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From waste to value: how Finnish manufacturing sector can adopt circular value chains through systems thinking and service design

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Abstract

Our tendency to think in linear ways has begun to test the Earth's limits. This research is driven by the urgent need to put circular thinking into practice, and thus explores how circular value chain (CVC) innovations can unlock new forms of value and support meaningful, systemic change. Focusing on Finland's manufacturing industry, the study analyses CVC innovations through the application of R-strategies, identifying key enablers and barriers, and examining how service design and systems thinking can support the linear-to-circular transition. A pragmatist qualitative approach was applied, using semi-structured interviews with experts from manufacturing companies and public sector support organisations.

Data were analysed using the multi-level perspective (MLP) framework to identify drivers, challenges, and patterns across micro, meso, and macro levels. The findings reveal that circularity is not simply an operational shift but a systemic transformation requiring internal alignment, cross-sector collaboration, and enabling policy environments. Among R-strategies, reduce, reuse, recycle, and recover emerged as most commonly applied, while more radical strategies such as refuse, rethink, remanufacture and refurbish remain underutilised due to higher economic and regulatory barriers. At the company level, cost efficiency, leadership commitment, and measurable goals drive the transition. Collaboration, customer demand, regulatory clarity, and growing resource scarcity are critical at broader system levels.

This thesis contributes to circular economy (CE) research by linking theory with practice and introducing the Circular Value Chain Blueprint – a practical tool that applies systems thinking and service design to help companies initiate, map, and redesign value chains through a circular lens. While the path to CVCs is complex, this research demonstrates that with the right mindset, partnerships, and tools, companies can initiate successful transitions towards a more sustainable and resilient manufacturing sector.

Keywords: circular economy, circular value chain, systems thinking, manufacturing, service design

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To the industry experts who generously shared their time, experience, and knowledge – this research would not exist without you. I admire your efforts to challenge existing mindsets and initiate meaningful change the world needs. Our conversations were the highlight of my thesis process.

I’m grateful to my peers in SDSI, especially my partner in crime, Derya, for the solidarity during the long writing days, the shared meals, and the spontaneous dance breaks. We did it!

I thank my parents for always being just a phone call away and waiting for me to come home. My dear sister, thank you for your honest feedback and for always being ready to reflect on my half-baked ideas. Merci! To my Mikko, thank you for always being there and supporting me. A heartfelt thanks to the rest of my family, friends, and colleagues in Estonia for cheering me on.

It takes a village, and I hope this research offers a small contribution toward designing more circularly and meaningfully.

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Abbreviations

CE – circular economy

CVC – circular value chain

EU – European Union

GHG – greenhouse gases

MLP – multi-level perspective

1. INTRODUCTION

1.1. Background of the research

“Reality is made up of circles, but we see straight lines” (Senge, 2006, p. 63). Systems scientist Peter Senge has pointedly observed that humans tend to perceive and think of the world linearly. This mindset, however, limits our ability to understand the complexity of the systems that our world is made of. However, in recent years, as the consequences of our oversimplifications – biodiversity loss, human-made structures overriding the natural life forms, and resource scarcity, to name a few – have become acutely apparent, the linear, numbers-based view has become increasingly challenged (Shtarkman & Ménard, 2024).

Step by step and company by company, circular thinking is gaining momentum as it helps to make sense of sophisticated systemic structures. The Circularity Gap Report 2024 (2024) states that over the past five years, the interest in circularity-related topics in academic publications and public discussions has tripled. In the same timeframe, according to the Circular Economy Outlook Nordics Report 2024 (2024), 86% of public companies in the Nordics, often depicted as the pioneers of circular transition, have included circularity in their business strategy at least to some extent. These changes indicate a shift towards the circular economy (CE).

Nonetheless, the global circularity rate has been declining since 2018 and has fallen from 9.1% to 7.2% between 2018 and 2023 (Circle Economy, 2024). This means that 92,8% of materials entering the economy are new raw materials extracted from the earth. One might ask, “So what, this is how we’ve been operating for decades”. Decades ago, the prominent economic discussions were all developed in the context of “empty world”. In the 1950s, around three billion people inhabited Earth, and the global economy was ten times smaller. Kate Raworth (2022, p. 75) draws attention to the “full world” we inhabit today, in which our ways of producing, consuming, and discarding products and materials are increasingly testing the Earth’s limits.

In the best-case scenario, an increase in global average temperature will stay below 2°C by 2100, and the global economy is still expected to lose up to 4% of its cumulative GDP. In the more likely trajectory, where the global temperature rises by 3°C, the global economy might face an economic output loss of 15% to 34%, due to increasing physical damage to infrastructure, reduced agricultural productivity, and deepening health challenges (Benayad et al., 2025).

The European Union (EU) has set a clear goal of adopting the circular economy as the only economy (Raudaskoski, 2025). Manufacturing accounts for over €2 trillion in value contributed to the EU's GDP and more than 32 million jobs across the EU, making it a key participant in the European economy (Salminen et al., 2022). Given the sector's scale and importance to the economy, manufacturing is critical in enabling the transition to circularity. The choices about how products are designed, distributed, consumed, and eventually discarded directly influence the material flows and their environmental impact. Therefore, rethinking our manufacturing value chains can accelerate the systemic redesign towards circularity.

Transitioning from linear to circular mindset is not an equation that can be solved by a handful of passionate pioneers or forward-looking policymakers sitting in isolated rooms. The challenge calls for a broad-scale collaborative reimagining of value creation, materials circulation, and how various ecosystem stakeholders can work together. As circularity gains traction and the shortcomings of linear models become indisputable, there is a growing urgency to translate circular thinking into practical applications. This research is motivated by the need to explore how circular value chain innovations can take shape, scale, and contribute to real, meaningful change within the manufacturing sector.

1.2. Research motivation

I find the topic of circularity and critical examination of our current mindset and business practices a fascinating opportunity to create positive change. As many companies still operate within linear models where resources are extracted, depleted, and discarded, there's an urgent need to rethink value chains. With the use of secondary materials in decline (the global circularity rate decreased from 9.1% to 7.2% between 2018–2023) and consumption on the rise, especially in high-income *Shift* countries that generate 43% of global greenhouse gas (GHG) emissions, a radical change is imperative (Circle Economy, 2024). I believe that more manufacturing businesses adopting circular practices will lead to a more resilient, high-quality, and intelligent value creation while reducing the reckless consumption of Earth's resources.

My interest in this research has both academic and practical considerations. The industrial shift to circularity won't happen overnight. There is a need to create awareness, discover new and unconventional innovation opportunities, and develop interdisciplinary skills and capabilities. Academically, I hope to contribute to the discussion at the intersection of circular economy, value chain innovation, service design, and systems thinking while challenging the more conventional value chain management theories.

Faced with a fast-changing regulatory landscape, deepening resource scarcity, and challenging economic situations, companies struggle to comply with new legislations, stay competitive, and integrate circularity into their operations. From a practical perspective, I aim to propose actionable recommendations and solutions for businesses to take their first steps towards circularity and redesigning their value chains.

1.3. Research goals and research questions

This research aims to analyse circular value chain innovations and explore how service design and systems thinking can support the transition of value chains from linear to circular in Finland's manufacturing industry.

This research has three main objectives:

1. Examine the existing circular value chain innovations through R-strategies (see section 2.1.4).
2. Identify the key enablers and barriers for companies looking to transition from linear to circular value chains.

3. Develop a framework to support manufacturing companies in creating circular value chains.

In alignment with the key objectives, this research aims to answer the following questions:

RQ1: How can manufacturing companies integrate R-strategies into their value chains?

RQ2: What are the key enablers and barriers of transitioning linear value chains into circular?

RQ3: How can service design and systems thinking be applied to developing circular value chains?

1.4. Research scope

This research focuses on circular value chain innovations in the Finnish manufacturing sector. By interviewing industry experts (e.g. researchers and consultants) from research and support organisations and professionals (e.g. sustainability, technology, and value chain management experts) from manufacturing companies, this study brings together different perspectives regarding the trends, challenges, and success stories of circular transition. By combining two target groups – industry experts from research and support organisations and professionals from manufacturing companies – this research takes a multi-level perspective, covering big-picture factors (policy and regulations, geopolitical impact) and interactions between value chains, as well as the more pragmatic company-specific aspects. By following this approach, the study aims to bridge the gap, often criticised in the literature on circular economy, between theory and practice.

Finland's manufacturing sector is the cornerstone of the national economy: it accounts for 51% of the country's exports and almost 28% of its GDP. The sector directly employs more than 320,000 people and provides 700,000 jobs. Finland's key manufacturing industries include electronics, mechanical engineering, metals, and information technology (Martikainen, 2020). Known for its strong digital capabilities and energy-efficient processes, Finland ranks among the most innovative and sustainable manufacturing countries globally (EFIS Centre et al., 2024).

