees that strategies tackling circular barriers coincide with initiatives to harness drivers. This may improve the impact of interventions, fostering a synergy between addressing obstacles and leveraging existing drivers. Recognising drivers within the same areas where barriers are found enables focused interventions, transforming difficulties into opportunities (Hopkinson, Zils, Hawkins & Roper, 2018). Finally, by examining the interactions between particular dimensions/categories, researchers and practitioners can obtain practical insights. For example, grasping how cultural motivators offset cultural obstacles, or how regulatory incentives correspond with regulatory constraints, offers detailed perspectives for successful intervention approaches (Geng et al., 2012; Geissdoerfer et al., 2022).

In conclusion, applying the same classifications for CE drivers as those utilised for obstacles encourages uniformity, comparability and a thorough comprehension of research and promotes the creation of focused and efficient methods for promoting CE. In the remainder of this paragraph, a brief understanding of the factors propelling the integration of circular practices will be offered, drawing from evidence and foundations from the existing literature on CE drivers.

2.5.1. Cultural/social drivers

Cultural and social drivers play an important role in promoting the integration of CE principles. An increasing awareness and consciousness among individuals and communities about environmental sustainability and resource conservation can act as a strong driver. This (societal) shift in mindset emphasises responsible consumption, fostering a culture of reuse, recycling and waste reduction, and internal capabilities such as sustainability-oriented leadership and long-term vision can play a decisive role in shaping CE integration (Linder & Williander, 2015). Increasing consumer or customer interest in sustainable products, combined with a rising awareness of the environmental effects of linear consumption, can motivate businesses to adopt circular practices (Rizos et al., 2015; Bocken et al., 2016). Furthermore, social movements promoting sustainable practices and increased environmental awareness can become, pushing both consumers and businesses towards more circular behaviours (Geissdoerfer et al., 2017).

2.5.2. Regulatory/institutional drivers

Clear regulatory frameworks and supportive institutional measures serve as key drivers for the integration of CE practices. Governments and international bodies are increasingly recognising the importance of a CE and implementing policies to incentivise and regulate businesses. Legislation supporting Extended Producer Responsibility, targets for waste reduction and tax benefits for circular initiatives could establish a regulatory basis that encourages companies to become circular (Grafström & Aasma, 2021). Changing institutional norms and expectations, in which sustainable practices are seen as the norm rather than the exception, can also influence CE initiatives (DiMaggio & Powell, 1983). Organisations like industry associations and certification entities can play a big role by establishing standards and motivating companies to follow sustainable practices (Geng et al., 2012; Kirchherr et al., 2018).

2.5.3. Market/economic drivers

Market and economic factors also contribute significantly to driving CE integration. Businesses are increasingly acknowledging the economic advantages of circular practices, including cost savings through resource efficiency, reduced waste management costs and access to new revenue streams through circular business models (Kirchherr et al., 2017). Consumer preferences for sustainability products may generate market demand, driving companies to distinguish themselves by adopting circularity and aligning their products with circular principles to stay competitive and increase their market share. Circular supply chains could therefore emerge as a strategic advantage, improving company resilience and reducing reliance on scarce resources (Geissdoerfer et al., 2017; de Jesus & Mendonca, 2018).

2.5.4. Technological drivers

Lastly, technological advancements and innovations play a pivotal role in driving CE integration. Breakthroughs or innovations in recycling technologies, remanufacturing processes and material innovations can enable businesses to close the loop in their production cycles (Geng et al., 2012). Likewise, technological innovations such as materials science and data analytics could enable more efficient resource use and waste reduction, thereby driving sustainable transitions (Geels et al., 2017). The development and adoption of digital platforms and technologies, such as the Internet of Things (IoT), blockchain and materials passports, could improve traceability and transparency in supply chains, facilitating circular material flows. Furthermore, automation and AI can contribute to the optimisation of processes, which could in turn support circular business models by minimising waste and enhancing resource recovery (Geng et al., 2012; Geissdoerfer et al., 2017; de Jesus & Mendonca, 2018).

2.6. Conceptual framework

Figure 2.4 shows the conceptual framework for this study. The conceptual framework navigates the dynamic landscape of CE integration within manufacturing companies in Noord-Limburg, and does this from two types of dimensions: internal and external. At its core are three variables: 'CE integration', 'Barriers to CE' and 'Drivers to CE'. 'CE integration', serving as the dependent variable, represents the extent to which manufacturing companies in the region of Noord-Limburg embrace circular practices. The arrow(s) in the conceptual model depict(s) the influence of external factors (consisting of both external barriers and drivers to CE) on the level of 'CE integration'. The collective/combination of barriers and drivers constitutes a broad external influence, internally shaping the trajectory of CE

within manufacturing companies. This external influence eventually converges on 'CE integration', impacting how companies implement CE principles.

'CE integration', the ultimate outcome, is intricately defined by three key components. Firstly, the adoption of R-imperatives elucidates the specific circular strategies employed by manufacturing companies. Secondly, alignment with the Corporate Sustainability Reporting Directive (CSRD) sheds light on how well companies are aligned with regulatory standards concerning 'resource use and circular economy'. Lastly, internal barriers and drivers existing within each company contribute to the understanding of the journey towards CE integration. This conceptual framework serves as the compass for investigating the interplay between external forces, internal dynamics and the practical manifestations of circularity in the manufacturing industry of Noord-Limburg. How exactly these relations have been investigated, is explained in detail in the following chapter.

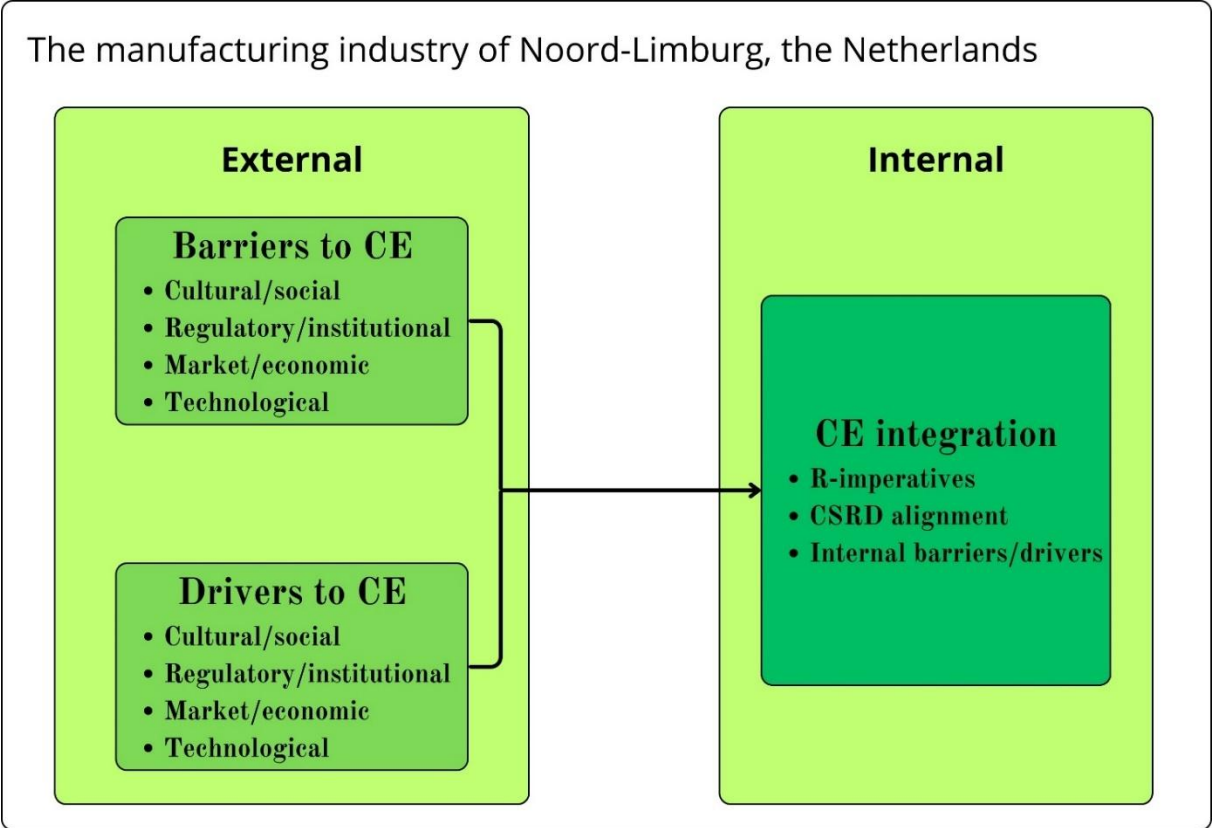


Figure 2.4 Conceptual framework

3. Methodology

This chapter elaborates on the methodology of the research; on how the research was carried out. The main research question of this study reads as follows:

HOW DO EXTERNAL FACTORS, SPECIFICALLY EXTERNAL BARRIERS AND DRIVERS TO CIRCULAR ECONOMY (CE), INTERNALLY INFLUENCE THE LEVEL OF CE INTEGRATION WITHIN MANUFACTURING COMPANIES IN NOORD-LIMBURG, THE NETHERLANDS?

The chapter starts with a description of the research philosophy and research approach for answering this question. Thereafter, the design of the research and the methods of inquiry will be discussed. The chapter will conclude with remarks on the validity and the reliability of the research, followed by a section on ethics.

3.1. Research strategy

3.1.1. Research philosophy: A post-positivist paradigm

In exploring CE integration within the manufacturing industry in Noord-Limburg and the external factors influencing this, selecting a suitable research philosophy/paradigm is crucial. These philosophical foundations shape a study's design, choice of methods and interpretations of the findings (Creswell & Creswell, 2018). This study adopts a post-positivist paradigm, inspired by the works of Guba & Lincoln (1994) and Moon & Blackman (2014), which provides a fitting framework and a nuanced foundation for exploring the context-specific meanings and causal relationships that attribute to manufacturing companies' CE practices and external influences, while maintaining a cautious realism about the nature of truth and knowledge.

Ontologically, a post-positivist paradigm views reality as objective and separate from human perception/interpretation, yet it recognises that our grasp of reality is fundamentally flawed and tentative (Guba & Lincoln, 1994). Post-positivism acknowledges the presence of an objective reality that exists independently of perception but also recognises the constraints in fully understanding this reality because of our subjective perspectives and the interpretative nature of investigation (Phillips & Burbules, 2000). This corresponds with the nature of CE implementation, which does not adhere to a one-size-fits-all trajectory, but is influenced by unique organisational, regional and sectoral contexts. In this study's context, this perspective allows for the investigation of external factors, aiming to uncover causal mechanisms and (semi-)generalisable patterns that influence organisational actions.

Epistemologically, post-positivism recognises that all observations are theory-laden and that researchers cannot fully be neutral observers. Moon & Blackman (2014) emphasise the importance of understanding knowledge as contextual and situated. While striving for objectivity and preciseness, post-positivism acknowledges that findings are influenced both by the researcher's interpretations and the contextual realities of participants (Guba & Lincoln, 1994). In this study, CE integration-related knowledge is therefore generated through the careful interpretation of qualitative data while maintaining a critical stance towards potential biases, aiming for plausible, empirically grounded explanations.

Although post-positivism is often associated with quantitative methods, it also can inform qualitative and case study research, particularly when the aim is to identify underlying patterns and determine meanings and purposes that participants ascribe to their actions (Guba & Lincoln, 1994). Given the

complex and evolving nature of CE transitions, this study's goal is to uncover recurrent themes, influences and contextual factors that help explain the level of CE integration among manufacturers in Noord-Limburg, rather than seeking universal laws. This approach also involves a degree of analytical generalisation, whereby insights from in-depth cases connect to theoretical constructs (Yin, 2017). The study does not claim to provide statistically generalisable findings but seeks to contribute to theory development around CE, by linking observed practices to broader strategic and institutional dynamics.

In summary, a post-positivist paradigm offers a philosophical coherent basis for this study. It supports the employment of qualitative methods to explore complex organisational phenomena, while acknowledging both the existence of an external reality and the interpretive lens through which this is achieved. By combining empirical exploration with critical reflection, post-positivism enables a rigorous yet context-sensitive examination of how external influences shape internal CE integration of manufacturing companies in Noord-Limburg.

3.1.2. Qualitative and inductive research approach

The research adopts a qualitative approach, as it is well-suited to address the exploratory nature of the research questions, which focus on in-depth understanding of the experiences and perceptions of manufacturing companies in the framework of CE integration. Employing qualitative research methods in this study offers several advantages for addressing the research questions. CE practices involve subjective interpretations, varying across industries and organisational contexts. Qualitative research allows for an in-depth exploration of the subjective experiences and perceptions of stakeholders by generating rich, narrative data, providing a richer understanding of circularity (Denzin & Lincoln, 2018; Moon & Blackman, 2014), crucial for understanding the complexities of CE integration.

Understanding the unique circumstances of the region of Noord-Limburg, and its manufacturing companies' interactions with circularity, is essential. Qualitative research allows for the exploration of the local cultural, social, institutional and technological factors that affect the implementation of CE principles (Creswell & Creswell, 2018; Kirchherr et al., 2018). By focusing on the narratives of manufacturing companies, it enables the contextual sensitivity of findings within the region of Noord-Limburg. Additionally, qualitative research inquiry is flexible and adaptive, allowing for exploring emergent themes and unexpected insights during data collection and analysis, flexible to the unique aspects of the Noord-Limburg context (Creswell & Creswell, 2018).

In summary, a qualitative research strategy aligns with the aim of gaining a comprehensive and contextually rich understanding of the integration CE principles in the manufacturing industry in Noord-Limburg. By capturing the external factors influencing this CE integration, this strategy ensures the exploration of complex, context-specific factors crucial for addressing the research questions.

This research utilises an inductive reasoning approach, which involves progressing from specific observations or data to broader principles and theories. Unlike deductive reasoning, where hypotheses are formulated based on established theories and evaluated using specific data, inductive reasoning facilitates a more open-ended and emergent approach (Bryman, 2016). This study aims to grasp the intricacies and complexities of CE integration in Noord-Limburg's manufacturing industry. Inductive reasoning enables an exploration of diverse factors and perspectives without preconceived notions, which fosters a nuanced understanding (Eisenhardt, 1989). Also, through inductive reasoning, the research aims to reveal patterns and trends within the data. Thematic analysis, guided by constant comparative analysis, allows the identification of recurring elements, enabling themes to emerge

naturally from the rich qualitative data gathered through interviews and case studies (Braun & Clarke, 2006). Moreover, since inductive reasoning supports an iterative and flexible exploration of CE integration, it allows for adaptations in data collection/analysis based on emerging insights, ensuring a holistic but dynamic understanding of the research phenomena (Yin, 2017).

This inductive reasoning coincides with the qualitative and exploratory aims of this research, promoting a comprehensive and nuanced understanding of CE integration in Noord-Limburg and the external influences affecting it. It guarantees that insights regarding this topic arise naturally from the data, contributing to a sophisticated and contextually rooted comprehension of the complex realities surrounding CE integration within the regional framework.

3.2. Research design

3.2.1. Case study research

A case study is a commonly used research design and approach to inquiry allowing researchers to explore, analyse and gain an in-depth understanding of a specific, real-world phenomenon, often in its natural context (Yin, 2017). This section elaborates on the motivations behind selecting a case study as the research design and highlights its relevance within the context of this study.

In the pursuit of understanding CE integration within the manufacturing industry in Noord-Limburg, and the external factors influencing this, employing a case study research design is a strategic choice. Noord-Limburg's journey towards a CE is a unique and complex phenomenon that cannot be fully understood through isolated variables of simplified models. Furthermore, a case study allows for the exploration of CE integration within their multifaceted local context (Yin, 2017). It provides a platform to delve into the intricate web of external barriers and drivers that shape CE integration of manufacturing companies in the region. The region's manufacturing landscape is diverse, and different companies may approach CE practices in unique ways. A case study design thus allows for an holistic and in-depth exploration of these contextual nuances (Yin, 2017). Also, the research questions are exploratory in nature. Consequently, case studies are appropriate for investigating complex phenomena within their natural settings (Creswell & Creswell, 2018; Yin, 2017). Furthermore, CE integration involves multifaceted practices. A case study approach allows for the examination of interconnected elements within the manufacturing companies, providing a comprehensive understanding of circular practices (Eisenhardt, 1989). Finally, the nature of case study research is quite iterative and flexible, which aligns well with the research's qualitative and exploratory objectives. This design thus accommodates eventual adaptations in data collection and analysis at emerging insights (Yin, 2017).