While Finland has a strong engineering and industrial innovation legacy, its manufacturing sector is at a crossroads. The slowing productivity growth, underinvestment in R&D, and urgency for climate neutrality and supply chain resilience have prompted various national efforts to shift towards circular and sustainable practices (Martikainen, 2020).

This research is therefore located in a context where Finnish manufacturing is both the economic backbone and a critical enabler of the national and European sustainability goals. This study aims to connect the macro-level influences with the practical realities that companies and ecosystems face. By analysing the perspectives and challenges of the Finnish manufacturing industry experts, this research explores how service design and systems thinking intersect with circular value chain transitions. In doing so, it looks to discover both new and existing intervention points to support the shift towards, and innovations in, the circular value chains.

1.5. Thesis structure overview

This thesis is structured across seven chapters to explore the manufacturing sector's transition from linear to circular value chains. Chapter 1 introduces the research topic, outlining the motivation, research questions, scope, ethical considerations, and an overview of the thesis structure. Chapter 2 presents the literature review, building a theoretical foundation around circular economy principles, R-strategies, and the role of systems thinking and service design in value chain innovation. It also highlights how value chains operate in the manufacturing context and the shifts required to transition them toward circularity. The chapter concludes by highlighting the main research gaps.

Chapter 3 outlines the research design, describing the pragmatist philosophy, selected research methods, target groups, and data collection process. Chapter 4 presents the results and findings from nine expert interviews. It applies the multi-level perspective framework to interpret drivers, barriers, and patterns at the macro, meso, and micro levels, highlighting how various actors and strategies influence circular transitions. Chapter 5 introduces the practical outcome of the thesis – the Circular Value Chain Blueprint – a visual and actionable tool to support companies in mapping and redesigning their value chains from a circular perspective.

Chapter 6 discusses the findings, linking them to the research questions and literature, and explores their implications for practice and future research. Finally, Chapter 7 concludes the thesis by summarising the main insights and contributions to both theory and practice in the field of circular economy and manufacturing.

1.6. Ethical consideration

Ethical considerations were essential to the thesis and were addressed carefully throughout the research. The study followed the ethical guidelines provided by the University of Lapland, with particular attention to data privacy and handling. All interview participants were adult professionals working in various manufacturing companies or support organisations connected to the manufacturing industry. No vulnerable groups were included in the study. Participation was voluntary, and informed consent was obtained before each interview. Interviewees were provided information about the research purpose, data use, and their right to withdraw before the data analysis. All data were stored securely in compliance with the GDPR, and any personal identifiers were removed from transcripts to protect participant privacy.

2. LITERATURE REVIEW

This research focuses on circular value chain innovations that derive from the broader concept of a circular economy, making it the fundamental theoretical starting point. The chapter first introduces key definitions and principles of the circular economy, including R-strategies, levels of application, and the current regulatory landscape. The second part explores the development of value chains and the nuances involved in transitioning from linear to circular models, highlighting how service design and systems thinking can support this shift.

2.1. Theoretical foundations of circular economy

To understand the formation of the circular economy, it is helpful first to examine how it fits into other economic models. Since the 1930s, mainstream economics has been based on the neoclassical model, characterised by linear ways of creating value, rapid technological progress, and mass production, which encourages a high-consumption lifestyle (Ghisellini et al., 2016; Schaeper, 2023). In the 1960s and 1970s, growing concern over environmental impacts led to the development of new approaches, such as industrial ecology, introduced by Ayres and Kneese (1969), which introduced the concept of industrial metabolism to describe the economic system. They emphasise the interconnectedness of various actors through the continuous circulation of waste and resources within the system's resource inventory.

Based on the extensive literature review by Ghisellini and colleagues (2016), CE originates from ecological economics, environmental economics, and industrial ecology, drawing on the laws of nature as a model to rethink and restructure the neoclassical production approach. In addition to the mentioned disciplines, Prieto-Sandoval et al. (2018) found that CE has also been shaped by business, design and engineering, making it a rather interdisciplinary approach.

The development of CE has been a reaction to the worrisome predictions about the ever-growing linear use of materials, resulting in increasing economic risks, inequality, and humanity's need for at least two or even three planets by 2060 (The World Bank, 2022). And it is no secret that there exists only one planet Earth. Until now, the neoclassical approach has associated growth in quality of life with an increase in material use, justifying the largely unrestricted resource consumption. The Circularity Gap Report 2024 (2024) states that in high-income countries, the same formula doesn't necessarily ensure better living standards anymore.

As a solution, CE offers a mindset, a model and tools to separate wealth from resource use (The World Bank, 2022). In contrast to neoclassical economics, CE treats end-of-life waste as part of the industrial food web. Integrating material and energy flows into product and process design enables the creation of closed-loop systems that reduce environmental harm and minimise reliance on virgin materials while maximising waste utilisation (Ghisellini et al., 2016).

2.1.1. Key definitions

Before exploring further the applications of CE, it is essential to first establish a clear understanding of its meaning and core principles. As CE is still an evolving and not yet mature concept (Murray et al., 2017; Skýpalová, 2024), it is especially important to base the research on definitions that have been proven to be accurate and validated by scholars, practitioners and policymakers. Kirchherr and colleagues (2017) analysed 114 circular economy definitions and noticed that for many authors, CE corresponds to recycling, and the concept of reducing might be overlooked due to concerns of inhibiting economic growth. On the other hand, CE has been most often described through three activities – reduce, reuse, recycle (Ellen MacArthur Foundation, 2012; Kirchherr et al., 2017; The World Bank, 2022). The following section analyses several CE definitions from the literature to understand the core elements of CE.

Various definitions of CE highlight different aspects of the concept, from its systemic nature and operating processes to socio-economic and environmental aims. Commonly, CE is described as an economic model or industrial system that aims to switch from a linear end-of-life approach to cyclical and regenerative production and consumption processes (Ellen MacArthur Foundation, 2012; Kirchherr et al., 2017).

Some authors have included the broader economic, social and environmental impacts of the CE concept. Murray et al. (2017) provide a characterisation, where CE integrates planning, resourcing, procurement, production and reprocessing to maximise human wellbeing and ecosystem functioning. Prieto-Sandoval et al. (2018) emphasise the connection between human society and nature and CE's role in initiating a paradigm shift. To complete the circle, van Buren et al. (2016) define circular economy as an umbrella of value creation, with increased economic value of materials, reduced social value destruction and enhanced resilience of environmental resources.

To make a systemic switch to circular model, CE is described through multiple levels: the micro level (companies, products, consumers), meso level (industrial symbiosis, economic clusters), and macro level (cities, regions, and governments) (Kirchherr et al., 2017; Prieto-Sandoval et al., 2018). The 3-levelled approach represents a holistic perspective of this multidisciplinary concept to drive sustainable development (Kirchherr et al., 2017).

To answer the question 'how', CE is often described through R-strategies or rules. The rule of 3Rs (reduce, reuse, and recycle) dominated the earlier literature and has later expanded into more detailed frameworks, like the 9Rs hierarchy, also addressing the upstream of the supply chain (The World Bank, 2022). Bourguignon (2016) mentions the application of reuse, repair, refurbishment and recycling to maintain the highest value of products and materials, whereas Kirchherr et al. (2017) highlight reduce, reuse, recycle, and recover as the core mechanisms. The research will elaborate more on the different takes of R-strategies in section 2.1.3.

Through closing material loops and improving efficiency in processes and material use throughout the product life cycle, CE aims to prevent deficiency in resources and minimise waste (Prieto-Sandoval et al., 2018; The World Bank, 2022). Skýpalová's (2024) interpretation aligns with the aforementioned, with an additional emphasis on minimising the input and reliance on primary materials. Ellen MacArthur Foundation (2012) even states "the elimination of waste through the superior design of materials, products, systems, and, within this, business models".

Furthermore, innovation has an important role in defining CE and rethinking value creation. Through a set of R-strategies applied at multiple levels (micro, meso, macro), new products, services, business models, and market opportunities emerge (Ellen MacArthur Foundation, 2012; Kirchherr et al., 2017; Skýpalová, 2024; The World Bank, 2022). In addition, Bourguignon (2016) highlights sharing and leasing as a way to contribute to circularity.

The common understanding of CE is still shaping and will probably evolve over time. Based on the literature, the core of the CE comprises:

- a contrast with traditional linearity to move towards regenerative and resource-efficient processes;
- the combination of economic, social, and environmental value;
- the dimensions of micro, meso, and macro;
- R-strategies as implementational mechanisms.