In conclusion, using the case study design as the approach of inquiry is a well-suited and strategic approach for unravelling the complexities of CE integration in the manufacturing industry in Noord-Limburg. By delving into the unique contexts of the region and its manufacturing companies, this design facilitates a comprehensive exploration of external factors influencing CE integration, contributing to a deeper understanding of practices within the specified regional landscape.

3.2.2. Case selection: the region of Noord-Limburg

Choosing a suitable case is a critical aspect of case study research, as it influences the study's depth, relevance and ability to address research questions effectively (Yin, 2017). This section presents an

argument supporting the region of Noord-Limburg as a well-chosen case for answering the research questions, driven by several compelling reasons grounded in the context and objectives of the study.

Noord-Limburg features a diverse manufacturing landscape, encompassing industries ranging from food processing to high-tech manufacturing (Land van de Makers, 2020). This variety is vital for encompassing a wide range of circular practices, allowing for a comprehensive understanding of how different sectors approach and integrate CE (Eisenhardt, 1989). Noord-Limburg has already demonstrated a notable commitment to sustainability initiatives. The region's strategic emphasis on environmental responsibility and sustainable development fosters a setting in which manufacturers are inclined to adopt CE practices within their wider sustainability efforts. This region is also near various national and international CE initiatives. This closeness offers manufacturers in Noord-Limburg access to resources, networks and best practices, potentially enhancing a dynamic and evolving framework of circular practices (Kirchherr et al., 2017). Moreover, the cooperative business environment in the region promotes knowledge exchange and inter-organisational learning. This commitment to promoting collaboration between businesses, governmental entities and research institutions cultivates an environment conducive to sharing experiences and best practices concerning CE integration (Ankrah & Al-Tabbaa, 2015). Finally, the presence of supportive institutions and policies in Noord-Limburg is a key factor. Regional and national policies that encourage sustainable practices and CE initiatives provide a supportive framework for manufacturing companies to engage in and experiment with CE (Creswell & Creswell, 2018).

In conclusion, Noord-Limburg emerges as an exemplary case for investigating CE integration within the manufacturing industry, as the characteristics of Noord-Limburg closely match the research objectives, ensuring a rich and meaningful exploration of circular practices within the defined regional framework.

3.2.3. Cross-sectional time horizon

The chosen time horizon indicates the time frame used for carrying out a study and significantly influences the study's objectives and outcomes. They include cross-sectional and longitudinal approaches. A cross-sectional study investigates a topic during a specific period, while longitudinal research spans an extended timeframe (Saunders, Lewis & Thornhill, 2012). For this study on CE integration in Noord-Limburg's manufacturing industry, a cross-sectional time horizon is favoured to capture current external factors influencing CE practices (Creswell & Creswell, 2018).

CE practices are constantly changing, affected by technological advancements, policy changes and evolving market dynamics. A cross-sectional method allows the investigation into how manufacturers are presently managing this dynamic landscape. It provides insights into the diverse strategies employed at a specific point in time, offering a snapshot of the current state of circular practices (Eisenhardt, 1989). Furthermore, longitudinal studies would pose challenges like changes in availability of participants, organisational structures and other external factors that may influence circular practices. A cross-sectional design mitigates these challenges, allowing focused examination of the current landscape, and is more resource-efficient, especially for qualitative research. While longitudinal research provides insights into temporal changes, it is often more resource-intensive and time-consuming than cross-sectional studies (Creswell & Creswell, 2018; Yin, 2017). Given time and resource constraints, a cross-sectional approach is more feasible for gaining initial insights into CE integration within Noord-Limburg's manufacturing industry.

3.3. Research methods

3.3.1. Data collection

As already mentioned for this study, only qualitative research methods are used, as they are very suitable for providing rich insights into the complex and nuanced phenomenon of CE principles and practices within the specific cultural and environmental context of Noord-Limburg. The research methods selected aim to provide a deep understanding of the research phenomenon through a case study in Noord-Limburg. Accordingly, the study relies on qualitative in-depth interviews.

In-depth, semi-structured interviews serve as a cornerstone in qualitative research. They provide a platform for participants to express their perspectives, experiences and insights openly (Creswell & Creswell, 2018). In-depth interviews facilitate a comprehensive exploration of stakeholder perspectives, and they capture the factors that influence CE integration within manufacturing companies in Noord-Limburg. Participants can express their visions, values and strategic approaches (Patton, 2015), offering valuable insights for answering the research questions. The open-ended nature of in-depth interviews allows participants to narratively explore their experiences and perspectives. This narrative depth is vital for revealing the complex external factors linked to CE integration. It guarantees that the intricacies of stakeholders' viewpoints are not overly simplified and offers a detailed comprehension of the contextual elements influencing CE integration (Patton, 2015). Interviews were designed to probe participants' views on current CE practices within their organisations, as well as the external barriers/drivers they perceive to be influencing CE integration. The open-ended structure of the interview questions allowed for the emergence of unexpected themes and deeper understanding, consistent with the research's aim to explore rather than validating predefined hypotheses, with the results supporting a nuanced and context-sensitive understanding of the research phenomenon.

In Appendix 2, an overview of the practical issues regarding the semi-structured interviews can be found. In Appendix 4, the full interview guide used during the semi-structured interviews has been attached. Although the original design included the potential for document analysis, this method was ultimately not executed due to practical constraints. As a result, all findings discussed in this thesis are based exclusively on interview data and the sole document 'Maakindustrie Noord-Limburg: Actieprogramma 2022-2024' (Crossroads Limburg, 2022), which served for context before the conduction of the interviews.

3.3.2. Operationalisation

The operationalisation of the key concepts and variables from the conceptual model is an essential step in ensuring consistency and clarity in the collection and analysis of data (Creswell & Creswell, 2018). In this research, operationalisation involves defining and breaking down abstract concepts, these being internal CE integration and barriers/drivers to CE, into measurable and observable indicators that have been explored empirically through qualitative interviews.

To achieve this, the research draws directly from the theoretical framework and conceptual model. The concept of internal CE integration is structured using the R-imperatives framework (Potting et al., 2017), enabling to distinguish between various levels and strategies of circularity. These were operationalised into interview questions that explore how these practices are currently implemented or considered within a company's operations, product design, and supply chain strategies. Similarly, external factors were operationalised using categories derived from existing CE literature (e.g., Rizos

et al., 2016; Kirchherr et al., 2018). These informed a set of targeted interview questions aimed at uncovering perceived obstacles and enablers influencing CE integration at the organisational level.

These indicators form the foundation for structuring the interview questions and have guided the data collection efforts. While the interview format allowed flexibility to explore emerging themes, the operationalised indicators ensured that core topics were consistently addressed across all interviews. This dual structure maintained depth and comparability. In Appendix 3, a detailed overview of the operationalisation scheme can be found, where the specific indicators are outlined. In Appendix 4, the interview guide can be found, based on this operationalisation.

3.3.3. Data analysis

The qualitative nature of the data requires a thoughtful and systematic approach to make sense of the rich and diverse insights provided by participants. In this study, thematic analysis serves as a systematic and flexible method for identifying, analysing and documenting patterns within the data. The initial step involves the identification of key themes that emerge from the interviews. These themes encapsulate recurring ideas, narratives and concepts associated with external influences in the context of CE integration (Braun & Clarke, 2006). Thematic analysis involves a rigorous process of data coding and categorisation. Raw data is systematically coded into meaningful categories, which allows the organisation and synthesis of information. For this, the coding programme ATLAS.ti has been used. This coding process ensures that diverse perspectives and insights are captured, which leads to a thorough understanding of the dynamics within the manufacturing industry in Noord-Limburg (Guest, MacQueen & Namey, 2012). Integrated in the thematic analysis process, is constant comparative analysis. As themes and codes emerged, they were continuously compared within and between interviews. This iterative process improves the precision and consistency of the data analysis, enabling the refinement and development of themes as the analysis progresses (Charmaz, 2006).

The analysis resulted in a narrative synthesis that assembles the identified themes and patterns. This involved crafting a cohesive story that captures the reality of CE integration in the manufacturing industry of Noord-Limburg. This narrative process was not merely descriptive. It critically engaged with the data, linking emerging insights back to the theoretical framework and the broader literature on CE. This provides a compelling and contextually embedded account of external influences to CE integration, ensuring that the findings are accessible and resonate with the complexity of the studied phenomenon (Riessman, 2008).

In conclusion, the integration of thematic analysis, constant comparative methods and narrative synthesis allows this research to provide a solid, evidence-based and theory-guided understanding of how CE is influenced by external elements and internal dynamics within a distinct regional context. This analytical method aids the research goal of generating detailed, context-dependent insights that enhance both academic understanding and practical considerations regarding CE integration.

3.4. Validity and reliability

3.4.1. Internal validity

Internal validity, or credibility, is an essential factor in qualitative research. It refers to the extent to which the study's findings can be ascribed to the causal relationships being tested, rather than to other variables or confounding factors (Trochim & Donnelly, 2006). This section focuses on how the internal

validity of this study has been attempted to guarantee, enhancing the trustworthiness and credibility of the research findings.

Several strategies were employed to enhance the internal validity. First, methodological triangulation was pursued by incorporating diverse perspectives across interviews. Triangulation occurred within the interview data, by comparing and contrasting participant perspectives across companies, roles and CE maturity levels. This helped reduce individual bias and strengthened the plausibility of identified themes (Creswell & Creswell, 2018). The thematic analysis of this research, as well as the constant comparative analysis embedded within this thematic analysis, also contributes to the internal validity. This coding process specifically improves the reliability and consistency of the analysis (Braun & Clarke, 2006), and the iterative refinement guarantees that themes are not merely identified, but rather continuously revisited and revised as the analysis progresses. Together, these strategies have contributed to the trustworthiness and credibility of the research findings, ensuring that the results correctly represent the complexities of CE integration within the manufacturing industry of Noord-Limburg.

3.4.2. External validity

Similar to internal validity, external validity is an essential component of research design. External validity pertains to the generalisability and applicability of the study findings to other settings, populations, or conditions (Creswell & Creswell, 2018). Given the focus on Noord-Limburg, the external validity of this study may be limited to comparable contexts or regions. Although qualitative research often prioritises depth over generalisability, the external validity of this study has ought to be enhanced in various ways.

One way is by providing a rich description of the contextual factors surrounding CE integration in Noord-Limburg's manufacturing industry. This includes detailed information about the region's economic, social and environmental dynamics. Such detailed contextual information aids in the transferability of findings to other, similar contexts (Stake, 1995). Also, the process of data collection and analysis is described in a detailed manner. Because of this, a detailed and nuanced account of participants' experiences and perspectives has been provided, as the results are presented in the context of the described context and research process. This boosts external validity too, as such thick descriptions provide researchers with a detailed and in-depth description of the context and process of the research (Stake, 1995). This allows readers to assess the applicability of findings to similar situations in different contexts. The external validity of the study is also strengthened through the detailed reporting of the research methods.

By detailing the study's methodology thoroughly, the research allows the reader to evaluate the applicability of the results to environments with comparable features (Guba & Lincoln, 1989). Additionally, the research acknowledges the significance of contextual sensitivity in qualitative studies. By recognising the distinct characteristics of Noord-Limburg's manufacturing industry, the research seeks to provide a detailed comprehension of CE integration, while also contemplating the possible transferability of findings to comparable regions. Together, the strategies used in this study improve external validity, guaranteeing that its results provide significant insights that extend beyond the particular boundaries of Noord-Limburg.

3.4.3. Reliability

Reliability in qualitative research is crucial for ensuring the consistency, dependability and trustworthiness of the methods and results. It concerns whether the study could be repeated with similar outcomes or if another researcher could obtain similar findings using the same methods (Creswell & Creswell, 2018). A comprehensive approach has been employed to enhance the reliability of this research. Firstly, to ensure reliability, the research rigorously adheres to consistent data collection procedures, including the use of standardised interview protocols. Maintaining consistency across data collection methods is fundamental in establishing reliability (Miles, Huberman, Saldaña, 2014). Secondly, the principle of prolonged engagement is embraced, which involves spending sufficient time in the field to learn and understand the participating companies and the context (Lincoln & Guba, 1985). This facilitates understanding and co-construction of meaning between the researcher and the researched object. Through this, the risk of misinterpretation is reduced, and the reliability of the data enhanced. Thirdly, the study has made use of peer debriefing as a measure to enhance the reliability. Discussions with peers and colleagues provide an external perspective on the research process and emerging findings. This external input contributes to the refinement of interpretations and bolsters the overall reliability of the study (Guba & Lincoln, 1989). Besides, the presentation of the findings in the light of the described context and research process so that the reader can interpret the meaning, captures the nuances and complexities of participants' experiences, enhancing the reliability of the research. These rich and detailed descriptions serve as a comprehensive narrative, enabling the reader to assess the credibility and dependability of the interpretations (Stake, 1995).

Of course, such a qualitative analysis inevitably requires interpretive judgement. While absolute consistency is neither achievable nor desirable in such research, this study aimed to ensure its findings are reliable by maintaining a transparent, rigorous and reflective analytical process. In summary, the reliability of this research is enhanced through consistent data collection methods, peer debriefing, and the triangulation of data. These strategies aim to establish a robust foundation that guarantees that the findings are consistent, dependable and trustworthy.

3.5. Ethical considerations

Conducting research requires careful ethical consideration to ensure that the study has been conducted in a respectful, fair and responsive manner. This requires a commitment to the rights, dignity and autonomy of participants, while also/still generating valuable and valid findings (InnovateMR, 2023). The ethical aspects of this research consist of multiple matters.

Ethical conduct begins by obtaining informed consent from all participants. Before their involvement, the participants received detailed information about the essence and nature of the research. This transparency ensures that participants make informed decisions about their participation, aligning well with the principles of voluntary and informed consent (Ponterotto, 2010). To safeguard the identity and privacy of the participants, the study rigorously adheres to principles of confidentiality and privacy/anonymity. Interviews are conducted in private/secure locations, all data is securely stored and identifiable information is carefully redacted to prevent the disclosure of participants' identities. The company names as mentioned hereafter in this study are therefore fictitious and do not relate/correspond to the actual company names. This protects participants from possible consequences linked to their contributions (Denzin & Lincoln, 2018). While the invented names might imply a direct connection to CE, they are simply made up, but with a little nod to the subject matter.

Respecting the autonomy of participants is essential. Participants were given the freedom to withdraw from the research at any point without facing any repercussions. Also, the research has actively sought to minimise any potential harm to participants. Topics and questions are approached with sensitivity, and participants are assured that they can refrain from answering any questions if they may cause discomfort. The participants were regarded with dignity and respect, and aware of own biases and assumptions, the study has tried to avoid imposition of own beliefs on the participants (InnovateMR, 2023). Data collection and analysis are crucial components of qualitative research, yet they also raise concerns regarding research ethics. For this research, it is ensured that the methods of data collection and analysis are appropriate and valid and that they do not manipulate or alter the data in any way to convey a different story (InnovateMR, 2023). Also, it has always been transparent about the methods to ensure that the research is replicable, and the findings of this study have been used in a responsible and respectful manner, to make sure that they are not used to harm or stigmatise participants or companies (InnovateMR, 2023; Ponterotto, 2010). The study is transparent about its limitations, and there have not been sweeping generalisations that are not evidently supported by the findings. Finally, the results of the study are communicated in a clear and accessible manner to stakeholders in Noord-Limburg. In doing so, it is ensured that the research is contributing to positive change and improves the lives of those affected by the issues being studied (InnovateMR, 2023).

By assigning value to these considerations, the research has aimed to guarantee that it is carried out in a respectful, fair and responsive manner, thereby contributing to positive and more informed change in society.

4. Results

In this chapter, the findings of the research are presented based on the eight semi-structured interviews and the analysis of the document 'Maakindustrie Noord-Limburg: Actieprogramma 2022-2024'. But initially, the chapter starts with a brief description of the manufacturing industry of Noord-Limburg, the Netherlands.

The manufacturing industry of Noord-Limburg consists of almost three hundred companies, of which more than 260 can be classified as SMEs and the remaining dozens as large companies (Crossroads Limburg, 2022). Altogether, they are responsible for 33% of the Gross Regional Product. For context, the manufacturing industry nationally accounts for (only) 12% of the Gross Domestic Product (Crossroads Limburg, 2022). With that, the industry is a real heavyweight regionally. And with a view to the near future, in which the CE is taking on an increasingly prominent role, this once again underscores the relevancy of this study. The region as an instance has, together with the central government and the province, confirmed their 'regional deal' "On the way to the healthiest region" (Noord-Limburg, 2025). Together with partners and initiators from various industries, supra-local projects will be prepared that have a long-term effect and strengthen the broad prosperity in the region. The four themes that bundle together this regional deal are (Noord-Limburg, 2025): 1) knowledge, research & sustainable entrepreneurship, 2) attracting, developing & retaining talent, 3) vital communities & positive health, and 4) security & undermining.

In the remainder of this chapter, the results of the eight semi-structured interviews and the document analysis will be depicted, after which the basis is laid for ultimately answering the research question(s) of this study. As stated in Chapter 3, the data collected from the interviews and the document was analysed with the use of codes, resulting in specific themes related and corresponding to the conceptual model, thereby achieving methodological validity. The first time a quote from a respondent (c.q. company) is used, the position of that respondent within the company is used, accompanied by the notion of 'personal communication' and the mentioning of the date of the concerned interview, referring to Appendix 2. In subsequent quotes, only the (fictitious) name of the company in question is mentioned. As has already been accounted for, these names are fictitious (made up only with a nod to the topic) and do not relate to the actual company names.

4.1. Internal CE integration

The interviews with the manufacturing companies in Noord-Limburg predominantly started with the question what their companies understand by the term CE, and to what extent their company is engaged in circularity. The CEO of BlueCycle speaks about CE as a very broad concept, but particularly that "the raw materials you use ultimately become available again in the process and are used again in a subsequent application. This could be in your own process, or somewhere else, but you don't add anything to the waste heap." (personal communication, 15-05-2024) The Managing Director (MD) of InnoFabb believes it is about:

"That we think more carefully about the lifespan of a product. So during its lifespan we can upgrade, create or repair a product so that it can be used again. And when it finally reaches the end of its life, we can take it apart in such a way that we can fully recycle it and bring it back to the same level in the production process and therefore ultimately back into a final product." (personal communication, 04-06-2024)

The MD of RenewTech regards CE as:

“the reuse of materials, to make it go circular. So, can we look at: how can we use materials [to generate] as little waste as possible? That's what it's about. For ourselves, but also for our customers. (...) And not just the materials, but also packaging, for example, but also everything that happens in and around the building.” (personal communication, 06-05-2024)

And the MD of TerraNova adds to this: “everything that goes with it to actually be able to reuse an item with less footprint than when making it again from scratch.” (personal communication, 13-05-2024)

The companies were then asked to what extent they are engaged in CE, what the reasons are for this, whether or not and how they try to shape CE within their company. With the exception of one, all companies indicate that, in a way, they try to be actively engaged in CE-related issues. “No relevant [theme]. So the company is mainly concerned with making something out of steel and returning it somewhere to the world”, says the MD of HorizonWorks (personal communication, 30-04-2024), and adds to this that after thirty/forty years, their materials and products are dirty and damaged to such an extent, that they are being processed as waste. Nevertheless, the company carries out activities that, even if it is not from a circularity perspective, can certainly be classified under the R-imperatives. They try to reduce as much excess material as possible, albeit more cost-driven, and these redundancies are being applied elsewhere in production where possible.

Looking at the specific strategies that can be employed to increase (product) circularity, and thereby starting at the bottom of the R-ladder, it shows that companies generally focus on R-imperatives higher up the hierarchy already, with InnoFabb carrying out recovery practices (‘R9: Recover’). They namely use residual heat from machines and compressors to warm up production halls, so that even in winter, the heating does not have to be turned on. The manufacturing industry of Noord-Limburg is, looking at the latter stages of the material lifecycle (the long loops from Chapter 2), slightly more focused on ‘R8: Recycle’: “Whatever waste we have in the process all goes back to the mills, everything is being recycled. We ensure that all that is possible.” (COO of EcoLine, personal communication, 25-04-2024) The same goes for CircoCraft, having firm arrangements with their waste processor/recycling company and even with themselves through “a WEEELABEX certificate, which we now have” (CircoCraft, personal communication, 06-05-2024), which is a quality standard that establishes the minimum quality level for collection, storage and recycling of waste electrical and electronic equipment (Holland Recycling, 2022).

Within the CE domain in the manufacturing industry in Noord-Limburg, the interviews showed that more attention is being paid already to extending the lifespan of products and parts (the medium long loops), rather than solely looking at CE options related to waste. Starting with ‘R7: Repurpose’, EcoLine develops new products, in collaboration with designers, out of materials that otherwise would be processed as waste: “So we have a whole series of beautiful lamps made from hooks that we would normally recycle here into a new raw material.” The same goes for BlueCycle, who make new products with residual materials that perhaps would otherwise be thrown away. Moving on to ‘R6: Remanufacture’, the best example from the interviews comes from CircoCraft, who have full-on “re-man programs” as they call it: “so we can make state-of-the-art technology for every type of machine coming in here. So we have all the knowledge and materials for that [parts of an old machine can be

used for a new machine with that same function]”. InnoFabb have designed ways to extend the lifespan of their packaging materials through creative refurbishment (‘R5: Refurbish’): “Everything we process internally in terms of plastic into end products, now goes into crates. If these break, we can indeed push them through the shredder again and make new ones.” Thereby they restore and improve products (packaging in this case) to a satisfactory condition for extended use (Malooly & Daphne, 2023). CircoCraft have arranged this in a way that machine parts coming back from the field are getting completely reconditioned(/refurbished) after which they can be put in different other machines. And the same goes for GreenStar, having their own “large Service-and-Spare-Parts department” (personal communication, 24-04-2024) where they both refurbish and repair their products for their customers.

Proceeding with ‘R4: Repair’, steps have already been taken to maintain and repair existing products (parts). RenewTech, e.g., “can also fix some items from customers instead of making a new one straight away”, where in the past they often sent whole new sets to customers: “That was just purely from a sales perspective. Now we look at: which parts do we [actually] need to replace and only then back to the customer. Not playing a game.” The same goes for CircoCraft, who store “parts that come back, we call them repairables (...) and if a customer request comes in, well, then we take those repairables”, which actually classifies both under ‘refurbish’ and ‘repair’. Regarding ‘R3: Reuse’, the final imperative of the medium loops, multiple examples emerged from the interviews, ranging from the reuse of end products (parts) to the reuse of packaging materials. “Yes, reuse of discarded, not yet... still good products for the same function by another user.” (CircoCraft) HorizonWorks make a lot of effort to reuse water: “We spray quite a lot and (...) because that is not micro accurate, there is quite some waste. And those drops you try to collect and somehow return into the circuit.” And various manufacturers have produced ways to reuse their packaging. InnoFabb, for example, not only with their plastic crates but also through the introduction of a cardboard press container, with which “everything is compressed again, collected and new boxes are made from it.” RenewTech reuse their packaging materials in a likewise manner: “Everything we receive from our suppliers, including the filling of the boxes, is of course not being thrown away. Boxes that we could reuse are thus actually reused.” Also for the machines they manufacture, RenewTech have produced a circular solution regarding the packaging:

“On the other hand, we have certain machines (...), which always go in a box, and that box went there on the firewood, so to speak. And (...) it is now designed in such a way that you can take the box apart and it will now be returned as a plank package once in a while, so that we will reuse it.”

Across the manufacturing companies, medium-loop practices (R3–R7) consistently focus on extending product lifespans during the consumption phase, focusing on optimal use with the goal of preserving/extending the life of products and/or materials (Malooly & Daphne, 2023). The short loops (R0-R2), meanwhile, are exercised in the (product) design phase. Value is being added at the front end, the focus lies on responsible manufacturing and use/ownership, and according to Malooly & Daphne (2023), they therefore are being considered the most sustainable imperatives. Starting with ‘R2: Reduce’, the interviews showed that the manufacturing industry in Noord-Limburg is increasingly thinking about and working on practices aimed at using fewer raw materials and producing less waste, and thereby increasing the efficiency of their manufacturing operations (whether or not from a purely sustainability perspective, but this will be discussed further later in this chapter). GreenStar, for

example, are increasingly asking themselves the question: “Hey, can't I make it [new product] with just a little less material or make it a little more efficient? Or can't I make something with recycled plastics instead of using a new product?” The same goes for HorizonWorks, who have a supplier with “quite the exuberant use of materials. Everything too thick and too coarse and so we take on one or two machines every year that we dimension based on the actual calculated need.” InnoFabb looks at making products lighter through thinner wall thicknesses, BlueCycle equally try to use less materials, and explicitly to use less raw materials: “We also look upstream when purchasing to ensure that we buy materials that have already been reused.” And finally, EcoLine state: “the goal is always to reduce, and to ensure that you use less to make the product.”

Reducing raw materials purchasing goes hand in hand with a waste stream reduction, and it appears that a lot of emphasis is placed on this in the region, too. BlueCycle and GreenStar are currently making sure that all the material they use, actually goes into their products through order-driven purchasing, only purchasing materials “...that you have already sold. So no items or material in stock that then become obsolete.” (BlueCycle) And in addition, they are occupied with reducing the waste coming from their own production processes. However, some waste-reduction efforts reflect low-hanging fruit rather than systemic transformation, as among others GreenStar and RenewTech state and show, in the form of replacing plastic or cardboard drinking cups with mugs. This example could actually also be placed under imperative ‘R1: Rethink’, referring to making a product more use-extensive (Malooly & Daphne, 2023). CircoCraft intensify product uses through their “platform strategy”: “So that multiple products use the same motor, so that you design one motor, but that it can be used for multiple machines.” This imperative also means re-thinking the materials that companies choose to purchase at the front end. “We can choose from thousands of different raw materials and grades, we now try to choose grades that are already widely used and that can be easily recycled.” (InnoFabb) Also through design, some manufacturers in Noord-Limburg are progressively re-thinking their operations. The ‘reuse’ example of RenewTech’s packaging method showcases this, emphasising the fact that to make something more circular, re-thinking it is required (Morseletto, 2020). The same is being done regarding product design:

“We are now trying to focus on design for disassembly, so that you can take it apart. (...) When we get such a design, we also look at certain click connections or screw connections with which you can easily take a product apart again (...) and repair, and also take it apart more easily for assembly, for disassembly and for recycling, ultimately.” (InnoFabb)

This ‘design for disassembly’ is increasingly being applied, with CircoCraft having developed a “design-framework for circularity” and with BlueCycle “construct[ing] products in such a way that the materials can be separated in a clean manner and reused as clean flows.” Likewise, TerraNova are doing small research projects aiming to replace powder coating, which is not appropriate for disassembly, with alternatives that can be separated into base materials. For ‘R0: Refuse’, not particularly much has been found from the interviews. EcoLine is committed to influencing tenders so that certain material types, like zinc, are no longer getting prescribed, which BlueCycle also do themselves already: “Refuse, not using materials that are already wrong at the front end, there is already a big part in that [here].”

The next questions were related to the CSRD, and the respondents were asked about their (company’s) knowledge and opinion, and what this legislation implies for their company and its circular practices. At the time of interviewing, every respondent/company was already aware of their future obligation

to report on their ESG performances, with most of them even working on it on the sidelines already: “We don't have to do it yet, but [a big customer company] do. And they will immediately ask for things and then we will already have it ready.” Others have already made the first organisational steps, with EcoLine making strides with their sustainability vision already in place, working already with sustainability process indicators and e.g. having calculated their total footprint including scope 1, 2 and 3. “So we're not just starting to only do that now because CSRD is coming. We have already come a long way towards being able to comply with CSRD.”

The opinions on the CSRD and its practicality were, however, slightly nuanced/divided. Although the underlying sustainability idea and objectives are commonly endorsed, about every respondent comments on this, essentially coming down to two main things of concern. The first one is related to regulatory pressure being transformed into an expenditure/cost item: “I think it is very doable for the larger companies. But I think it will be a blow to small businesses, [because] you almost have to fully put someone there...” (InnoFabb) “... who is only concerned with the reporting structure and keeping track of it, to create overviews to please someone” (GreenStar). “Smaller companies that may have to set up something like this with forty employees will have to incur relatively high costs and may therefore simply not be able to get it fixed”, TerraNova summarise. And the second critical note of the respondents is related to the fact that practice is often tougher than theory:

“In practice, this means that it takes a lot of work to document something again, and the question is whether that actually changes behaviour or whether it is capturing the status quo that already existed. So I wonder whether that will actually contribute or whether it will mainly involve a lot of administration.” (BlueCycle)

Subsequently, the respondents were indirectly asked how they align to ESRS E5 regarding ‘resource use and circular economy’, by asking about the company’s insight/awareness of its resource use and waste stream, what is being done with that information/awareness on the material flows, and by asking to what extent policies, targets and actions plans (as fundamental elements of ESRS E5) have been formulated. In general, the companies indicated that they have good global insight into their in-and-outgoing material flows, as well as their waste streams. And it is here where BlueCycle immediately underline the significance of the CSRD, summarised in one sentence: “because insight is the first step to actually doing something (...) and that will become clear under the CSRD”.

“We always have an overview; on content of materials, but also on material types. We work a lot with parties of which we want to see data sheets on what's in it (...) and we often have to send that to customers as well.” (GreenStar)

EcoLine have configured materials passports, allowing them to easily record the contents of materials, their quantities and material types for every individual system, and also InnoFabb know “exactly what the stock is of our own recycled material, what we can use ourselves and what we can no longer use and thus sell to another party.” The reasons for recording that information are varied: some companies do it out of their own motivation, some do it because it is imposed on them by the industry, and some do it because of legislation. However, although the respondents have a high degree of insight into their company's material flows, it cannot be said (and this is also generally admitted) that much is being done with this information/awareness. “You notice that the market is not really yet asking for it,”

EcoLine state as a possible explanation for this, and proceeds: “These questions are coming up more and more [through CSRD], but we mainly do it for ourselves.” And if anything is done with this information, it is mainly from a production-related or financial point of view (“where the waste flow must be as few kilos as possible, because that is all loss, that's my trigger”) (RenewTech) and less “from an environmental point of view.” (BlueCycle)

They were then asked about policies, targets and action plans (already) in place related to resource use and CE. Where CSRD explicitly asks for textual information regarding policies to manage a company's material impacts, risks and opportunities related to resource use and CE, it became rather clear that these are to a certain extent anchored in the majority of companies internally, but that this is not yet really (textually) communicated externally with the label 'policy' as the CSRD prescribes. “I don't necessarily call it policy, we just have purchasing plans and sustainability plans. (...) We are a pragmatic entrepreneur and we do what we say”, argue EcoLine. RenewTech “are working on it. Look, our renewed mission also states that we want to reduce waste, but (...) the mission is also for our customers. (...) So we already mentioned it in there.” And InnoFabb, too, admit that although they claim to make efforts regarding resource use and CE, the concrete texts indicating this are missing yet. That is something CircoCraft attest: “Something that will come, but which is not yet concrete.” BlueCycle, on the other hand, state to have concrete policies in place, with concrete targets respectively set as well: “So in many departments this [material use] is measured and are targets and objectives to reduce it, thus keeping cutting loss minimal. So yes, that's in place, and there is also a policy to replace some materials with better materials”, where it remained unclear during the interview whether this policy has also been yet elaborated textually as the CSRD prescribes.