One of the most used CE definitions was created by the renowned Ellen MacArthur Foundation. It seems to act as a guiding star for the academic community as well as for practitioners and policymakers.

> A CE is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals ... and aims for the elimination of waste … (Ellen MacArthur Foundation, 2012, p. 7)

Kirchherr and colleagues (2017) developed their adapted version of the CE definition, which closely follows the main meaning of the one provided by the Ellen MacArthur Foundation. Additionally, the revised definition covers all the core components of CE mentioned earlier and explicitly states that CE takes into account both current and future generations. Due to its comprehensiveness and thoroughness, the following research will be based on and follow this definition of CE.

> A CE describes an economic system ... based on business models which replace the 'end-of-life' concept with reducing, reusing, recycling and recovering materials ... at

> the micro, meso and macro levels ... to accomplish sustainable development ... to the benefit of current and future generations. (Kirchherr et al., 2017, p. 225)

2.1.2. Adopting the circular economy

As discussed previously, our ever-expanding extraction and use of materials has begun to signal a need for adapting a different way of doing things. To put humanity's consumption in perspective, it is good to compare the past and present. While hunter-gatherers lived on 0.5–1 tons of resources per capita a year and agricultural societies thrived on 3–6 tons, the global average today operates annually on around 12.5 tons per capita (The World Bank, 2022).

According to Circle Economy (2021), the handling and use of natural resources produce 70% of GHG emissions, including primarily carbon dioxide, along with methane, nitrous oxide, and fluorinated gases. With the global average temperature rising to 1.55°C above preindustrial levels, keeping up the linear business-as-usual approach will have severe economic and environmental consequences (Benayad et al., 2025). Some effects are evident already today, as material handling is evaluated to drive 90% of biodiversity loss and water shortages, and 33% of air pollution-related health issues (The World Bank, 2022). As a silver lining, the CE applications have been estimated to decrease the global GHG emissions by 39%, while reducing excessive consumption and meeting societal needs like housing, food and manufactured goods (Circle Economy, 2021). The following section will focus on the key foundations and frameworks, barriers and drivers of CE.

To zoom out and understand the bigger picture of the change modern day economics needs, Kate Raworth (2022) introduced the doughnut economics (Figure 1) – a compass for the 21st century with the essence of staying, living and operating in the safe and just space for all. The outer circle depicts an ecological ceiling of planetary boundaries not to be crossed. As a balancing force, the inner circle offers a social floor no person should fall below.

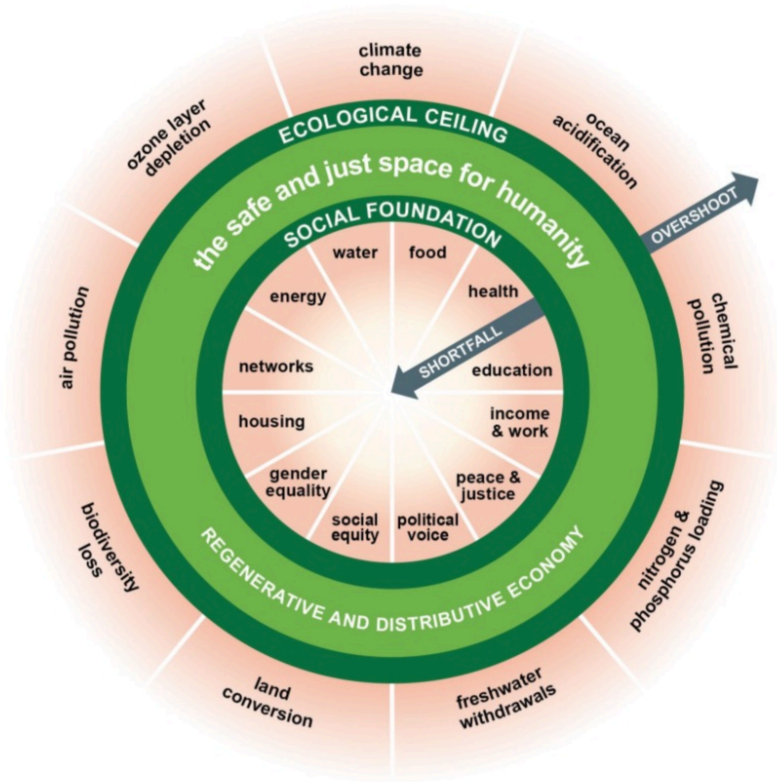


Figure 1. The Doughnut of social and planetary boundaries.
Source: Raworth, 2022, p. 44

The planetary boundaries (Figure 2) represent nine interdependent processes that are essential for sustaining the stability, resiliency and functioning of Earth, and set the safe limits within which humanity must stay (Rockström et al., 2009). In September 2023, all nine processes were scientifically quantified, and it became evident that six of the nine boundaries have been transgressed, posing a threat to our ecosystems and daily living (Richardson et al., 2023). According to the authors (Rockström et al., 2024), the planetary boundaries framework offers a systemic view of the planet, based entirely on biophysical grounds, without including any specific human needs or demands. The key message of the framework is to nudge the reconnection between the human world and Earth by making sure human activities take into account the Earth's boundaries. Murray and colleagues (2017) offer a supporting view through bio-participation, where we learn to exist within the biosphere rather than pretending to be biological by imitating natural systems, as the approach named biomimetics suggests.

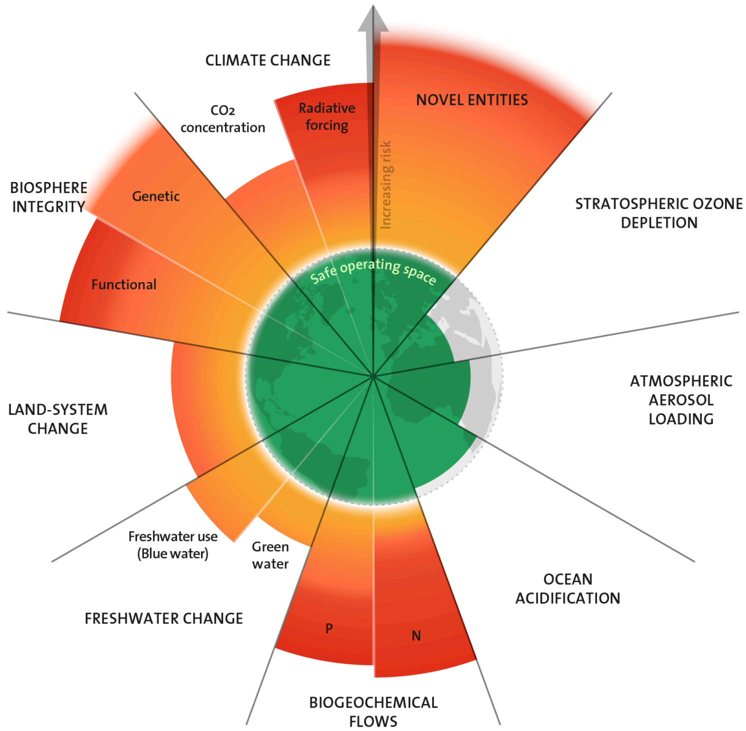


Figure 2. The 2023 update to the planetary boundaries.

Source: Azote for Stockholm Resilience Centre, based on analysis in Richardson et al, 2023

On the other side of Raworth's (2022) doughnut lie the twelve dimensions of the social foundation, based on the Sustainable Development Goals. The dimensions describe the minimum social standards for food, water, energy, education, social equity, etc. the whole society should have access to. The finite planetary budgets and necessary human needs (Rockström et al., 2024) come together on the inside of the doughnut as a regenerative and distributive economy where humanity can securely operate for the future to come (Raworth, 2022).

The planetary boundaries framework can be applied in various fields of study and business to set restrictions or change the course of development. As an example, a study by Abrahão et al. (2024) found that enhancing material efficiency and adopting more sustainable consumption practices could lower the industrial production demand and, in turn reduce the GHG emissions to a level that would prevent 0.09°C of warming overshoot in 2050, while also contributing to mitigating ocean acidification. In addition, the findings show that circular economy approaches can effectively reduce plastic pollution while maintaining progress toward climate goals.

On the micro level, doughnut economics can be applied to align business operations with ecological and social sustainability. As an example (Doughnut Economics Action Lab, 2024), Scott Bader, an employee-owned chemicals manufacturer, has integrated this approach into its strategy by redesigning production processes to minimise waste and source all raw materials from recycled materials or by-products, reduce carbon emissions, and enhance social responsibility within the community. By taking a long-term approach, Scott Bader balances economic success with environmental stewardship and social equity.