Continuing with targets regarding resource use and CE, the interviews showed that these are considerably more present than policies, especially because these are more easily concretised than policies. But it has also been shown that not every company has these concrete targets, but might be “disguised in the target that you want to make as much profit as possible. And if you reduce waste, you earn more money. So in that sense there is [a related target] (TerraNova) InnoFabb target “to double the recycled material we purchase within the next five years. (...) And our goal is to use 95% of our own scrap or waste [again], which is actually working very well.” GreenStar also tackle their production waste: “we want to reduce waste from the laser... to reduce that from 15 to 8%”, and returning to their purchasing plans and sustainability plans, EcoLine work with “KPIs that state that, for example, 100% of my wood must be certified and must come from sustainable areas.” HorizonWorks state that “there are no further secondary objectives in terms of CE”, showing that even when there are no concrete targets in place at first glance, companies indeed do have them anchored somewhere in the business operations. Under the CSRD it again turns out to be a matter of writing down, starting with the low hanging fruit.

Closing of with action plans in relation to resource use and CE, where naturally the question of ‘how will the company endeavour to achieve those targets set?’ should get answered, the interviews have shown that the region not really aligns so well to the textual concretisation of this CSRD element yet. EcoLine's target to only use 100% certified wood is being attempted to be accomplished by “only resourcing PEFC certified suppliers (...) and FSC.” Besides, BlueCycle apply action plans aimed at “reconstructing [their products] to make it possible to use certain sustainable materials more often”, and GreenStar has employed an action plan around its targets to reduce waste, where a team takes measurements and looks at how the production processes can be improved to reach these targets. So,

with a view to concretising and aligning to CSRD guidelines, it is a matter for these manufacturing companies in Noord-Limburg to define and especially elaborate on paper what targets there are with regard to ESRS E5 and how attempts will be made to achieve these targets, in the form of action plans.

In sum, while many companies in Noord-Limburg engage in CE practices across all stages of the R-ladder, these are often piecemeal and not embedded within formal strategies or policies. Nonetheless, increasing awareness of CSRD requirements is pushing firms toward more structured approaches.

4.2. Barriers to CE

This paragraph presents the key barriers to circular economy (CE) integration identified in the interviews with the manufacturing industry of Noord-Limburg. Categorised according to Kirchherr et al.' (2018) dimensions, these barriers demonstrate a complex interplay of systemic and operational challenges in Noord-Limburg. Understanding these barriers is essential for identifying areas where targeted interventions can promote CE integration in the region. Consequently, the results in this section help to frame the elements that influence CE practices in the region's manufacturing industry.

The collected data highlights a range of cultural and social barriers that hinder the adoption of CE practices within Noord-Limburg. Firstly, a lacking belief in and insufficient knowledge of the concept of CE at the top of the organisation is adverse to fostering circular practices in that organisation. "That [CE as a theme] has never really been discussed", acknowledges HorizonWorks, which can be a plausible reason for a company not having made great strides yet regarding CE. Respondents admitted that it is difficult to escape from cultural lock-ins, especially when things are going well. "We are doing well, we are successful (...) Why would you change that?" (GreenStar) Others also admitted that the mindset and culture is definitely not fully there yet to shift to circularity, with still rather a focus on linear models. "We are a bit of an old culture. That [mindset] won't be that easy to convert." (CircoCraft) "Let's be honest, the culture is more like: how can we earn as much money as possible instead of: how can we produce as little waste as possible or be as circular as possible?" (TerraNova) Age composition within the companies in the region is a hindrance, with in particular the "old guard" (GreenStar; CircoCraft) being rather conservative within the organisations, not really thinking about circularity and sustainability per se, which are "things that you have to struggle with" (GreenStar) company-wide.

Next to these in-house barriers, the interviews revealed that cultural/social barriers can also be recognised outside company boundaries. Because, just like internally, there should be a certain mindset towards circularity among customers. "There is no demand from the market" (HorizonWorks), and "in many cases, our customers are primarily not that interested in this theme at all and therefore we cannot do much with it." (TerraNova) And in addition, respondents often experience a form of dependence as a supplier, making them dependent on the choice and wishes of their customers in many cases. "Because we do not have a decisive voice (...) the customer ultimately chooses." (InnoFabb) This sometimes leads to the customer making a certain choice not fully supported by the respondents, and this is further reinforced the further away the company is in the supply chain from end customers: "If you do not supply directly to an end customer, you are very much at the mercy of your customer, who must therefore develop something that is circular [for end customers]." (TerraNova) And when asked how customers feel about CE, the response was in some cases quite negative, impacting the circular ambitions of the companies interviewed. "Well, I hear very little about that. It is that I know there will be regulations, but many of our customers (...) I don't hear anything

about it.” (RenewTech) “I never hear it at any meeting, that someone thinks something about it or asks questions about it.” (HorizonWorks) Also upstream, companies encounter resistance. BlueCycle, for example, have had an experience with a supplier who said: “Sorry, I just won’t comply with that, because it costs me a lot of money to get the certificates, and you are the only customer who wants it, then it doesn’t pay off for me”, meaning that BlueCycle cannot push through their own circular ambitions upstream.

The respondents’ circularity efforts have been proved to be slowed down outside of supply chains too, through the lacking interest and awareness of ‘the people’. It is the consumer mindset that poses a barrier, as “there is [simply] no culture of returning the product to a supplier” (BlueCycle). And it is that same mindset that determines how a product is getting made. “So you can have it in your portfolio [circular alternatives], but you see that few customers are really motivated in such a way that they are willing to do that.” (BlueCycle) “If you can buy something made with recycled materials or a new material for the same price, then a customer will choose the new material.” (TerraNova) And “we also notice that if people notice that sustainable is also more expensive, they opt for traditional again.” (InnoFabb) And this price consideration appears to be the dominant discourse, showing that the price of products weighs more than the sustainability/circularity of it. This is closely related to the category of market/economic related barriers, but, as TerraNova summarises, it is the “the culture in society” that is a guiding principle for the success of manufacturers’ CE efforts, as there is “just little awareness from the people”. This results in the retaining of linear systems instead of shifting towards circular systems where prices and sales are subordinate to how the product or service relates to sustainability/circularity. “We are all focused on producing, (...) producing as much as possible.” (InnoFabb)

Next to these cultural and social barriers, the interviews uncovered several barriers of regulatory and institutional nature. What stood out during the interviews was that they all cope with internationally differing laws and regulations, which, according to them, hinder them to make further strides regarding CE as they operate in international markets. “Legislation clashes, of course” (BlueCycle). “Governments have to take a strong stand, and I don't see that happening in many countries yet” (EcoLine). A result of these internationally differing laws and regulations is that production processes can still easily be shifted “to the parties that are the least circular” (BlueCycle), or “to a region where they are less critical” (TerraNova). GreenStar summarise it as “the laws and regulations in the rest of the world are even counterproductive to the idea of sustainability.” “As a small country, we want and demand a lot from our companies, but within the EU I see very big differences.” (RenewTech) This poses a huge barrier to CE for the manufacturers, as this makes production in the Netherlands more expensive, with which “we will price ourselves out of the market with that.” (InnoFabb) And:

“if you price yourself out of the market, you will exceed your goal. And no matter how many ambitions you have, if that means you don't get the job, you can't pursue them. So European and global consensus would not be so bad.” (InnoFabb)

But not only international laws and regulations form barriers for the respondents, so can the ones that apply specifically to themselves: “It is not feasible for an SME to comply with five different rules and have different materials in your portfolio for all the rules [and then still go circular].” (BlueCycle) In most industries where the respondents operate, there are certain quality requirements that must be met. Both RenewTech and InnoFabb may only use virgin materials occasionally because the industry

in which they operate instructs them to do so: “It is forbidden for certain products to use recycled material. (...) Some products lend themselves very well to this, but are not possible.” (InnoFabb) InnoFabb also experience incomplete regulation in the form of an official certificate that is getting issued when “only 10% of the material is a bio material and 90% is still conventionally made from petroleum (...) while you just know that you are actually just getting a gray material, not a green one.” Regulations thus may be present and appearing quite credible, while they are actually misleading:

“Because regulations do not regulate this properly, we do the wrong things. So we do the things that have a certificate, but that are actually not that green at all, instead of the things that are very green, but have not yet been officially released as green.” (InnoFabb)

On the other hand, the lack of such regulation or certification can also form a barrier to CE. “It is a shame that we do not yet have obtained the tools that we need to be able to offer [our green product] for the same price [as the ‘falsely’ certified product]”, says InnoFabb. And RenewTech informed that sometimes “I don't have to provide any proof, I don't have to provide any certificate.” (RenewTech) As this is closely related to a lack of standardisation, this will be discussed later in this paragraph.

GreenStar, subsequently, experience an institutional barrier about the fact that according to them, the Dutch government is trying to shrink the Dutch primary sector, while one needs this to implement innovations:

“Suppose I want to develop a new machine or improve my machine, then I want to be able to test it in the Netherlands. (...) And if everyone quits here and the government tries to push out the entire agricultural sector, we cannot test it here. So you also need the primary sector and I see that as a threat [to my circular ambitions].” (GreenStar)

Another related institutional barrier concerns a lack of circular procurement in general. As by BlueCycle, it is difficult “especially finding the right materials. So if you are looking for material that is suitable for bringing it back into the chain, your choice is often very limited.” TerraNova confirms this, evaluating that “it is relatively disappointing: how nervous we may be about climate change and how little we actually do about it.” Thus, according to the respondents, not enough attention is being paid (top-down) to the means by which a CE can be commenced, despite the growing recognition for it: “A lot of discussion groups, but not much action yet.” (CircoCraft)

Subsequently, the interviews also pointed out market- and economy-related barriers. As already stated, there is a lack of standardisation regarding CE efforts that companies can make, making their meaningful efforts meaningless, because “there is no unambiguity in the market.” (InnoFabb) RenewTech add that there are still few requirements for showing the evidence of circular entrepreneurship. And “... good definitions, something that is well organised, that is demonstrable, with no room for greenwashing (...) I think there is still too little of that.” (EcoLine) And when probing further on standards, CircoCraft stated: “These have not yet been formally recorded, so they are not required by law. If that would be the case, it would help us in circularity, because then everyone would have to adhere to it.” TerraNova therefore summarise the lack of standardisation and the effect it has on circularity as: “it is quite difficult to really see integrally whether you are actually doing well.”

Another market/economic barrier is about the price difference between virgin and non-virgin materials and how this relates to the aforementioned social/cultural barriers. More often than not, virgin materials (and therefore end products) are cheaper than non-virgin materials. And when it turns out to be more expensive, “one chooses traditional again.” (InnoFabb) “Well, which company is going to make its shampoo bottle from recycled plastic if the consumer is not willing to pay for it. That is why a cheaper material is simply purchased. Of course, it's that simple.” (BlueCycle) When talking about their machines, RenewTech concluded that “a virgin one is cheaper [than when it also consists of non-virgin materials], because the other one involves so many actions and so much work.” In addition, as there is generally a lot of competition within a market, the manufacturers in Noord-Limburg are not able to determine, on their own, which materials are used in their market and against what price: “Our market is really a market where there is a lot of competition (...) All that has to be done for next to nothing, it has lot of competitors.” (TerraNova) So, even if you are fully motivated to bring circular products to the market, meaning that the overall price tag will increase slightly, “what happens then is that the volume flows to the parties that are the least circular. So you don't achieve anything with that.” (BlueCycle)

Not only individual materials contribute to the price tag, so do the costs to set up and initiate circularity in the first place. When being asked about those and whether these have hindered them in decision-making processes, RenewTech stated: “Yes, we consider that to be high. Because otherwise we would have done all that already, we would have taken much bigger steps.” And because the investment costs and “engineering costs” (GreenStar) are often so high, with CE still being in its infancy and an “innovation trajectory [that] is long” (GreenStar), there is a chance that you will hardly earn it back over the years according to TerraNova: “We are going to make losses here for ten years just to become circular.”

Lastly, the interviews revealed some technological barriers, the first one attributable to a level of quality that is sacrificed when switching to a new, circular material: “I do want a sustainable material, but only if it can meet the same quality requirements as the material I have now” (BlueCycle), which cannot yet be guaranteed: “you simply have a certain quality standard at this point. And the alternatives are not quite there yet.” (GreenStar) And as had already been stated, the desired materials are often not yet available at a price that the customer is willing to pay for. Next, product designability is occasionally beyond control of manufacturers, making it difficult to implement circular changes, which is also related to the institutional barriers. “We produce design from our customers (...) we do not have a determining voice”, state InnoFabb. And of product types that a company produces, it can also be said that a circular equivalent simply cannot be designed “because we don't have a consumable product.” (EcoLine). And: “because if you make a sheet metal part, what can you do to make it circular?” (TerraNova)

Regarding large-scale demonstration projects to test the (up)scalability of the use of circular materials, GreenStar pose that it is difficult to implement changes, “because the primary sector is continuing to shrink and you need the primary sector to implement innovations.” And before one is able to implement those changes, “you have to test that locally in the region before you take it worldwide.” And in addition, GreenStar states that “my innovation process is long. The costs are therefore high, but my risk is also very high if it is wrong.”

The final technological barrier found in Noord-Limburg is related to the lack of data (on the impacts) of certain circular practices. “As far as I know, there are few mature calculation models that simply

indicate: yes, if I turn that button here now, it will have this positive effect at the end of a product's life, for example.” (TerraNova)

“If you say: I am now going to use refurbished steel and it will rust away after two years, am I being sustainable, yes or no? Or do I now have virgin steel that is being processed and will therefore last twenty years? So it is often: how do you determine what is sustainable? And then it seems as if you say I have a sustainable product, but you are actually not working sustainably as an organisation.” (GreenStar)

CircoCraft adds to this the fact that CE is all still in its infancy, which “makes you more reserved when it comes to improving (...) making your product circular.” All this can thus be summarised as BlueCycle do: “it is a real challenge to actually achieve a circular economy.”

4.3. Drivers to CE

Building on the barriers discussed in the previous paragraph, this paragraph shifts focus to the drivers that promote CE integration within Noord-Limburg’s manufacturing industry. They provide valuable insight into the forces enabling progress toward circular practices, offering a counterbalance to the challenges previously highlighted. Like the barriers, the drivers are organised into the same categories, reflecting the diverse factors influencing CE adoption. By examining these drivers, this section underscores the range of opportunities for enhancing CE strategies, addressing barriers, and leveraging positive momentum within the region’s manufacturing sector.

The findings reveal a range of drivers that actively facilitate CE practices integration. Cultural and social factors were highlighted, starting with the culture within the manufacturing companies themselves. Intrinsic motivation has proven to be a very dominant factor in this. “We do it because we think it is important and we see that as the only way, also for the future, for ourselves and for the world.” (EcoLine) “... for myself, that is the future. The future of my children is also that.” (InnoFabb) “We can't continue like this as a company, as the Netherlands, as the world. So something has to happen. And I think you should not only look at each other, but you should also do better yourself.” (GreenStar) “I want to go along with it. I have children, I certainly want for the future that the children have a nice world.” (RenewTech) “Stubbornly doing it because you believe as a company that you just have to do it. (...) there is a very strong culture of looking for more circularity and more environmental awareness.” (BlueCycle) “Whatever legislation does, we move forward. So we want to be and remain a frontrunner.” (EcoLine) “We are doing it because we think it is good. And if that motivation isn't there, things won't get going.” (InnoFabb)

This goes hand-in-hand with leadership and employee involvement. If the top does not see circularity as important, things do not get off the ground: “So here the management is fully convinced and fully of the opinion that we should be working on this every day. If we don't think so, then it will not fly.” (EcoLine) According to BlueCycle, a leader can convince people if telling a good story to go along with that train of thought more, resulting in “very interesting ideas coming from the floor, where people really think for themselves: hey, this is a waste, can't we do it differently and can't we reuse this in a certain way?” For RenewTech, their relatively young company contributes to their CE efforts, because “you can also see here that young people really think more about the future, and that is a different mindset anyway”. This also applies to InnoFabb, where the younger generation is “really concerned

with their own future and with the next generations. So I notice a drive to be able to do something with that. And because we have a fairly young team, that also happens quite naturally.” And these correlate, creating an upwards spiral: “We also attract a lot of young people. Not because we are the most sustainable company, but because they see that it is a company that pays attention to that.” (BlueCycle)

Knowledge dissemination both within and outside of the company and taking people along with it through building awareness is, in conjunction with intrinsic motivation and leadership, a massive cultural enabler for the companies, enabling them to convince and take along employees, customers and suppliers, and therefore to really make an impact on CE. At EcoLine, five years ago not everyone understood the seriousness of sustainability, but through “keep coming back to it and not just explain once, explain ten times why we think this is important” it has landed throughout the company nowadays. CircoCraft acknowledge that “you have to create demand, so people have to see it in their own interest”, so they invite people in-house to “let people come here and let people experience what it [the possibilities] is. (...) We believe in this concept. Green business is good business.” And InnoFabb attempt to inform and encourage people through knowledge dissemination to make more circular choices, by “at the moment that only virgin is requested, we offer a recycled grade that is comparable to standard, and also make that image in which you will make it very clearly visible [why the recycled grade is the preferred one].”