As Raudaskoski (2025, p. 11) writes: “The transition to a circular economy is not a question of ‘if’, but a question of ‘when’.” To rethink business activities by considering Earth’s boundaries, CE offers a new mindset. In its essence, CE aims to replace the “take-make-use-waste” linear economic model with a life cycle approach that enables decoupling raw material use from high quality of life and wellbeing (European Environment Agency, 2016; Ghisellini et al., 2016; Kirchherr et al., 2017; The World Bank, 2022). To reach that goal, the Ellen MacArthur Foundation (2023) bases CE on three design-driven principles:

- design out waste and prevent pollution
- keep products and materials in circulation at their highest value
- regenerate natural ecosystems

Additionally, Eljas-Taal et al. (2019) characterise the adoption of CE through new sharing-based business models, changes in consumer behaviour and awareness, local initiatives in collaboration with the local government and NGOs and personalised services and tailor-made solutions.

Prieto-Sandoval and colleagues (2018) describe the functioning of CE through a dynamic interplay between regulation, supply-side factors, and demand-side factors. Regulatory and policy determinants establish a legal framework to encourage consumers and suppliers to adopt sustainable practices. The transition to circularity on the supply side, i.e in companies and industries, is shaped by technological innovation, cost efficiency, and market structure. On the demand side, consumer awareness, preferences for sustainable products, and market success affect the acceptance of circular innovations. The three determinants are interconnected, as the behaviour of consumers influences demand and eco-innovations and new business models can, in turn, prompt updates in regulatory frameworks, creating a continuous feedback loop.

To illustrate the goals and principles of CE, the European Environment Agency (2016) offers a simplified model (Figure 3), where waste generation and material inputs are minimised through eco-design, recycling, and reusing products, creating economic and environmental benefits.

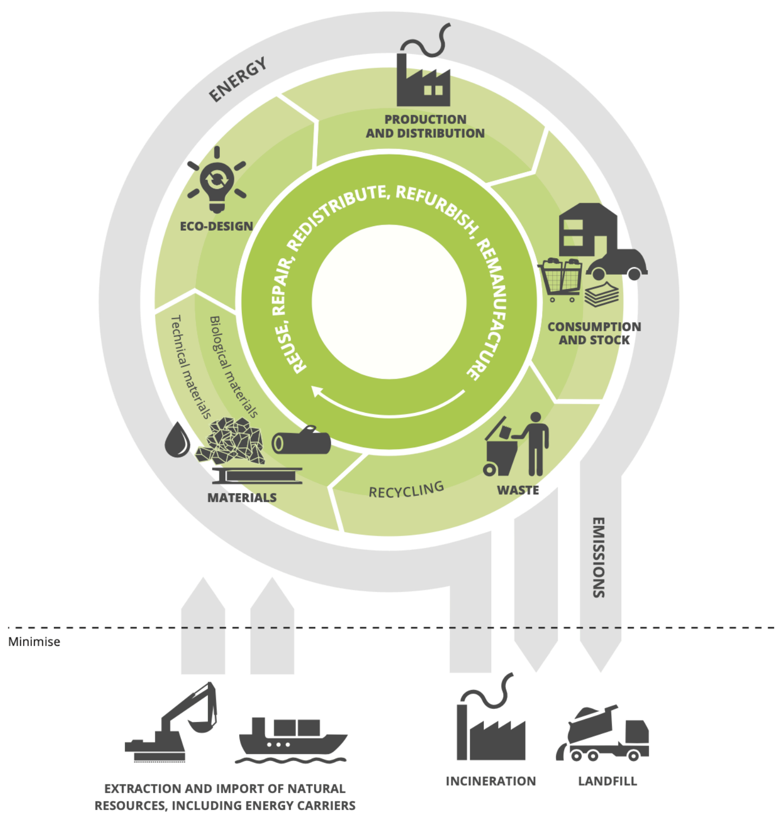


Figure 3. A simplified model of the circular economy for materials and energy.
Source: European Environment Agency, 2016, p. 10

The model consists of three circles, where:

- the outer circle represents energy flows, emphasising increased efficiency and the use of renewables while minimising incineration;
- the middle circle represents material flows, distinguishing between renewable biological materials and non-renewable technical materials, and highlighting how mixing the two affects biodegradability and recyclability;
- the inner circle presents a set of R-strategies (reuse, redistribution, repair, remanufacture and refurbishment), which minimise resource input by maintaining product and material value at the highest possible level.

Leading companies see CE as an opportunity to build a competitive advantage by becoming a pioneer in their sector, while legislation acts as a secondary guide (Raudaskoski, 2025). Nevertheless, the adoption of CE is still rather nascent, with over 87% of EU resource usage coming from primary materials, according to the World Bank report on EU circular transition (2022). While the material footprint per capita has remained stable in the EU after the financial crisis in 2008, it is expected to continue on a rising trend, indicating a lack of progress in disconnecting growth from material use.

To keep a realistic approach to the adoption of CE, it is essential to understand the barriers and challenges associated with the concept. The fluctuations in understanding and defining CE arose already during the analysis of key definitions. The inconsistent definitions, varied interpretations of R-strategies, and the oversimplification of CE as idealised closed-loop systems or merely an approach to waste management can hinder the implementation of the concept and overlook opportunities for waste prevention and regeneration (Ghisellini et al., 2016; The World Bank, 2022).

On a more practical level, the oversimplification of CE might have some unforeseen rebound effects, resulting in negative impacts to the environment (Murray et al., 2017) or increased consumption (Potting et al., 2017).

For example, while CE favours designing longer-lasting products, it can be ecologically inefficient when not thought through. A highly durable plastic fork may consume more energy in production and remain in the environment for centuries, whereas a bamboo chopstick, despite having a shorter lifespan, is made out of only natural nutrients and can be reintegrated into the biosphere rather easily (Murray et al., 2017). As a rule, reducing the use of natural resources and producing less new materials also reduces environmental impacts, but keeping an eye out for the secondary effects is recommended. For example, car-sharing may motivate people without personal cars to rent one in situations they otherwise would have used public transport, thus increasing the usage of cars within this user group (Potting et al., 2017).

According to Benayad et al. (2025), another complexity is connected to the fact that governments and companies must make most of the expenditures related to climate and circular transition before 2050, whereas the majority of economic benefits will only become tangible after 2050. Adding to that, cognitive biases among decision-makers, i.e. humans, make us prioritise immediate gains over long-term ones and feel overly optimistic that future innovations will resolve climate challenges.

Murray et al. (2017) point out the lack of social dimension in many of the applications of CE, focusing mainly on ecological renewal and resource efficiency. Although these efforts certainly serve humankind, other social aspects, like social equity, diversity or financial equality, might be overlooked. To address this gap, the Doughnut Economics framework, discussed earlier, offers a more holistic approach by representing all three aspects – economic, environmental and social – of sustainability.

To succeed in the adoption of CE, the focus shouldn't only be on raising efficiency and continue economical growth, but to radically change the approach to design, production and consumption to reduce material usage and lessen the pressure on planetary boundaries, while sustaining societal wellbeing (Circle Economy, 2024; Ghisellini et al., 2016).

2.1.3. Policy shifts influencing circular economy development

In the last decade, CE has started to play a growingly more important role in the European Union (EU), with the EU becoming a global frontrunner in CE policymaking. Since the publication of the Roadmap to a Resource-Efficient Europe in 2011, EU regulatory actions have started to increasingly prioritise systemic interventions across the entire value chain over waste management efforts (The World Bank, 2022).

Reike et al. (2018) introduce the CE 3.0, starting from 2010 to the present day and characterise it as the third development phase where the emphasis is on maximising value retention amid resource scarcity. To do just that and accelerate the EU's transition to a circular economy, the European Commission announced the revised Circular Economy Action Plan in 2020, setting measures across the entire product life cycle, focusing on the design phase, circular practices, keeping resources in use for as long as possible as well as the end-of-life stage (European Commission, 2020). It is one of the building blocks of the European Green Deal – a roadmap to reduce emissions 55% by 2030 and reach climate-neutrality in Europe by 2050 (European Parliament, 2022). Another building block for supporting the Green Deal is formed by the Green Deal Industrial Plan, aimed at boosting the EU's manufacturing capabilities for net-zero technologies and products essential to achieving its climate goals (European Commission, 2023).

Under the Green Deal, there are over 175 directives and regulations regarding a wide scope of topics, such as energy, transportation, climate & emissions, water, land & animals, chemicals & pollutants, waste, consumer goods, products & materials, reporting, and funding & support (CircuLaw, 2024). Regarding the focus of this thesis, the most relevant regulations are: Ecodesign for Sustainable Products Regulation (ESPR), Digital Product Passport (DPP), Right to Repair, Corporate Sustainability Reporting Directive (CSRD), Green Claims Directive, Critical Raw Materials Act, and Packaging and Packaging Waste Regulation. The following table (Table 1) gives an overview of the EU circular economy policies across the three levels, the micro level (companies, products, consumers), meso level (industrial symbiosis, economic clusters), and macro level (cities, regions, and governments), as described by Kirchherr et al. (2017).