Next to these in-house drivers related to the culture of the company, the interviews revealed cultural/social drivers coming from outside company boundaries. Because just like within the company itself, a certain mindset towards circularity among customers and consumers is desired. To some extent, this has proven to be the case, which for InnoFabb even has led to a project in collaboration with, and initiated by, one of their customers: “our customers are our driving force. The owners are (...) driven by the desire to put the most sustainable high chair on the market.” For InnoFabb, it really helps for their own circularity ambitions “... that our suppliers and parties are working on it, that our customers are asking for it, that consumers are asking for it.” And since as a company you are always dependent on your value chain, as shown previously, companies really need the same mindset from their value chain. “You see, if more and more customers ask for it, you will naturally put more emphasis on it” (BlueCycle) And “now I see it slowly going in the right direction again. Also because there is more demand from the market, which is finding this increasingly important” (CircoCraft) and “the world has also become somewhat critical in recent years. (...) you can see that it is changing.” (EcoLine)

“People who are having children now (...) They have a very different outlook on life than the generation that already has adult children, so they do look at products that are produced in a certain way. (...) So we do notice that the demand from the market is also coming.” (InnoFabb)

Next to this growing consumer awareness and interest, the willingness to cooperate throughout the value chain is slowly expanding. InnoFabb experience a group of suppliers that themselves are highly ambitious regarding CE, helping InnoFabb significantly with their ambitions. When knocking on their door with: “listen, this is a virgin material, do you have a sustainable alternative that at least has about the same specifications? Well, we only have to ask them.” GreenStar, too, notices that because customers want it, it becomes easier for themselves to advance, and the same applies to CircoCraft: “We happen to be working on two projects right now with external suppliers who [normally] simply supply us with new products, and who have responded positively to also include reused units in their

process.” Lastly, InnoFabb have a partnership with the designer and the material supplier where an end-of-life product “comes back to us and we take it apart, and ultimately it goes back to the raw material supplier who can also return it to basic raw material. So that you really close the loop there.” These drivers are strongly market-related, on which will be elaborated further on.

Next to cultural/social drivers, the interviews uncovered driving forces of regulatory and institutional nature. GreenStar indicate that it is increasingly demanded from higher powers that companies act upon issues like waste separation: “it is also instilled in us by the government.” Although no concrete laws and regulations exist in this regard yet, as the previous paragraph showed, respondents expect that those will be introduced. EcoLine therefore applauds it when more legislation is getting introduced regarding circularity. “The legislator is going to enforce it and I think that is the only way to really get it shaped quickly enough.” (TerraNova) This eventually growing governmental pressure serves as a driver, for example from InnoFabb’s perspective: “people know and feel that regulations will change and therefore they are already preparing for this. I think now in 70% of the cases when something is requested, an alternative is requested; a recycled material”, indicating that upcoming laws and regulations are imminent and anticipating this in turn will guide companies in the right direction already. “If you don’t fix it from what is legally required, then you’re done for”, summarise TerraNova.

In addition, the CSRD is regarded by some companies as a proper regulatory/institutional driver. EcoLine e.g., are annoyed by the fact that “any company can participate [in the battle for a tender], regardless of whether you meet those sustainability criteria”. But due to CSRD transparency, it will become possible to judge companies not solely on their price: “When you are not going to add sustainability criteria from a government, what are you still doing in this era? So I think that is a good thing and the CSRD will also help with that.” And BlueCycle names a more pragmatic advantage of the obligation CSRD imposes: “insight is the first step to actually doing something.”

Institutional shifts that some respondents unveil are beneficial to the region’s circularity performances. Formerly, RenewTech operated in a much more turnover-oriented market, while today it goes more often like: “all right, no. Let’s disassemble and look what parts we need to replace and only then go back to the customer. Without playing games.” CircoCraft, too, notices a positive societal mindset shift: “What comes out of school and what flows in here [the younger generation] ... they find it quite normal [sustainability or circularity] rather than really innovative.” It is those institutional shifts in train of thought that naturally fosters CE. Another institutional driver is the “continuity of the company.” (GreenStar) Considering all the developments regarding legislation and institutions the respondents mention, as a company you will have to keep up with these developments to maintain “raison d’être” (EcoLine), because “you want to still be there in forty years” (GreenStar), compelling companies to move with the times and invest in the CE.

Subsequently, the interviews also pointed out other market/economy-related drivers. When quoting their Service-and-Spare-Parts department, GreenStar informed that they made this choice particularly because of the financial profitability of it: “Service and Spare Parts are more profitable than new products.” More manufacturers share this opinion: “reusing materials is simply very financially attractive for the company” (CircoCraft); “I even think to a large extent that circularity is very interesting if you look purely at profitability.” (TerraNova) InnoFabb also recognises this among customers, stating that they “don’t always have the right motivation to want to be green or to want to be circular (...) more because they think they can sell more. So that the reasons behind circularity are

actually commercial again.” But, as has been highlighted in the literature, the economic benefits of a CE can indeed serve as important drivers.

The increased attention CE is getting worldwide is visibly creating “new markets, new opportunities” (GreenStar). Moreover, GreenStar benefit from the fact that they are market leaders, meaning that “you are always being watched. What are you doing? Are you being sustainable? Are you innovative? So there are opportunities there.” “Green business is good business (...) It's just a profitable concept”, sum up CircoCraft. A final market/economy-related driver discovered actually concerns with what was seen earlier as a barrier, namely the price difference between virgin and non-virgin materials. Since companies and market participants still opt for virgin materials, it is inevitable that this consumption of finite resources (see Chapter 2) leads to scarcity, and therefore (through natural market forces) to a price increase: “if the availability of raw materials is hampered, this will affect [their] costs.” (HorizonWorks) And it is precisely here that opportunities arise: “I also think that you have to look at opportunities like: how can I take steps to anticipate possible scarcity in the long term? (...) the opportunities that hereby arise in the market.” (GreenStar)

Lastly, the interviews revealed technological drivers, the first one being about the ability to deliver high quality products with a circular edge. For some respondents, the presence of appropriate technology underlies this: “If things have to be thought up from technology to improve everything [CE-wise], then the creativity and the capacity are there”, say TerraNova. The same applies to CircoCraft: “Have you seen the R&D campus? If you thought this [building] was big, R&D is even bigger. Yes, so we really do have the knowledge in-house.” For others, this is being ascribed to a quality product that lasts a relatively long time. “Look, a lot of people come to us because we have a product that can last 20, 30 years. And not to a competitor whose product falls apart after ten years.” (GreenStar) And “our products exist for 30, 40 years. You can simply redeploy them again after that, because they are so solidly made that they hardly wear out.” (EcoLine)

Furthermore, CircoCraft notice the circular designability of their products, stating that “the design that is there, is already reasonably good for circularity. We simply build solid products that lend themselves perfectly to reuse”, arguing that for a contemporary product to become more circular, it is not necessarily required for product designs to change rigorously. CircoCraft continues with “what we do have an advantage with is that our technology that we are introducing in this [Circular Economy Manufacturing] line has already been introduced in the [regular] new construction line.” (CircoCraft), making it easier and risk-free to probe and demonstrate on larger scales, even as to assess the ecological impact of such product transitions, eliminating what previously might have been considered barriers.

4.4. The manufacturing industry of Noord-Limburg: an analysis

The manufacturing industry in Noord-Limburg demonstrates a unique landscape shaped by a combination of internal practices and external influences, as captured through the lenses of CE integration, barriers, and drivers. This concluding paragraph synthesises the previous paragraphs' findings, offering a comprehensive analysis of CE integration within the manufacturing industry of Noord-Limburg. Here, the distinction between internal and external aspects of CE integration becomes notable. While internal aspects, like the adoption of the 10 R-imperatives and the alignment to CSRD requirements, reveal the degree of CE integration, external barriers and drivers illustrate the broader systemic forces shaping this. This analysis bridges these internal and external dimensions, identifying

key patterns, interdependencies, and areas for intervention. By synthesising these findings, a clearer picture emerges of the regional industry's overall readiness and potential for circular transformation. By drawing these elements together, this paragraph provides a nuanced understanding of the challenges and opportunities facing the region's manufacturing industry on its journey towards circularity and lays the foundation for answering the research questions of this study.

Building on the conceptual model, this section analyses how the external context shapes the extent to which manufacturing companies in Noord-Limburg integrate CE principles internally. It is here where the sub-questions are answered, to ultimately answer the main research question in the final chapter. The interpretation of the findings is grounded in the theoretical pillars of CE, including the R-imperatives framework, the emerging regulatory influence of the CSRD and the factors affecting CE integration. The analysis will first answer the two first sub-questions.

1. *Which, and to what extent have, R-imperatives been adopted by manufacturing companies in Noord-Limburg?*
2. *What is the level of alignment between manufacturing companies in Noord-Limburg and the CSRD regarding 'resource use and circular economy'?*

The findings illustrate that while manufacturers actively engage in circular practices along various stages of the R-imperatives framework (Potting et al., 2017), these remain largely fragmented, operational, and informal rather than formal and company-wide. This aligns with literature, suggesting that CE adoption in organisations often lacks strategic embedding and is instead driven by ad-hoc opportunities or short-term operational gains (Ritzen & Sandström, 2017; Kirchherr et al., 2018). Although aligning with various R-imperatives, CE implementation is shaped by internal knowledge, company culture, technical capacity, and to a lesser extent, formalised policies. This section therefore focuses on internally anchored CE practices, before the next sections shift to the external environment influencing CE integration.

The data show strong uptake of mid-ladder R-imperatives, often motivated by production efficiency, cost savings, or customer demand. For example, actions like design simplification (GreenStar), use of recycled material (InnoFabb), or waste minimisation (EcoLine) are clearly tied to operational drivers. However, higher-order R-strategies were less frequently mentioned, confirming academic claims that these strategies are more complex and are often hindered by technical or economic feasibility (Reike et al., 2018). The variation in adoption levels between firms echoes the idea that internal capabilities, like sustainability-oriented leadership, technical expertise, and long-term vision, play a decisive role in shaping CE integration (Linder & Williander, 2015). EcoLine and BlueCycle, for instance, demonstrate that having a proactive mindset and some degree of internal structure facilitates the development of higher CE maturity.

CSRD awareness was found to be high among all respondents, yet levels of alignment to its ESRS E5 standard varied significantly, ranging from informal discussions to structured data collection. This supports claims that while external (regulatory) pressures can act as triggers for CE adoption (Bocken et al., 2016), internal readiness determines the depth and speed of integration. The CSRD appears to function as both a driver (stimulating documentation, awareness, and planning) and a barrier (administrative burden and ambiguity), confirming findings by De Jesus and Mendonça (2018) regarding regulations' dual nature. Although most companies show high insight into their material flows, this awareness is not yet systematically translated into formal policies, targets, or action plans

as the CSRD prescribes. This reflects a key tension in CE transitions: the gap between knowing and doing (Rizos et al., 2015).

Many firms operate under informal sustainability principles but lack formalisation, which is essential for long-term strategic alignment and measurable outcomes. The CSRD has clearly influenced internal awareness of resource flows. Most companies claim to have a good overview of their key material inputs and waste streams. As BlueCycle puts it, "insight is the first step to actually doing something", highlighting how regulatory frameworks can serve as a bridge between external pressures and internal action. Nonetheless, companies like EcoLine and RenewTech admit that, despite having rich internal data, it is often used for operational optimisation rather than environmental gains, again showing the internal framing of CE as cost-efficiency.

When it comes to the policies, targets and action plans required under ESRS E5, a more nuanced picture emerges. While many firms already act in ways that reduce resource use or increase circularity, these internal practices are often not formalised. Policies are frequently embedded in informal routines or internal communications rather than public-facing documents. EcoLine, for example, refers to purchasing and sustainability plans but hesitates to label them as 'policy'. InnoFabb admit that their sustainable practices are habitual rather than documented. This lack of textual policy articulation may also stem from companies' pragmatic culture and limited resources, as suggested by EcoLine and CircoCraft.

Targets are more common than policies. They lend themselves more easily to concrete, measurable outcomes. GreenStar and HorizonWorks set numeric goals for waste reduction and material efficiency. InnoFabb has clear internal targets for increasing recycled material use. However, these are often internally motivated and not necessarily framed within the CSRD's conceptual structure or linked to CE explicitly. TerraNova even describes circular targets as embedded within broader profit-maximisation goals, showing how CE practices can be internally justified through economic rather than environmental logic.

As the literature suggests, metrics and KPIs are crucial for monitoring and steering circular progress (Martinetti & Havas, 2021), and their absence or informality risks reducing CE to opportunistic or reactive behaviour. Similarly, action plans are the least developed component and were only described by a few companies, reinforcing that operational CE activities often lack strategic planning and institutionalisation. Although companies like GreenStar and BlueCycle mention team-led process improvements and material substitution projects, these initiatives are not always tied to formal goals. They stem from internal initiatives rather than strategic compliance with ESRS E5. Thus, while internal CE engagement exists across R-imperatives and aligns partly with CSRD principles, companies remain in a transition phase from informal, internally motivated action to externally aligned, formalised reporting and strategy.

In sum, the internal CE integration in the region reveals a landscape of emerging, but fragmented practices, where operational circularity efforts are increasingly visible across R-strategies but often lack formalisation, cohesion, and strategic anchoring. This highlights how CE integration is largely an internal, operational matter for companies, shaped by production efficiency, material use, and company culture. The R-imperatives serve as a practical lens to map current efforts, yet also expose a tendency to focus on short-term, lower-hierarchy strategies with tangible economic benefits, and not embedded within formal strategies or policies. Nonetheless, increasing awareness of external

requirements is gradually nudging these practices toward more structured, formalised strategies that can also satisfy regulatory and market expectations. The CSRD appears as a pivotal external trigger, nudging companies toward greater transparency and planning, yet its potential to drive transformation is moderated by internal capacity, perceived administrative burdens, and the gap between insight and implementation. These findings indicate a transitional phase of CE integration, with companies advancing from awareness to action but remain in need of strategic cohesion and alignment. Bridging the gap between informal, pragmatic sustainability efforts and formal, policy-oriented CE integration, particularly in light of the CSRD, is crucial for companies to mature in their circular ambitions and contribute meaningfully to systemic change. This underscores the significance of both barriers and drivers, setting the stage for the next section which explores these external dynamics more thoroughly.

3. Which internal barriers and drivers play a role in shaping CE integration within manufacturing companies in Noord-Limburg?

Through thematic analysis, the findings confirm the theoretical assumption that barriers are multifaceted, intersecting across multiple levels. This analysis critically interprets the empirical data, situating these barriers within the wider context of CE adoption. In contrast to the internal practices discussed above, the barriers to CE integration within the manufacturing industry encompass both internal barriers and external ones arising from broader systemic factors. Understanding these barriers is vital for developing effective strategies to address them and promote sustainable practices in the regional industry.