Table 1. EU circular economy policy overview

Policy impact level	Policy/regulation	Aim	Industry scope	Status
Micro level (companies, products, consumers)	Right to Repair (Baccini, 2024)	Ensure products are repairable by mandating access to spare parts, repair information, and software tools, extending product lifetime and reducing waste.	Electronics, appliances, consumer goods, vehicles	Adopted in 2024, transposed in EU member states legislation by 2026
	Green Claims Directive (European Commission, 2025a)	Avoid greenwashing and prevent misleading environmental claims about products and services by setting clear criteria and requirements.	Consumer goods	Proposal adopted in Mar 2023, national laws expected by 2027
Micro level (companies, products, consumers) Meso level (industrial symbiosis, economic clusters)	Ecodesign for Sustainable Products Regulation (ESPR), Digital Product Passport (DPP), a part of it (European Parliament & Council of the European Union., 2024a)	Improve the sustainability of physical products on the EU market by setting ecodesign requirements for durability, circularity, energy efficiency, and recyclability DPP provides standardised, accessible data about products, components, and materials to support traceability and informed decision-making across value chains.	All physical products (starting with electronics, batteries, textiles, and construction) & product ecosystems	Proposed in 2022, ESPR working plan in Q2 2025, full implementation by 2030
Meso level (industrial symbiosis, economic clusters)	Packaging and Packaging Waste Regulation (European Commission, 2025b)	Setting rules on packaging and packaging to prevent waste generation, increase recyclability, and decrease the use of virgin materials in packaging.	Packaging across all sectors	Went into effect in Feb 2025, general application by Aug 2026
	Critical Raw Materials Act (European Parliament & Council of the European Union, 2024b)	Secure a sustainable supply of critical raw materials essential for green and digital transitions, and ensure industrial competitiveness.	Automotive, renewable energy, defence and aerospace	Entered into force in May 2024
Macro level (cities, regions, and governments)	Corporate Sustainability Reporting Directive (CSRD), focus on E5 (European Commission, 2022)	Require large companies to report on their social and environmental risks and impacts, including circularity and value chain transparency, to improve accountability and comparability.	All large companies and listed companies (1000+ employees criteria proposed)	Applies from 2024 for large companies, simplification omnibus proposed in Feb 2025

Source: Adapted from various regulations as cited in the references.

The EU circular economy policies are developing more and more towards systemic value chain governance and support R-strategies (see 2.1.4) with higher value retention. For example, the Right to Repair rules and ESPR push product designers and manufacturers to think of the durability and repairability of products already in the design phase to be able to extend the product's life cycle. In addition, the Critical Raw Materials Act, while aiming to secure access to key inputs for industrial transformation, incentivises the rethinking, reuse and recycling of materials within the EU (The World Bank, 2022).

Despite the evolving legislation and stricter rules, the EU material intensity is high, and a part of the negative environmental impacts is shifted abroad through international trade, signalling a concern regarding growing import dependencies and the lack of coordination of sustainability policies (The World Bank, 2022). To accelerate the scale of circular transition, Benayad et al. (2025) suggest working towards a global consensus, creating even more ambitious, clear and detailed plans, and finding practical collaboration opportunities across different sectors.

2.1.4. R-strategies as a practical framework for circular transition

As mentioned in the discussion of the meaning of CE, R-strategies, ladders, or rules act as the implementational principles of the circular concept by bringing together and categorising actions to maintain the value of resources throughout the whole life cycle (Reike et al., 2018; The World Bank, 2022). For clarity and consistency, the term ‘R-strategies’ will be used in this research (see Table 2 for an overview).

Although Kirchherr et al. (2017) and Ghisellini et al. (2016) found the 3R (reduce, reuse, recycle) or 4R (reduce, reuse, recycle, recover) approach to be the most widely recognised in the literature, practical implementation at the policy and company level have been mostly circling around recycling, with less emphasis on reduction and reuse. Kirchherr et al. (2017) attribute the practitioners’ modest interest in reduction strategies to concerns that this approach might hinder consumption and economic growth, particularly if a transition to the product-as-a-service business model is not considered. Therefore, they point out, not prioritising reduction could result in CE becoming a superficial approach with companies undertaking minimal changes, such as improved recycling. Moraga et al. (2019) also highlight how many manufacturing firms focus their CE efforts on end-of-life recycling indicators rather than upstream strategies like reduction or reuse. This focus comes from the ease of measuring recycling rates and adjusting them with existing business models. However, it still risks neglecting the more transformative potential of CE to reduce resource throughput and rethink product design.

To tackle this weak spot of R-strategies focusing mainly on waste hierarchies, more recent publications (Bajuk & Linder, 2024; Potting et al., 2017; Reike et al., 2018) have been highlighting more detailed strategies, ranging from 5R to 10R approaches, and ranking the strategies hierarchically based on the level of value retention or circularity. Based on their extensive literature review, Reike et al. (2018) identified almost 40 different 're-'words used to describe R-strategies, showing both a popular and simplistic concept for CE operationalisation and the prevailing confusion around defining their precise meaning at the same time.

It is important to highlight that CE begins in the design phase to make sure the end-of-life phase is intentionally planned, allowing waste prevention and product and materials to be circulated at their highest value (Ellen MacArthur Foundation, 2012; Winquist et al., 2023). Winquist et al. (2023) also stress the role of hierarchical ranking that prioritises prevention, followed by reuse, recycling, recovery, and finally landfilling. In fact, Reike et al. (2018) found that the growing emphasis on refuse and reduce, the shortest loops, reflects the increase of perceived necessity of decreasing overall inputs and consumption.

To structure and provide examples of the application of R-strategies, this study follows R-strategy hierarchy (Figure 4) developed by the PBL Netherlands Environmental Assessment Agency (Potting et al., 2017) due to its clarity and academic recognition (Eljas-Taal et al., 2019; Kivikytö-Reponen et al., 2022; Winquist et al., 2023).

The hierarchy consists of 10 R-strategies that, in turn, can be grouped into three:

- smarter product use and manufacture (R0 Refuse, R1 Rethink, R2 Reduce);
- life extension strategies (R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose);
- maximising material usefulness (R8 Recycle, R9 Recover).

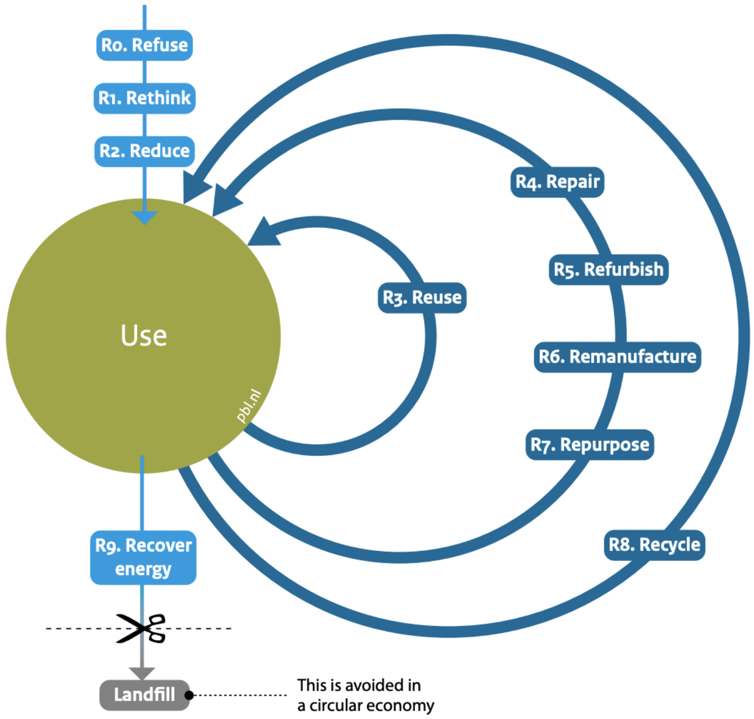


Figure 4. 10 R-strategies as implementation principles of CE
Source: Potting et al., 2018, p. 11

R-strategies act as levels of circularity with R0 refuse, i.e. actions towards prevention, presenting the highest level of circularity, and R9 recover being a low-circularity strategy, as after incineration, it is no longer possible to use the materials. Although, as a general rule, higher circularity brings more environmental benefits, Potting et al. (2017) and Winquist et al. (2023) recommend to pay attention to case-specific elements when selecting R-strategies, as the differences in use of raw materials and chemicals, recycling technologies or product design also influence the possible environmental gains.