Internally, a key barrier identified is the cultural resistance to change. Many companies have embedded mindsets, prioritising traditional linear models over CE principles. This resistance is often compounded by a lack of awareness and understanding of CE concepts among management and the organisational workforce. This cultural lock-in is further supported by the success and stability perceived in existing linear business models, prompting questions like, "Why change when things are going well?" Despite growing awareness and occasional engagement with CE principles, companies frequently encounter internal challenges in transitioning to holistic circular strategies. While companies like GreenStar and HorizonWorks exercise specific CE practices (waste reduction and material efficiency), these are predominantly driven by immediate economic benefits rather than long-term environmental goals. This operational focus underscores a common challenge: the tendency to prioritise short-term gains over strategic, systemic changes necessary for full CE integration (Ritzen & Sandström, 2017).

Moreover, the absence of formalised CE policies and clear targets reflects a broader issue of internal readiness and capacity. Many companies operate with informal sustainability principles in routine practices rather than structured, documented strategies. This lack of formalisation obstructs the (up)scalability and replicability of CE efforts, preventing companies from achieving higher levels of circular maturity (Kirchherr et al., 2018). Also, the age composition within these companies plays a crucial role, with the "old guard" mentality often displaying conservative attitudes towards sustainability initiatives. This demographic factor contributes to a slower uptake of CE practices, as acknowledged by respondents, who noted that cultural shifts towards circularity are challenging and require collaborative efforts to overcome 'linear' mindsets. The prevailing cultural norms within these organisations emphasise on profit maximisation rather than waste minimisation or circularity, as expressed by TerraNova: "Let's be honest, the culture is more like: how can we earn as much money as possible instead of: how can we produce as little waste as possible or be as circular as possible?"

Analysing the internal drivers reveals the significant role of intrinsic motivation, leadership commitment and organisational culture. At the centre of the manufacturers' commitment to CE lies a strong intrinsic motivation, with several companies describing sustainability/circularity as a personal belief or moral duty, often tied to intergenerational concerns: "We do it because we think it is important and we see that as the only way, also for the future, for ourselves and for the world." This aligns with broader literature seeing intrinsic values and environmental stewardship as essential motivators for CE adoption (Rizos et al., 2016; Kirchherr et al., 2018). Intrinsic motivation was complemented by active leadership engagement and employee participation, with EcoLine underscoring proactive leadership in shaping organisational values and fostering a culture of sustainability. A sense of responsibility, rooted in personal beliefs about the future, emerged as a driver for CE practices, with employees being encouraged to contribute ideas. This finding aligns with prior research, acknowledging the importance of leadership commitment and a strong internal culture in facilitating organisational change towards sustainability (Bocken et al., 2016).

Furthermore, several respondents stated the importance of knowledge dissemination and awareness-building as a mechanism to drive CE understanding and action. For instance, EcoLine adopted a strategy of consistent internal communication, and CircoCraft emphasised the importance of educating stakeholders and creating awareness about the benefits of CE. This aligns with Korhonen et al.'s (2018) assertion that knowledge transfer and social learning are critical for a CE transition, emphasising the role of leadership to inspire, leading to bottom-up initiatives that enhance CE practices: "Very interesting ideas coming from the floor." Moreover, the active involvement of younger generations in companies like InnoFabb and BlueCycle gives fresh perspectives and dynamism, contributing to a more sustainable mindset across the workforce: "you can also see here that young people really think more about the future, and that is a different mindset anyway."

Internally, the findings reveal a technological driver, too, with companies emphasising their internal R&D capabilities in product design and manufacturing processes as enabler: "If things have to be thought up from technology to improve everything [CE-wise], then the creativity and the capacity are there." Others pointed to long product lifespans as inherent technological advantages, stating that their quality products can last a very long time. This demonstrates that design for longevity and modularity, the imperatives of CE design, are already embedded, even prior to formal CE adoption.

4. How do external barriers hinder CE integration within manufacturing companies in Noord-Limburg?

The external barriers, positioned outside the immediate control of companies in the conceptual model, were found to exert a significant influence on the internal CE integration, intersecting across every level from Kirchherr et al.' (2018) categorisation. Cultural and social barriers extend beyond organisational boundaries to encompass customer attitudes and consumer demands. Respondents highlighted the lack of consumer demand for circular products. For instance, TerraNova and CircoCraft noted that customer preferences often favour new materials over recycled or circular options due to perceived cost advantages and familiarity. This preference poses a challenge as the companies strive to align their offerings with CE principles but face resistance from customer/consumer demands prioritising traditional products over sustainable alternatives. This external barrier reinforces internal cultural resistance, as companies struggle to justify investing in circular practices without sufficient supply chain incentives or consumer support.

Moreover, external supply-chain dependencies complicate CE efforts. Respondents emphasise their limited influence in supply chains, where decisions by end-customers dictate material choices. This restricts their ability to adopt circular practices when customers opt for non-circular alternatives. This reinforces a linear approach to production/consumption, undermining efforts towards circularity. Consumer behaviour poses another substantial barrier, with the general lack of awareness among consumers/society regarding the benefits of circular products results in minimal demand. This cultural inertia towards traditional consumption patterns further hinders the adoption of CE practices, as there is no prevailing cultural norm where returning products or favouring recycled materials is not commonplace.

The regulatory and institutional landscape, too, inflicts barriers to CE adoption, compounded by (international) variations in laws and regulations. Companies mentioned the challenges of navigating contrasting regulatory frameworks across global markets, which often conflict with local sustainability goals. This regulatory fragmentation not only increases compliance costs but also limits the flexibility to adopt innovative CE practices (as companies are at risk to be priced out of the market) and therefore incentivises practices that are less environmentally friendly, indicating a lack of cohesive regulatory support for CE ("governments have yet to take a strong stand").

Beyond international barriers, companies struggle with the burden of complying with multiple conflicting rules within their operational contexts. The restrictive use of recycled materials in their industries due to regulatory constraints is mentioned, and InnoFabb provides an agitating example of how incomplete or misleading regulations ("greenwashing") hinders CE efforts: "regulations do not regulate this properly, so we do the wrong things that have a certificate but that are actually not that green at all." The fact that some materials legally classified as "waste" cannot be reintegrated into production cycles due to regulatory hurdles proves the conflict between circular innovation and traditional regulatory frameworks. Without clear regulations, companies are left uncertain about compliance and reluctant to invest in new, unproven/untested technologies, establishing an entry barrier for firms unwilling to accept regulatory risk or ambiguous legal landscapes, thus stalling broader adoption of CE principles.

Institutional barriers also include the lack of supportive policies and procurement that incentivise CE adoption. GreenStar laments that Dutch governmental policies favour shrinking primary sectors over fostering innovation, which threatens their ability to test and implement CE innovations locally. This lack of top-down circular procurement also limits the availability of sustainable materials, making it difficult to source appropriate, standardised materials for circularity. This institutional gap obstructs internal CE integration by restricting access to sustainable inputs and deterring investments in CE innovations that may not conform to conventional procurement practices.

The CSRD, while acting as a driver to enhance transparency and accountability, also presents challenges. Adhering to CSRD mandates entails administrative challenges and ambiguities, particularly for the smaller companies without the means to manage intricate regulatory environments (De Jesus & Mendonça, 2018). These regulatory barriers are closely connected to the theoretical framework, which highlights how institutional pressures and regulatory contexts influence organisational behaviour. Based on the theory suggesting that organisations adapt to external institutional pressures to retain legitimacy, it becomes evident that the lack of regulatory harmonisation hinders the implementation of CE practices, as companies are restricted by regulations that prioritise economic efficiency over environmental sustainability.

Economic factors significantly hinder CE adoption, with market dynamics and cost considerations playing a big role in the region. The lack of market standards and price differences between virgin and non-virgin materials were identified as major barriers. Companies like InnoFabb and TerraNova cited competitive pressures and consumer price sensitivity as factors driving decisions towards conventional, virgin materials instead of circular materials, reinforcing Kirchherr et al.'s (2018) notion of a linear lock-in, a trend echoed across multiple interviews, suggesting that the economic barrier is region-wide. This bolsters a market environment where sustainable choices are economically disadvantageous, reinforcing the status quo of linear production models, underscoring the interconnectedness between consumer behaviour (social barrier) and market forces (economic barrier). Market competition intensifies this. In a price-sensitive environment, the manufacturers in Noord-Limburg struggle to justify higher costs associated with circular products. This dynamic perpetuates a cycle where cost considerations outweigh environmental benefits, again reinforcing traditional, cheaper, linear practices over circular alternatives (Kirchherr et al., 2018).

The interviews highlighted significant (short-term) investment costs and uncertain economic viability (perceived financial risks) associated with implementing circular innovations (Rizos et al., 2016; Kirchherr et al., 2018). This financial burden discourages companies to embrace CE principles, despite long-term sustainability benefits. This corresponds with literature on sustainability transitions proving the importance of financial viability in driving organisational change (Geels et al., 2017) and the need for supportive policies and financial incentives to mitigate these economic barriers.

Another prominent market barrier is the lack of standardisation and certification for CE practices. InnoFabb highlighted the ambiguity in the market due to inconsistent standards. This lack of clarity undermines the credibility of companies' CE efforts, and contributes to uncertainty and hindering the broader adoption, as consumer reluctance to pay premiums for circular products remains. RenewTech recited this, emphasising the need for clearer definitions and rigorous standards to ensure accountability in circular entrepreneurship, a concern that aligns with De Jesus and Mendonça (2018), who stress the importance of enabling financial mechanisms in CE transitions. This external pressure reinforces a cycle where sustainability considerations take a backseat to market demands and economic pressures: if the consumer is not willing to pay for circularity/sustainability, the cheaper options prevail, stressing a fundamental tension between economic viability and environmental sustainability (Bocken et al., 2016).

Technological barriers primarily revolve around material quality and product design flexibility and the availability/suitability of technologies that support circular business models. Quality standards (performance consistency) and material compatibility proved to be critical concerns, as highlighted by BlueCycle and GreenStar, who emphasised the challenge of maintaining product quality while integrating (and sourcing prior to that) recycled materials while at the same time not losing consumer acceptance and regulatory requirements (“you simply have a certain quality standard at this point. And the alternatives are not quite there yet”), reflecting a broader challenge in adapting existing production processes to circular design principles. Furthermore, limitations in designability and the absence of scalable solutions were seen as barriers. This lack of autonomy limits the implementation of circular design principles, as companies are often constrained by existing product specifications and customer decisions. Moreover, the lack of impact assessment tools and standardised metrics for assessing the environmental impact of circular practices further complicates things. Without such metrics, evaluating the true circularity of product choices remains ambiguous, hindering investment in

sustainable technologies and undermining companies' efforts to quantify and communicate the benefits of circular initiatives, emphasising the role of technological innovation in driving sustainable transitions (Geels et al., 2017).

The intersection of internal and external barriers reveals a complex landscape where organisational culture, regulatory pressures, market dynamics and technological constraints converge to shape CE integration efforts. While internal barriers like cultural inertia and resource limitations hinder strategic alignment and formalisation of CE practices, external factors like regulatory frameworks and supply chain dynamics impose additional constraints and even enlarge internal ones. Notably, while most of these barriers are external to the firm, their effects cascade inward, shaping strategic decisions and company mindset, leadership behaviour, and the scope of CE initiatives in the future. In this sense, the findings validate the conceptual model's assumption that external barriers exert a constraining force on internal CE integration. Conversely, several external drivers are helping the manufacturers in Noord-Limburg to counterbalance (and overcome) these barriers.

5. How do external drivers positively influence CE integration among manufacturing companies in Noord-Limburg?

Cultural and social drivers extend beyond company boundaries, too, with changing broader societal attitudes and expectations facilitating sustainability/circularity. Growing awareness and an increase in CE-related demand, particularly among customers and consumers, was seen as a supportive force, stimulated by a shifting broader societal mindset towards sustainability. Respondents noted that consumer preferences increasingly favour sustainability, thereby reinforcing CE efforts, with this external cultural support often translated into supply chain collaborations. Companies such as InnoFabb and CircoCraft note that consumer preferences for eco-friendly products have positively influenced their CE strategies, with InnoFabb's collaborations with customers focused on sustainable products supporting the variable of internal CE integration, where companies adapt their operations to meet external expectations. Companies thus perceive CE not only as a regulatory requirement but also as a means to align with societal expectations and maintain "continuity of the company". These findings demonstrate how external cultural trends can amplify internal motivation, and internal CE integration eventually.

External stakeholders are vital in driving CE integration through their expectations and behaviours. Manufacturers in Noord-Limburg highlight the importance of aligning with stakeholders that resonate with their dedication to sustainability: "our customers are our driving force." Several firms mention being "invited" or "encouraged" to join CE initiatives by suppliers or clients, which enhances resilience and promotes circularity across supply chains, supporting the conceptual model's emphasis on external drivers and the interplay with internal CE integration, and reflects the literature's view of value chain interdependencies and shared responsibility as crucial to CE transitions (Geissdoerfer et al., 2017; Ritzèn & Sandström, 2017).

External drivers also include regulatory pressures and policy frameworks incentivising or even mandate CE practices. The respondents highlight the anticipation of stricter regulations, particularly around waste management and material circularity, as a primary incentive. They view the anticipated tightening of regulations as a driver to innovate and prepare for the future ("The legislator is going to enforce it and I think that is the only way to really get it shaped quickly enough"). This underlines the idea that soft law and institutional foresight can be crucial factors influencing CE adoption (De Jesus & Mendonça, 2018), supporting Kirchherr et al.'s (2018) claim that regulatory pressure can act as both a

barrier and a driver, as it can trigger companies to respond proactively (instead of reactively) to regulation, amplifying companies' strategic orientation and mindset.

The CSRD is identified as an essential regulatory driver, improving transparency and accountability in companies' sustainability efforts. Many respondents acknowledge the potential of CSRD to enhance CE integration, emphasising the significance of regulatory adherence in fostering internal shifts towards sustainable practices. The CSRD is believed by the respondents to further incentivise companies to enhance their sustainability practices, since "insight is the first step to actually doing something."

Institutional shifts highlight a broader societal movement towards sustainability. RenewTech and CircoCraft illustrate how changing societal norms (younger generations) and institutional expectations, particularly choosing longer-term sustainability over short-term profitability, are increasingly shaping CE, making sustainable practices a norm rather than an exception. This is consistent with the institutional theory (DiMaggio & Powell, 1983), and reflects the authors' view that organisations often adopt practices not only in response to legal requirements but also to align with evolving institutional norms to maintain "raison d'être". This reinforces CE as both a strategic and socially expected direction.

Market dynamics further accelerate CE adoption across Noord-Limburg's manufacturing industry, and external economic incentives are crucial in promoting this. The growing recognition of circularity as a profitable business strategy is evident across the region. For many companies, reusing materials is seen as not only an environmentally responsible choice but also a financially attractive option, which motivates manufacturers to operate more environmentally responsible: "circularity is very interesting if you look purely at profitability." This is being strengthened by (related to the changing societal attitudes) emerging market trends and consumer demand for sustainable options, with InnoFabb's collaboration with partners exemplifying how external market expectations drive internal innovation and differentiation towards a market for CE-aligned products and services that can provide companies with significant competitive advantages. Therefore, CE initiatives create new market opportunities and enhance market leadership ("new markets, new opportunities").

Furthermore, as companies begin to anticipate resource scarcity and rising costs, they view circular models as a way to secure long-term access to materials and reduce reliance on virgin resources, thereby positioning circularity as a form of risk mitigation: "if the availability of raw materials is hampered, this will affect costs." This reflects the notion of resource security as a long-term economic/market driver in the CE transition, with "green business is good business" as a strategic and financially attractive response to changing customer demands, economic incentives and market trends. This suggests that CE is becoming not only an ethical imperative but also a strategic business decision.

Technological capabilities enable manufacturing companies in Noord-Limburg to develop and implement CE solutions internally. TerraNova's and CircoCraft's emphasis on advanced technologies for product improvement and introduction demonstrates how external technological advancements drive internal operational efficiencies and product innovation. Companies like RenewTech and InnoFabb, for example, are able to take advantage of innovative technologies and design processes to maximise material reuse. This supports the internal CE integration by strengthening manufacturing adaptive capacity, optimising resource utilisation, and reducing environmental impact through innovative and sustainable technological solutions.

The intersection of internal and external drivers in Noord-Limburg's manufacturing sector underscores a dynamic interplay between company culture, social expectations, regulatory frameworks, market

dynamics and technological advancements that shapes the adoption and implementation of CE practices. Drivers enabling manufacturers to transition to a CE from the inside, such as intrinsic motivations and organisational culture, are often triggered or expanded by external pressures like consumer demand, legislation and economic incentives, which can even further drive internal decisions to invest in CE practices in the future. In this sense, the findings validate the conceptual model's assumption that external drivers exert a promoting force on internal CE integration. These findings set the stage for the concluding discussion on how firms can leverage these dynamics (to overcome the barriers) in the CE transition.

5. Conclusion and discussion

5.1. Conclusions

The study's main objective is to contribute to the knowledge and practical understanding around the CE concept by examining how external factors influence the level of internal CE integration within manufacturing companies in Noord-Limburg, the Netherlands. The main research question of this study was:

HOW DO EXTERNAL FACTORS, SPECIFICALLY EXTERNAL BARRIERS AND DRIVERS TO CIRCULAR ECONOMY (CE), INTERNALLY INFLUENCE THE LEVEL OF CE INTEGRATION WITHIN MANUFACTURING COMPANIES IN NOORD-LIMBURG, THE NETHERLANDS?

The thematic analysis of the interview data shows that external factors have a substantial and complex influence on how thoroughly CE practices are integrated into manufacturing companies in Noord-Limburg. This influence is both direct and indirect, with external factors both constraining and catalysing internal CE practices, and shaping internal organisational behaviour, strategic decisions, and the practical implications of CE initiatives. These findings substantiate the theoretical assumption underpinning the conceptual model that the external variables apply a direct and formative influence on how CE is internally perceived, prioritised and operationalised by manufacturing companies in Noord-Limburg. This interplay lies at the heart of CE transition and could offer valuable theoretical and practical insights into how manufacturing companies navigate through their circular ambitions.

External barriers evidently restrict manufacturing companies, as they interact with internal operations, capabilities and mindset in ways often impeding CE integration. These barriers do not operate independently. They reinforce one another and are deeply embedded in larger systemic structures. Social and cultural barriers, including consumer's price sensitivity and limited willingness to pay for sustainable products, limit the short-term viability of CE initiatives, which internally translates into conservative mindsets, limited innovation and an operational focus on efficiency over sustainability. This is a continuation of linear models whereby consumer behaviour directly influences strategic decisions and organisational culture. Regulatory fragmentation was also found to be a major obstacle, particularly due to inconsistent and ambiguous legislation. These findings align with De Jesus and Mendonça (2018), underlining the disruptive impact of uncoordinated policy frameworks on CE transitions. The lack of harmonisation across regulations also makes it difficult for manufacturers to confidently invest in the CE transition. The result is a risk-averse attitude, slowing down internal CE progress and fostering a reliance on status quo (Rizos et al., 2016; Kirchherr et al., 2018). Other, market-related, barriers, such as resource availability and price disparities (virgin/non-virgin), further establishes a linear lock-in (Kirchherr et al., 2018), where economic rationality and competition (coupled with customer price sensitivity) internally discourages companies from CE strategies even when those are environmentally preferable to maintain legitimacy. Technological limitations, including a lack of scalable circular design and material quality inconsistencies, further complicate these issues, reinforcing internal doubts about feasibility and return-on-investment.

Importantly, these external barriers often enlarge existing internal frictions, as regulatory complexities increase resistance to change/innovate, and economic pressures strengthen risk-averse mindsets organisation-wide. Thus, these external barriers not only exist in parallel to internal ones, instead they reinforce them. They not only affect tangible operational elements (such as investment decisions and

manufacturing methods), but also intangible elements, including mindset, leadership engagement and strategic prioritisation. This relation confirms the conceptual model, which posits that external barriers constrain internal CE integration, not just directly but also indirectly by enlarging internal limitations.

Conversely, external drivers exert strong enabling forces that stimulate internal CE integration. The analysis finds that these can serve as powerful catalysts for change, particularly when they align with (or reinforce) internal motivations and capabilities. Cultural shifts in consumer expectations were found to be crucial drivers, and a growing societal awareness and demand for sustainability enhances the legitimacy of CE internally, too. When external stakeholders explicitly demand sustainable practices, companies are often incentivised or even pressured to align their internal business operations accordingly, embedding CE deeper into company identity and values. This aligns with Geissdoerfer et al., 2017, where external actors serve as stimulus for the adoption of CE principles by shaping shared goals and mutual benefits. While some regulatory aspects pose challenges, others stimulate proactivity. The anticipation of tightening legislation and the CSRD's focus on transparency encourages companies to adopt innovative strategies. This duality reflects Kirchherr et al.'s (2018) assertion that regulations can function as both driver and barriers, ultimately depending on organisational readiness and interpretive framing.

Market and economic trends are perhaps the most prolific and dynamic drivers. As circularity progressively becomes not only a societal norm and it is being regarded as a strategic opportunity instead of a cost, manufacturers begin to regard circularity as a viable business strategy. Several companies noted that CE can improve profitability by enhancing resource efficiency and brand positioning, and also new market opportunities and material risk mitigation were named as drivers. This is particularly evident in companies that have managed to link CE initiatives with value creation. As such, market forces are shifting internal mindsets from compliance to competitiveness, encouraging the strategic integration of CE. This validates the conceptual model, which proposed that external drivers do not solely co-exist with internal CE efforts, but accelerate and legitimise them as well in the same dynamics that external barriers do.

The findings underscore a crucial insight: internal CE integration is not simply a response to external factors as isolated determinants, but it is co-shaped through an interaction between external contextual factors and internal capacity. External barriers increase internal barriers, while external drivers initiate or reinforce internal transformations regarding CE. Manufacturing companies with a stronger internal sustainability culture, a more proactive leadership and the 'right' mindset are better positioned to convert external drivers into real opportunities. Conversely, manufacturing companies lacking internal awareness, knowledge or mindset are more vulnerable to the external barriers present, and are therefore less likely to benefit from similar supportive external conditions and ultimately translating them into progress regarding CE integration. Thus, the influence of external factors on internal CE integration is further mediated by internal barriers and drivers, suggesting that while external factors are powerful determinants, internal organisational characteristics help shape how these factors are interpreted and acted upon.

In conclusion, the study finds that external barriers exert a preventing influence on CE integration within manufacturing companies in Noord-Limburg, often revealing and magnifying existing organisational limitations to it, while external drivers exert a motivating force, particularly when they align with (and can reinforce) internal capabilities and social/cultural readiness. The interaction between these forces is not linear but dynamic and context-dependent, and is governed by how

companies interpret, prioritise and respond to the pressures and opportunities within their external environments. This confirms the central notion of the conceptual model, positing that internal CE integration is shaped through a co-evolutionary process, where external pressures and internal elements influence each other.

Understanding this interaction is key in setting in motion more effective CE transitions, both at the company level and in policy design. By bridging the (yet) often-separated discussions on internal and external determinants of sustainability transitions, new opportunities open up for academic exploration of the (co-evolution of) internal and external determinants of circularity. These insights contribute to and expand on the work of scholars like Bocken et al. (2016) and Ranta et al. (2018), who have emphasised the need for integrated frameworks in CE research that bridge organisation-level and systems-level perspectives. The findings also enhance the academic understanding of how circular transitions (in manufacturing) are not purely top-down regulatory matters, nor solely internally driven innovations; they are complex, iterative interactions between companies and their societal, institutional and economic environments. The study also underscores the value of a spatially and sectorally grounded understanding of circularity, revealing how regional dynamics not only influence CE integration, but also hold the key to design more context-specific strategies for both practice and contemporary research on CE.

5.2. Discussion

5.2.1. Reflections and limitations

This study aimed to bridge two commonly isolated bodies of literature: one focused on firm-level CE integration, and the other focused on system-level approaches outside companies, like regulation, market structures and cultural norms (e.g., Bocken et al., 2016; Ranta et al., 2018). The findings not only confirmed the importance of external factors in shaping CE integration, but also added nuance by showing how those factors interact with internal organisational determinants. This dynamic, co-creating understanding represents a key theoretical contribution of the study, but it is one that must be viewed within the boundaries and limitations of the research design.

The conceptual model developed for this study proved useful, in structuring the empirical investigation and in framing the interpretation of results. A central theoretical insight from the study is the reinforcing nature of external and internal barriers. Rather than treating external constraints and internal resistance as separate phenomena, the study shows how regulatory ambiguity, societal mindsets and market forces embed themselves within companies by shaping culture and priorities. The data showed that external barriers often do more than just slow down progress, they reproduce and expand internal barriers, revealing a more complex causality than is typically assumed. Yet, while the model offered a theoretically grounded and empirically supported perspective, it simplifies what are, in reality, highly complex and context-dependent relationships. The model does not fully capture the feedback loops or multi-level dynamics that shape CE transitions over time.

One surprising finding was the extent to which internal CE integration hinges not just on the presence of external drivers, but also on the internal readiness and preparedness to consume and act upon them. This supports and extends previous work by Ranta et al. (2018), who argued that organisation absorptive capacity is a mediating factor in CE integration. However, this study nuances that perspective, because it shows that readiness is not merely a matter of technical capability and resources, but is also strongly shaped by internal agency; mindset, leadership and cultural alignment

with CE-worthy values. While companies operate within structural limitations, they are not passive recipients of external pressure. Several firms in this study demonstrated proactive engagement, seeing external drivers as real opportunities rather than that they only react to them conveniently. In this regard, the study contributes to the strand of literature that seeks to humanise and contextualise CE integration, moving beyond the techno-economic focus that has dominated the field thus far.

Nonetheless, the study has limitations that must be acknowledged that temper the generalisability and scope of the conclusions. First, the sample was limited to manufacturing firms within a single region. While this focus allows for deep contextual insight, it also means that findings cannot be blindly extended to other sectors or geographic areas, restricting the external validity and the direct applicability to other regions. Second, the data collection relied on semi-structured interviews, which, although rich in qualitative detail, are essentially interpretive and subject to social desirability bias, both from the interviewees and the researcher. But efforts were made to ensure that through thematic coding and triangulation with relevant literature, adequate objective measurements of CE performance were found, neutralising the perspectives and framing of those interviewed. But a more mixed-methods design could have offered a complementary layer of empirical verification.

Additionally, the study examined CE integration as a relatively static phenomenon (a snapshot in time). Yet, many of the involved dynamics around regulatory change (e.g. the CSRD) and cultural shifts in market demand, are evolving. The cross-sectional nature of the study therefore limits the ability to capture temporal change, or learning trajectories. A longitudinal design could have enabled a more complete understanding of how external and internal factors change and interact overtime, and whether certain barriers eventually become drivers, or vice versa. Lastly, the focus on organisational-level perceptions and practices meant that broader stakeholder networks (supply chain partners, local public institutions/governments or civil society) were not directly addressed. Yet, these actors play a vital role in shaping the (external) environment of CE transitions. While this study's scope demanded a degree of narrowing down, future research could approach it from a more multi-actor point to better understand CE integration as a collective rather than purely organisational efforts.

5.2.2. Recommendations and future research

Based on the findings and reflections outlined above, several recommendations can be made for practitioners, policymakers and researchers seeking to accelerate effective CE integration in manufacturing industries, particularly within regional contexts like Noord-Limburg. For manufacturers, the study suggests that internal readiness plays an important mediating role in how externalities are interpreted and acted upon. Companies wishing to advance their CE ambitions should therefore invest, not only in technologies, but also in employee education, managing change and collaboration throughout the supply chain, thereby creating a culture that values experimentation and integrates sustainability into its core values. The role of leadership emerges as crucial. Companies with committed leaders are more likely to frame CE as an opportunity rather than a burden. Growing a shared CE-minded vision internally can significantly increase that organisation's capacity to respond effectively to, for example, emerging regulations and market signals. Companies should also note the value of cross-sector collaboration and regional alliances to create collective responses to common barriers such as limited access to circular infrastructure.

For policymakers, on the other hand, the key recommendation is to reduce regulatory incoherence and unclarity. Fragmented and inconsistent policies currently act as impediments to CE investments, particularly among SMEs. Additionally, governments should prioritise supportive infrastructure (like

financing mechanisms or knowledge hubs) that lower the operational risk of CE innovations. Policy design could also consider the role of perception/discourse. The results showed that how companies interpret external factors plays a significant role in deciding action. Communication strategies framing CE as a journey to competitiveness, resilience and innovation (rather than solely compliance or obligatory) may improve internal adoption and public engagement of the concept.

For the region of Noord-Limburg as an instance, including CE more prominently within its 'regional deal' framework could be vital for promoting CE integration. Noord-Limburg aims to "strengthen broad prosperity and well-being in the region and provide impetus to regional developments with a sustainable effect" (Noord-Limburg, 2025). Therefore, emphasising and facilitating cooperation and shared ambitions between "governments, entrepreneurs, knowledge institutions, social partners and residents" (Noord-Limburg, 2025) regarding circularity in the regional deal can enhance innovation and attractiveness in CE initiatives. Consequently, this could position Noord-Limburg as a leader in sustainable development, enabling these stakeholders to bolster collaborative efforts, align policies across municipalities and foster an environment beneficial for CE practices.

From an academic perspective, the results and conclusions open up several avenues for future research that can deepen, challenge and extend the findings presented here. Future research could focus on longitudinal dynamics, the role of intermediaries, mixed-method designs, and comparative studies. Academics could adopt longitudinal designs to examine how companies' internal CE integration evolve over time, since CE transitions are dynamic and unfold over time. In response to changing external conditions like regulatory developments, shifting consumer preferences or material scarcity, those studies could track firms over multiple years to identify crucial turning points, lock-ins or setbacks. Such insights could enrich theoretical understanding of CE transitions as processes rather than single events, and could feed into transition pathway theories (Geels et al., 2017). Also, the role of intermediaries (consultants, industry associations, regional development bodies) in mediating between external environments and internal organisational change, is still underexplored. These 'boundary actors' may hold unexploited potential for driving the process of CE transition.

Future studies could also extend qualitative interviews with quantitative indicators of CE performance, such as circular material use rates or waste reduction metrics. This allows researchers to test whether the perceived influence of external factors correlates with actual circular outcomes. Such designs could help move the research field toward a more evidence-based understanding of what 'works'. There is also a need for more comparative studies that explore how CE integration differs across spatial and institutional contexts. Understanding how certain specificities shape CE outcomes could help unravel which findings are context-dependent and which represent more generalisable dynamics of CE integration. By stressing the spatial and sectoral embeddedness of CE practices, the study calls for more context-sensitive, actor-focused research, helping to bridge the gap between CE theory and its regional implementation. And beyond its empirical findings, the research encourages a shift in the CE debate: from a predominantly technology/policy-driven lens towards one that considers organisational agency, regional governance and institutional alignment as central levers in the CE transition, too.

In conclusion, this study opens up doors for further theoretical and empirical exploration. As the path to circularity is shaped by dynamic interactions between externalities, place, practice and perception, the findings support an academic move toward more integrated, dynamic, and situated understandings of CE; one that reflect not just the technical challenges of circularity, but also the interpretive, institutional and spatial dimensions that ultimately shape its success.

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Appendices

Appendix 1: Elaboration of the 10 R-imperatives in CE (Chapter 2)

The following text originally located in Chapter 2, but due to the consideration that this is not much 'news' to the average sustainability academic and due to concerns regarding the word count, it has been moved to the Appendices section of this document (with approval from the thesis supervisor).

Short loops: R0-R2

Short loops focus on smarter product use and manufacturing, and they consist of imperatives that tackle waste at the product design phase. As Figure 2.1 shows, these rank the highest on the R-ladder and therefore are the most desirable for an industry without waste. The essence of short loops lies in minimising resource consumption, redefining product design and fostering a fundamental shift in consumption patterns.