Table 2 provides an overview of R-strategies in the context of the product use phase. The high-circularity strategies R0–R2 occur before the use phase begins, usually in the design and production phase (Potting et al., 2017). Life extension strategies are presented in loops of varying size, indicating the proximity of the product to its original user and function. The bigger the loop, the more products are upgraded and producers get re-involved, until it loses its original function in R8 recycle and R9 recover (Reike et al., 2018).

Moreover, the shorter loops, such as R0 refuse, R2 reduce, R3 reuse and R4 repair, are considered the most preferable, because, in addition to maintaining value most effectively, they are often customer-oriented. Reike et al. (2018) give examples that customers have the choice to refuse to buy products containing toxic chemicals or having excessive packaging. They also have the power to buy reused products or contribute to extending the product's life cycle by selling the product to someone else to reuse or repair it when it breaks.

Potting et al. (2017) emphasise that the most commonly applied strategies – recycling, especially low-quality recycling, and incineration – still remain closely related to linear economic practices. The real CE transition should prioritise high-circularity strategies to reduce resource use and prevent waste generation. These strategies include smart manufacturing, more efficient product use, and extending the lifespan of products and their components.

Table 2. 10 R-strategies in order of priority

Category	R-strategy	Explanation	Example
Smarter product use and manufacture	R0 Refuse	Make the product redundant by abandoning its function or by offering the same function with a radically different product.	Stora Enso provides battery producers with a sustainable bio-based anode as an alternative to virgin raw materials.
	R1 Rethink	Make product use more intense (e.g. through sharing products, or by putting multi-functional products on the market).	MUD Jeans offers a 12-month lease with a fixed monthly fee; afterwards, jeans can be kept, swapped, or more pairs leased.
	R2 Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials.	Betolar replaces virgin cement with industrial by-products, thus reducing reliance on raw materials and cutting emissions by up to 80%.
Extended lifespan of the product and its parts	R3 Reuse	Reuse by another customer of a discarded product which is still in good condition and fulfils its original function.	Interface offers service contracts with maintenance, where used carpet tiles are cleaned and reused under new contracts.
	R4 Repair	Repair and maintenance of defective products so they can be used with their original function.	Global pallet pooling company CHEP offers pallets as a service and repairs them when needed, taking the responsibility from the customer.
	R5 Refurbish	Restore an old product and bring it up to date.	Swappie buys used iPhones, refurbishes and then sells them.
	R6 Remanufacture	Use parts of a discarded product in a new product with the same function.	Tractor manufacturer Valtra offers remanufactured gearboxes and engines at a lower price than entirely new ones.
	R7 Repurpose	Use discarded products or their parts in a new product with a different function.	Tracegrow Oy turns used alkaline batteries into organic-certified fertilisers, reducing carbon emissions and enhancing crop productivity.
Useful application of materials	R8 Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality.	Outokumpu recycles steel scrap and production waste to produce high-grade stainless steel, with over 90% recycled content.
	R9 Recover	Incineration of materials with energy recovery.	Although incineration for energy recovery is the least favourable method, a significant share of materials end up this way. Yara takes a step further by turning ash into fertilisers and construction materials.

Source: Adapted from Ellen MacArthur Foundation, 2023; Potting et al., 2017; Winquist et al., 2023

2.2. Circular value chains in the manufacturing sector

The focus of this research is narrowed down to the manufacturing sector, as the sector contributes to the overshoot of several planetary boundaries. As production processes today are mainly powered by fossil fuels, the sector generates around one-third of global GHG emissions and the material- and energy-intensive industrial activities account for approximately 15% of the pressure on both land use and freshwater planetary boundaries (Circle Economy, 2024). In addition, the manufacturing industry is highly dependent on non-renewable and often rare materials, facing growing supply risks due to increased global demand and limited availability (The World Bank, 2022). While some basic materials, like iron ore and nonmetallic minerals, remain relatively abundant, critical raw materials essential for fast-growing sectors like renewables and electronics, like cobalt, bauxite, and copper, are finite and increasingly difficult to access. This dependency, combined with global trade volatility, makes manufacturers vulnerable across their value chains (The World Bank, 2022).

The Circularity Gap Report 2024 (Circle Economy, 2024, p. 29) says, “Manufacturing makes the world go round: we need it to produce vehicles, clothing, appliances and equipment.” However, to keep the world spinning, the demand for materials has to decrease, and new solutions are needed. In response to the aforementioned macro-level forces, circular manufacturing has started to develop in recent years to drive system-level innovation and rethink the life cycle of manufactured goods. To keep materials in circulation for as long as possible, circular design principles have to be applied in R&D together with smart use of data and new digital technologies (World Manufacturing Foundation, 2022). Transitioning to circular value chains and implementing new business models poses a challenge for manufacturing companies in balancing profitability and environmental responsibility.

2.2.1. Understanding the value chain

Before exploring circular VCs, it is important to first differentiate between the terms supply chain and value chain, which are often used interchangeably but have different scopes and aspects of value creation. The Association for Supply Chain Management defines supply chain in their Supply Chain Dictionary as “a network of suppliers that deliver products from raw materials to end customers through either an engineered or transactional flow of information, goods, and money" (Gatewood & Drake, 2024, p. 190). Often, industry supply chains are divided into two – upstream and downstream. The former indicates activities around sourcing the raw materials, determining the supply available. The latter is the process where value is added to the products, as they leave production and arrive at the end customer, including inventory management, tracking, delivery, returns, etc (Singer & Donoso, 2008). Whereas value chain is defined as the full range of the functions, activities, resources, and relationships within and beyond a company that add value to its goods or services, from conception to delivery, consumption, and end-of-life (EFRAG, 2023; Gatewood & Drake, 2024). The definitions set the supply chain scope from raw material sourcing until the beginning of the product use stage, whereas the value chain takes a broader perspective, from conception or design phase until the end-of-life stage. EFRAG (the European Financial Reporting Advisory Group) (2023) expands on the full range of activities on three levels of the circular economy:

- Micro level – the company's internal operations, such as production processes and human resource management.
- Meso level – external interactions, such as suppliers, partners, and customers.
- Macro level – enabling environment, such as financing, geopolitical and regulatory landscape.

Berndt (2003) brings out the importance of the value chain approach on a strategic level, as it supports the company's value proposition and mission, hence indicating the company's strategic direction. For example, if a company aims to provide good-quality products for an affordable price (value proposition), operations across the value chain have to be structured to do just that. The VC can be used as a tool to identify the activities that add the most value and create a competitive advantage in the market (Berndt, 2003).

Porter (2001) widens the scope even more by arguing that a company's value chain is part of a broader concept called the value system. Value system includes, in addition to the company's value chain, the supplier, channel and buyer's value chain (Figure 5). The suppliers create value in the upstream VC by providing input to the company's VC. Products might be a part of the channel VC before getting to the buyer, involving intermediaries like retailers, online platforms, and logistics providers. And finally, the product becomes part of the buyer's VC, defined by the buyer's needs. Ultimately, all of the VCs affect each other, and to best understand the competitive advantage, a company must comprehend its entire value system.

Figure 5. Value system

Source: Porter, 2001, p. 51

To visualise the widely applied linear value chain, Figure 6 depicts the stages from product design to end-of-life disposal or the take-make-use-waste model. And while the problem of waste is discussed as the result of the linear approach, the root cause sits in the first part of the value chain. It is estimated that around 90% of raw materials used in manufacturing become waste before the final products leave the place of production, and that 80% of products are discarded within six months of use (The World Bank, 2022). With 80% of a product's environmental impact determined in the design phase, the need to rethink the whole operating system is crucial, starting from the first phases of the value chain (European Commission, Directorate General for Enterprise and Industry, 2012).

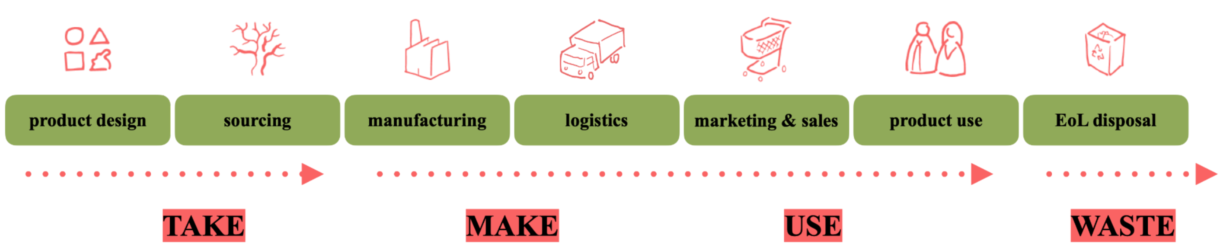


Figure 6. Linear value chain

Source: Adapted from Sitra et al., 2018, p. 11

To understand the potential of CVCs, it is necessary to evaluate the current limitations of the linear approach and how alternative models, like the butterfly diagram, challenge this logic. The World Manufacturing Report (2022) reflects how crises over the past 15 years, from the 2008 financial crisis to the Covid-19 pandemic, the Russian invasion of Ukraine and other geopolitical events, have revealed the weak spots of our global and efficiency-oriented supply chains. As the climate crisis and resource scarcity deepen while resource use is expected to grow, the frequency and intensity of these shocks will increase along with the growing commodity prices (Ellen MacArthur Foundation, 2023). The efficiency and low costs in traditional supply chains often come at the expense of the environment and are highly dependent on global networks (Accenture, 2014). This makes sourcing and logistics particularly fragile to crises, as companies often rely on single-sourcing strategies. Moreover, the linear flows are impacted by the slowdown in global integration called slowbalisation and a rise in protectionism to support critical supply chains (World Manufacturing Foundation, 2022).