R0: Refuse

Refuse, the first imperative in the CE framework, refers to “making a product redundant by abandoning its function or offering the same function with a radically different product” (Morseletto, 2020, p.8). By refusing unnecessary or excessive consumption, but also by refusing certain production processes, or the phasing out of one products that is detrimental to the environment in favour of an efficient alternative (Malooly & Daphne, 2023) and by refusing the disposal of unnecessary materials, companies can directly contribute to resource conservation and environmental sustainability (Reike et al., 2018). From a business standpoint, this imperative involves strategic decisions to limit or eliminate the extraction or production of items that contribute to environmental degradation or that may have limited recyclability/reusability. Strategic material selection, design choices, and consideration of consumer behaviour are integral components, as highlighted by various academic studies. By refusing materials or products that contribute to environmental harm, businesses play a vital role in fostering a sustainable and circular approach to production.

R1: Rethink

Potting et al. (2017) define rethinking as making “product use more intensive (e.g. through sharing products, or by putting multi-functional products on the market)” (p. 15) But the imperative has a wider connotation, as rethinking emphasises a fundamental and cognitive shift in mindset, encouraging stakeholders to question traditional linear practices and adopt a holistic, circular approach (Bocken et al., 2016). This includes the re-elaboration and re-conceptualisation of ideas, dynamics, processes, designs, concepts, uses and post-uses of a product (Morseletto, 2020). Geissdoerfer et al. (2017) emphasise the importance of a systemic approach to rethink product design, supply chains, and consumption patterns. Rethinking involves considering the entire life cycle of products and services. Rethinking is thus not merely a conceptual exercise but a transformative journey requiring a departure from conventional linear thinking. Academic literature underscores the necessity of adopting a systemic and holistic mindset to propel the CE forward. Through a critical examination of existing paradigms, stakeholders can foster innovation and reshape their approaches toward more sustainable and more circular practices.

R2: Reduce

“Reduce implies using fewer natural resources, and therefore fewer inputs of energy, raw materials, and waste” (Morseletto, 2020, p.8) and goes hand in hand with an increase in efficiency in product manufacturing and/or use (Potting et al., 2017). Ghisellini et al. (2016) highlight the significance of resource efficiency in reducing environmental impacts. They emphasise the role of eco-design and eco-innovation in minimising resource use and waste generation. Geissdoerfer et al. (2017) pose that reducing resource consumption is crucial for achieving circularity in product systems, and emphasise the role of reducing material and energy inputs through the adoption of sustainable practices. The reduce imperative thus goes beyond mere consumption reduction. It encompasses a strategic approach to enhance resource efficiency and minimise environmental impact. Academic literature underscores the importance of optimising material and energy use, aligning with circular principles to create a more sustainable and resource-efficient business. Fostering a culture of efficiency and eco-innovation is therefore essential for creating a more sustainable and circular future.

Medium long loops: R3-R7

Where the shorter loops focus on a smarter product use and manufacturing, the medium long loops rather focus on life extension strategies. Representing a more intermediate stage in sustainable resource management, these R-imperatives bridge the gap between initial consumption and the advanced stages of resource recovery. By emphasising product longevity, retaining goods and their parts in the economy for longer, medium long loops contribute to a more sustainable and circular economy.

R3: Reuse

Reuse can be defined as “the second or further use (by another user/owner) of a product that is still in good condition and manages to fulfil its original function.” (Morseletto, 2020, p. 7) The imperative involves the continuous use of products or components without undergoing significant alterations. Various authors highlight the role of reuse strategies in achieving circularity. They argue that the reuse of products, components and materials is essential for closing the loop and lowering reliance on virgin resources (Tukker, 2015). Bocken et al. (2016) highlight the potential for creating business models centred around product reuse. They discuss the role of collaborative consumption and product-as-a-service concepts in promoting reuse-oriented business strategies. ‘Reuse’ from a business perspective thus involves designing products and business models that prioritise extending product and component lifespans through multiple usage cycles. Academic literature underscores the economic and environmental benefits of incorporating reuse strategies into business models, contributing to resource efficiency and waste reduction. Fostering a shift toward reuse-oriented business practices is crucial for realising the potential of circularity in product systems (Cooper & Gutowski, 2015).

R4: Repair

Potting et al. (2017) define repairing as “repair and maintenance of [a] defective product so it can be used with its original function.” (p. 15) It involves restoring a product to its functional state, thereby extending its lifespan and reducing the need for new production. Replacing failed parts of that product also fall under this imperative, emphasising the importance of maintaining and fixing products rather than discarding them (Charter & Gray, 2008). Repairing aligns with the concept of circular consumption, accentuating the longevity of products, minimising the environmental impact associated with constant production (Blomsma & Brennan, 2017) and countering the prevalent “throwaway society” (Castellani, Sala & Mirabella, 2015, p. 373). Embracing this imperative presents businesses

multiple advantages, from enhancing product durability and customer relationships to economic benefits and job creation (Kirchherr et al., 2017). Repairing thus embodies a proactive approach to sustainable consumption. By promoting repair practices, individuals and businesses contribute to resource conservation, waste reduction, and the overall transition towards a CE.

R5: Refurbish

Refurbishing, sometimes also called as reconditioning, implies “restoring an old product and bringing it up to date” (Morseletto, 2020, p. 6). With refurbishing, the overall structure of a multi-component product remains intact, with some components being “replaced or repaired, resulting in an overall ‘upgrade’ of the product” (Reike et al., 2018, p. 12). This upgrading or modernising of a certain product can appear both within and on the outside of the company, with updated components or with new fabric, paint and casing, respectively (Malooly & Daphne, 2023). The imperative therefore emphasises the skilful restoration of products, extending their lifespan and minimising waste through the prevention of premature disposal. Academic literature underscores the environmental benefits of refurbishment, particularly in reducing electronic and plastic waste. Refurbishing products not only prevents premature disposal but also contributes to resource efficiency and conservation and a more sustainable product lifecycle. Since it may involve broader enhancements and modifications to improve the overall product conditions, refurbishing is slightly less circular than repairing (Murray, Skene & Haynes, 2015).

R6: Remanufacture

Remanufacturing implies the “use [of] parts of discarded products in a new product with the same function” (Potting et al., 2017, p. 15) The imperative thus integrates components of a product that are still intact into new products with the same function, involving the systematic disassembly, rebuilding and reassembly of products, restoring them to up to original, like-new conditions (Reike et al., 2018) while extending their lifespan and saving resources. It is particularly relevant in industries where components can be separated, disassembled, and reintegrated into the manufacturing process. It provides businesses opportunities to reduce the need for raw materials, by utilising returned products or components. Remanufacture, as a circular strategy, aligns with the principles of resource efficiency and waste reduction, thereby contributing significantly to sustainable manufacturing practices (Singhal, Tripathy & Jena, 2020; Malooly & Daphne, 2023). The systematic process involved in remanufacturing ensures that products reach a standard that is comparable to new ones, fostering a closed-loop approach within the CE framework.

R7: Repurpose

Morseletto (2020) defines repurpose as “the use of discarded products or their parts in the formation of a new product with a different function” (p. 6), which may otherwise had reached the end of their original use. Repurposing differs from the other medium long loop imperatives (R3-R6) in that the original product, or parts of the original product, acquires a different identity and function (Morseletto, 2020). Murray et al. (2015) argue that repurposing, as a strategy for reducing material consumption, offers a unique approach to sustainable consumption by extending functionalities and values of certain products. Repurposing therefore aligns with CE principles by diverting items from the waste stream and creating opportunities for novel applications (Geissdoerfer et al., 2017). The imperative encourages a mindset shift toward viewing products as valuable resources with the potential for extended use, and allows businesses to reduce waste streams and showcase a commitment to

sustainable practices. By finding innovative ways to give products or materials a second life, companies can work towards a circular business model that prioritises longevity and resource efficiency (Malooly & Daphne, 2023).

Long loops: R8-R9

Where the shorter loops focus on a smarter product use and manufacturing and where the medium long loops focus on life extension strategies, the long loops' focus lies in the focus on creative material applications. These loops are the least circular, and they represent the latter stages of the product lifecycle, focusing on resource regeneration and energy/heat recovery from incineration. Often, these imperatives are expensive, yield rates are often extremely low, and products' integrity is often destroyed (Reike et al., 2018). The long loops could be seen as merely "an upgrade to landfill management" (Reike et al., 2018, p. 12), but nevertheless, these imperatives could have valuable positive impact as long as industries still produce waste (Malooly & Daphne, 2023). Still, recycle and recover is thus also where most circular targets and policies are concentrated (Ghisellini et al., 2016; Reike et al., 2018; Morsetto, 2020)

R8: Recycle

Recycling is "the processing of materials to obtain the same (high-grade), or lower (low-grade), quality of recycled materials." (Morsetto, 2020, p. 5) It involves collecting waste, or discarded materials/products, which gets processed into new products, or materials that can be used for new products (Malooly & Daphne, 2023). As already mentioned, recycling is "in the bottom of ROs but at the top when it comes to frequency of use and confusing use." (Reike et al., 2018, p. 12) But nevertheless, the imperative could make sense, and therefore is part of the R-imperative ladder. Processing materials, especially when a product could otherwise not be used any longer and when there are certain materials within to be recovered (Malooly & Daphne, 2023), does in fact contribute to waste reduction and the conservation of virgin resources. Recycling therefore serves as a possible strategy in the CE by transforming waste into valuable resources. It embodies the concept of closing the loop, reducing reliance on virgin materials, and contributing to the overall sustainability of production processes, albeit on a relatively low level (Reike et al., 2018).

R9: Recover

Recovery in the context of CE is the "incineration of materials with energy recovery" (Potting et al., 2017, p. 15), focusing on extracting value from discarded resources, in the form of heat or electricity (Malooly & Daphne, 2023), or energy or biomass (Reike et al., 2018). Recovery thus refers to waste that is not recycled but rather used as a source of energy or valuable biochemical compounds when recycling is not a viable alternative for the processing of waste (Morsetto, 2020). Involving the dealing with materials that may not have been effectively addressed in an earlier phase (by higher-ranked R-imperatives), and therefore positioned at the bottom end of the R-imperative ladder, recovery processes still holds potential to transform waste into valuable resources (Gatto, 2023), eventually contributing to environmental sustainability and economic prosperity, although as a last straw (Potting et al., 2017).

Appendix 2: Overview of interviewees

Name company	Position interviewee within company	Date	Length
GreenStar	Managing Director	24-04-2024	1:01:27
EcoLine	COO	25-04-2024	51:38
HorizonWorks	Managing Director	30-04-2024	51:16
RenewTech	Managing Director	06-05-2024	59:14
CircoCraft	Industrial Engineer Circular Economy Manufacturing (CEM)	06-05-2024	1:06:02
TerraNova	Managing Director	13-05-2024	56:12
BlueCycle	CEO	15-05-2024	51:37
InnoFabb	Managing Director	04-06-2024	1:04:53

Table 1 Overview of interviewees

Appendix 3: Operationalisation scheme

Variables	Dimensions	Sub-dimensions / indicators
CE Integration	R-imperatives	R0: Refuse strategy
		R1: Rethink strategy
		R2: Reduce strategy
		R3: Reuse strategy
		R4: Repair strategy
		R5: Refurbish strategy
		R6: Remanufacture strategy
		R7: Repurpose strategy
		R8: Recycle strategy
	R9: Recover strategy	
	CSRD alignment	Policies related to resource use and CE
		Targets related to resource use and CE
		Actions and resources related to resource use and CE
		Disclosure on information on material inflows, material outflows and waste
	Internal barriers/drivers	Organisational culture and intrinsic motivation
Employee engagement and leadership support		
Resistance to change and inertia		
Technological infrastructure and innovation capacity		
Barriers to CE	Cultural/social	Company culture
		Willingness to cooperate throughout value chain
		Consumer awareness and interest
		Operating in a linear or circular system
	Regulatory/institutional	Circular procurement
		Laws and regulations
		Global consensus
	Market/economic	Prices of virgin materials
		Standardisation
		Upfront investment costs
		Funding for CE business models
	Technological	Ability to deliver high quality products
		Circular designability

		Large-scale demonstration projects
		Availability of data (on impacts)
Drivers to CE	Cultural/social	Company culture
		Willingness to cooperate throughout value chain
		Consumer awareness and interest
		Operating in a linear or circular system
	Regulatory/institutional	Circular procurement
		Laws and regulations
		Global consensus
	Market/economic	Prices of virgin materials
		Standardisation
		Upfront investment costs
		Funding for CE business models
	Technological	Ability to deliver high quality products
		Circular designability
Large-scale demonstration projects		
Availability of data (on impacts)		

Table 2 Operationalisation scheme (created by author)

INTERVIEW GUIDE

Name interviewer: Rowan van Kasteren
Name respondent: ...
Name company: ...
Position within company: ...
Date of interview: .. -.. -2024
Interview location: ...

Introduction

- Introduction + explain research/graduation process at Volantis/Circular Design Group
- Read out the research question
- Objective of research + interview
- Duration of interview (estimated approx. 60 minutes)
- Confirm consent recording of interview
- Anonymity due to publication Radboud University
- Interview topics: the 10 R-strategies, the CSRD directive, barriers + drivers for the CE
- Questions/wishes in advance

Part 1: Circular Economy (CE) integration within [name of company]

1. Can you give a brief introduction about your company, and what the company is involved in?
2. To what extent are you engaged in circularity as a company, and what have been the reasons for engaging in it?
3. What do you, and what does the company, understand by the term 'Circular Economy'?
4. To what extent are you, as a company, familiar with the R-ladder and the 10 R-strategies it consists of?
5. Which of these R-strategies are applied in your business (operations), and to what extent?
6. To what extent are you, as a company, further exploring and applying one or more R-strategies in your business operations in the near future?
7. Are you familiar with the Corporate Sustainability Reporting Directive (CSRD) and what it means for your company?
8. To what extent do you, as a company, have insight into what enters the company in terms of materials? And what goes out, in terms of products, materials and waste? (So to what extent are you as a company aware of your resource use and waste stream?)
9. To what extent have policies>objectives>action plans been drawn up within the company regarding resource use and the Circular Economy?
10. Looking at the 'big picture' (the whole company picture), where do you think the company stands in terms of the transition to a Circular Economy?

Part 2: Factors influencing CE integration

1. Would you describe your company's current production and consumption patterns as more linear or more circular?
2. Can you say a little more about the culture within your organisation regarding sustainability, and to what extent circularity is embraced within your organisation?
3. To what extent does the company invest in technological infrastructure and innovation to drive circularity initiatives?
4. What challenges/barriers does the company face from within (i.e. purely internal) with regard to the Circular Economy? And how do you deal with them? > What drivers (i.e. purely internal)?
5. How do your customers look at/perceive the Circular Economy? Is circularity being favoured more often and are customers taking responsibility in this, or do they prefer not to have anything to do with it yet? > Entire value chain?
6. To what extent do current laws and regulations influence the choice and opportunity to go circular?
7. Do you notice anything about this on an international level, in terms of laws and regulations? Is there a global consensus regarding the Circular Economy, or do you notice that objectives and strategies are still far apart on an international level?
8. What are the biggest cost-related and market-related challenges for the company regarding the transition to a Circular Economy? > What are the biggest drivers?
9. To what extent do you think external financing (funds) is needed for the transition to a Circular Economy?
10. What can you say about the price of 'virgin', non-renewable resources, compared to resources and materials that are renewable? And about the difference in price between linear products and more circular products?
11. To what extent are there already forms of standardisation in the market in the field of circularity (e.g. accreditations for recycled goods or market mechanisms for reverse logistics)? To what extent does this make circularity easier/more difficult?
12. What kind of circular products could/would you like to supply in the near future?
13. Now that we have gone through different aspects around circularity, what do you think are the main obstacles for your company to become more circular? > The main driving forces?

Closing

- Thank respondent
- Additions/questions?
- End recording