The pursuit of efficiency and low costs in traditional supply chains, often optimised for linear throughput, frequently results in significant environmental costs, including resource depletion, pollution, and waste (Dagilienė et al., 2020; Moreno et al., 2016), and creates a high dependency on complex global networks, increasing vulnerability to disruptions and reducing supply chain transparency (Awan et al., 2022; Gomes et al., 2024; Lin & Chu, 2024).

The broader lens of value chains is particularly relevant when analysing circular flows and operations to retain value and minimise waste across all stages. With the butterfly diagram (Figure 7), the Ellen MacArthur Foundation (2012) splits material flows into two: biological and technical. The biological cycle, concerning the renewables and biodegradable nutrients, involves consumable products, like food, that can return to the biosphere or loop through a sequence of multiple applications before moving back to outer loops and the earth (Ellen MacArthur Foundation, 2022a). The technical materials, such as plastics and metals, flow through processes where they are being used to maintain the highest possible value by applying different value retention activities, like R-strategies (Ellen MacArthur Foundation, 2022b). Separating the cycles emphasises the importance of pure circles, as the collection and redistribution of uncontaminated material flows is more efficient, especially when it comes to the technical cycle and extending product lifespan (Ellen MacArthur Foundation, 2012). The butterfly diagram challenges traditional supply chain thinking by opening up the complexity of circular value chains, where, instead of flowing from manufacturing to disposal, the materials have to loop back within or between VCs, relying on reverse and decentralised logistics (Batista et al., 2018).

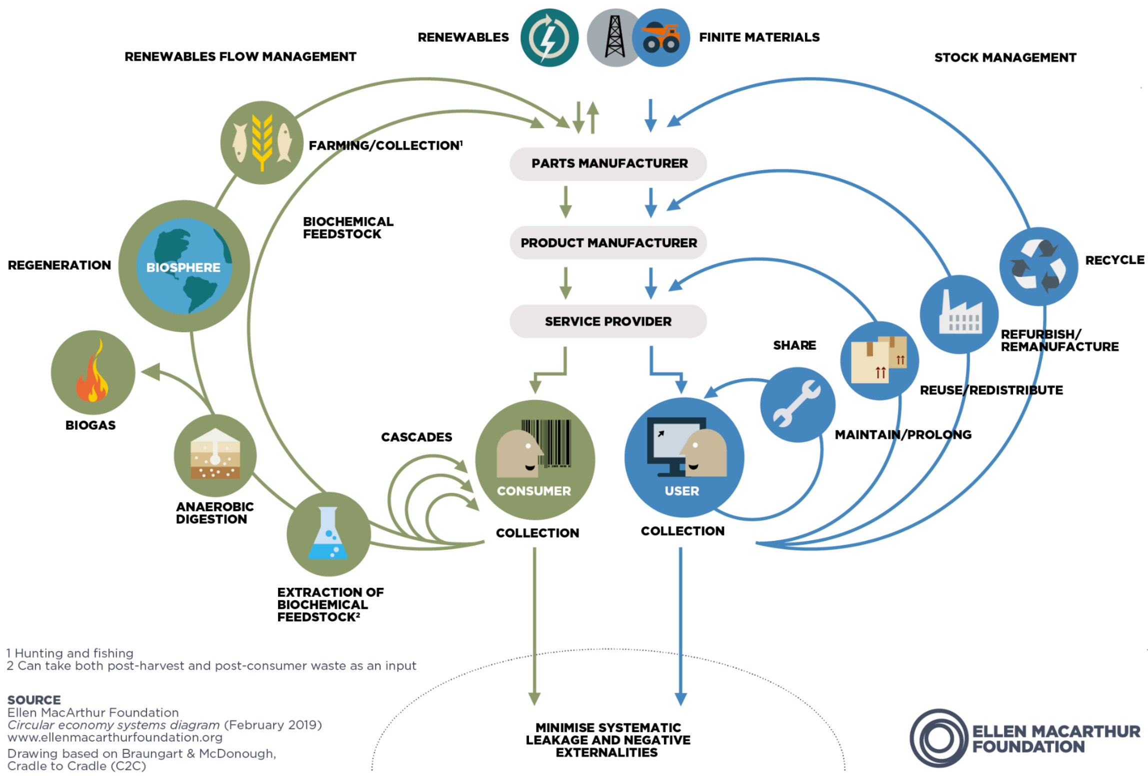


Figure 7. CE butterfly diagram

Source: Visual downloaded from website, Ellen MacArthur Foundation, 2021

The approach to circular VCs has evolved over the years. Batista and colleagues (2018) researched the aspects of a circular supply chain archetype by analysing reverse logistics, green supply chains, sustainable supply chain management and closed-loop supply chains. They highlighted the shift from expanding the focused closed-loop narrative to a wider value chain system scope via meaningful business ecosystem integration to create value from products and services, by-products and waste flows. Circular value chain thinking has to consider many stakeholders and collaborative connections to reach the restorative and regenerative goal of CE. Based on Batista et al. (2018) and Roos (2014), the key aspects of CVCs are:

- reaching beyond conventional closed-loop systems by incorporating reverse (restorative) and forward (open-loop) flows of products, by-products, and services across interconnected value networks;

- maximising resource efficiency by minimising the input required per unit of output and reducing energy, water, and material leakages throughout the value creation process;
- applying R-strategies within the inner technical cycle;
- recognising and realising the environmental and economic potential of side-streams and unutilised inputs (waste);
- taking a systems-oriented approach through the collaboration of multiple actors and industries at different levels of the economy.

As the butterfly diagram depicts the materials flows in a closed-loop process, adding an example of open-loop flows connecting several organisations' supply chains is important. Figure 8 visualises the cascaded use of products and materials in the textile industry. Cotton-based clothing moves through its first use cycle and is then turned into fiberfill for furniture, from which it becomes insulation material before circling back into the biosphere as a biological nutrient. This approach replaces raw materials and related costs with existing materials, from high-value to lower-value uses (Ellen MacArthur Foundation, 2012).

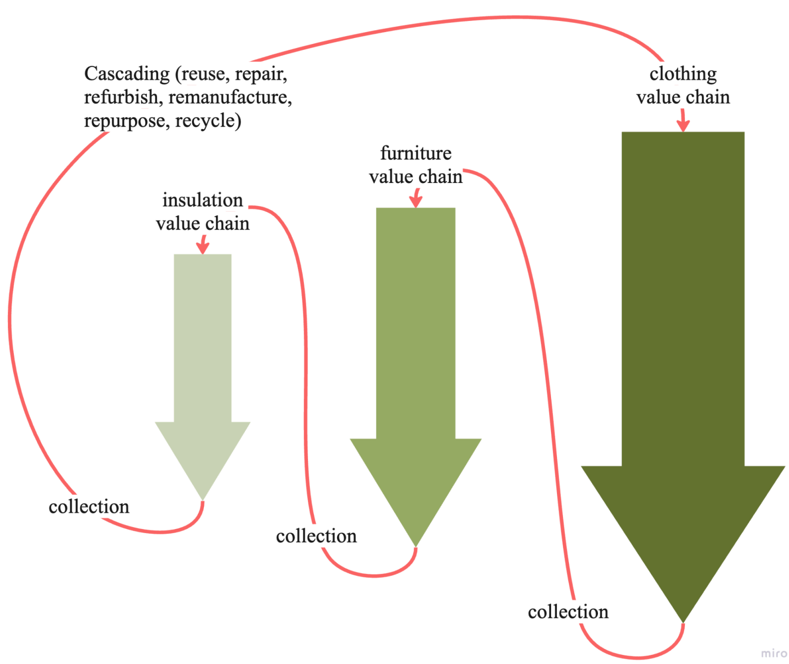


Figure 8. Open-loop flows through multiple supply chains
Source: Adapted from Ellen MacArthur Foundation, 2012, p. 33

So far, a single company-centric approach has been dominant in the literature. However, as a real systemic impact cannot be achieved alone, involving a wider group of stakeholders and taking an ecosystem view is recommended (Bressanelli et al., 2022).

2.2.2. Transitioning from linear to circular value chains

The transition from linear to circular ways of doing things in a company has its ups and downs, so it's important to open up the opportunities and challenges of moving towards CE from a company's point of view. Moving from linear to circular can require several shifts inside the company and changes regarding collaboration with partners, indicating adaptations on different decision-making levels of the company. Madani et al. (2024) divide decision levels into three: strategic (long-term), tactical (quarter to a year) and operational (daily). Horn (2014) explains that on a strategic level, a company's leadership has to balance shareholder expectations with long-term developments and daily operations. And even if they understand the importance of addressing environmental issues, the payoffs might be too complex or intangible (Benayad et al., 2025) to gain owners' or investors' approval.

The decision levels don't exist in isolation and are very much interconnected, affecting the whole value chain. For example, a change in product design might require a strategic decision about rethinking the logistics network, a tactical decision on material management operations, and adjustments at the operational level to ensure on-time delivery and good customer service (Madani et al., 2024). Adopting a life cycle perspective could offer a valuable starting point, as it brings together upstream and downstream processes, and equips the managerial level with practical tools that are not overly costly, but still support the integration of sustainability and climate considerations across the entire value chain (Horn, 2014). Additionally, the Circularity Gap Report 2024 recommends that the manufacturing sector focus more on making industrial symbiosis mainstream by building connections between their own and other industries to achieve better processes and decrease emissions and material loss (Circle Economy, 2024).

ISO 14004 standard (ISO, 2016) defines the life cycle perspective by considering the environmental aspects of the company's products, services and activities that the company can influence through the whole value chain. It is highlighted that companies should first consider the stages in the life cycle over which they have control, as the opportunities for resource reduction and waste minimisation are the greatest. Considering the product's lifespan and technological complexity, value chain length, and the organisation's ability to affect material use, processes, and end-of-life outcomes is needed.

To start a circular transition, understanding existing inefficiencies and focusing on high impact is key (Sitra et al., 2018). Accenture analysed over 120 company case studies from a wide range of geographies and industries, and discovered five inefficiencies in existing linear value chains and five circular business opportunities to turn into circular advantages. The five types of waste include (Lacy & Rutqvist, 2015; Sitra et al., 2018):

- Wasted resources – materials and energy that are not continually regenerated, but are lost after use.
- Wasted capacity – products and assets that are underutilised.
- Wasted life cycles – products have artificially short working lives (non-repairable), or their working life is not used to the fullest.
- Wasted embedded values – components, materials, and energy aren't recovered or recycled at the end of life.
- Wasted customer engagement – focus is on selling functionality rather than the customer problem, and opportunities to engage with customers are lost.

Lacy and Rutqvist also defined five business approaches that can be applied throughout the value chain to tackle the five types of waste in manufacturing companies (Figure 9). New approaches to business and profit-making are needed as the focus moves from linear transactions and cost-effectiveness to resource efficiency and value retention (Blom, 2020). New approaches and business models are highly important to CE adoption in the private sector, acting as a steering wheel of circular transition (Kirchherr et al., 2017).

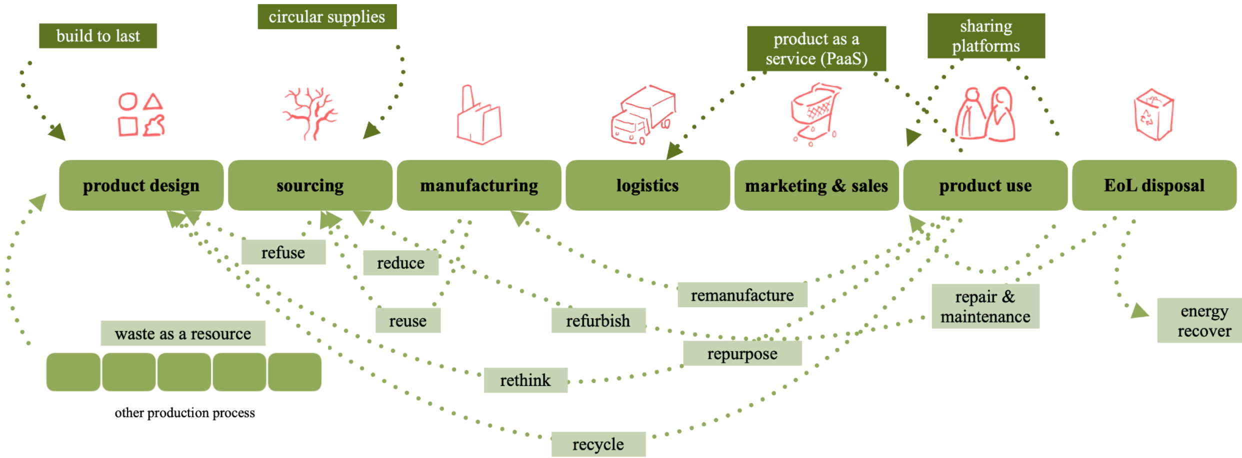


Figure 9. Circular opportunities in the value chain

Source: Adapted from Sitra et al., 2018, p. 25

Firstly, circular supplies should be considered alternatives to raw virgin materials and non-renewable energy. CVCs should be based on renewable energy, bio-based materials or biological nutrients that can be returned to earth safely and recyclable technical nutrients supported by functioning return chains (Blom, 2020; Lacy & Rutqvist, 2015). Regarding practice, the key sectors needing transformation, like plastics, construction and transport, are struggling to implement this approach. One of the main reasons is that the economic system is based on linear ways of doing things, and the practices for using secondary materials are only starting to take off. That reflects the price differences of primary and secondary materials, which are generally still cheaper (Ghisellini et al., 2016; The World Bank, 2022).

Secondly, recovering and recycling usable resources and energy from by-products and waste streams should be considered valuable (Sitra et al., 2018). The by-products and waste streams can be reutilised within the same value chain or sourced from another, creating an open-loop flow, minimising material leakage and maximising the economic value of product return flows. Circular inputs tend to be more local than linear inputs, due to the limitations of economically reasonable logistics. This way, business models become decentralised, focusing on local production, consumption and return (Accenture, 2014).

Thirdly, extending products' and materials' life cycles through reselling, repairing, refurbishing, remanufacturing and repurposing offers an alternative to the volume-based approach where growth is achieved by increasing throughput, while relying on cheap and infinite natural resources. This direction requires turning attention to product design so that products are durable and built in a way that is possible to upgrade and maintain (Lacy & Rutqvist, 2015). Here, a lack of a highly skilled workforce might pose a challenge, as some R-strategies, like repurposing and refurbishing, require more advanced competencies (The World Bank, 2022).

The fourth approach optimises capacity use with sharing platforms that enable shared use and ownership of resources and products. Sharing platforms make consumption growth possible without consistently producing new products and unlocking increased customer flexibility (Lacy & Rutqvist, 2015; Sitra et al., 2018).

Last but not least, product as a service models (PaaS) offer access to customers through leasing, subscribing or pay-per-use systems, while the company keeps ownership of the product. Product design, maintenance, remanufacturing, and recycling play crucial roles, and companies can stay closer to their customers (Lacy & Rutqvist, 2015).

The shift towards circularity by applying the aforementioned approaches often means creating more dynamic and collaborative value networks or ecosystems. Walrave et al. (2018, p. 7) explain the ecosystem as "a network of interdependent actors who combine specialised yet complementary resources and/or capabilities in seeking to co-create and deliver an overarching value proposition to end users, and appropriate the gains received in the process". This collaboration often requires engaging new actors, such as reverse logistics providers, recyclers, refurbishers, sharing platforms, and technology providers facilitating Industry 4.0 integration, to enable circular flows (Awan et al., 2022; Lacy & Rutqvist, 2015; Ortiz-de-Montellano et al., 2023).

Furthermore, the rise of Industry 4.0 technologies enables greater connectivity and data sharing within these networks, crucial for improved traceability, optimisation of resource flows, and the development of smart circular systems (Awan et al., 2022; Lin & Chu, 2024). As a result of these new practices, new business models and value propositions, where value is created across the network, can be realised (Harmaala, 2021; Jamadagni et al., 2024). Chirumalla et al. (2022) further highlight the importance of multi-stakeholder collaboration and creating win-win-win situations that benefit stakeholders, the environment, and society. This ecosystem perspective is key for developing resilient circular economies.

Despite the growing interest in circular approaches, real-life adoption is challenged by several barriers. Companies face micro-level challenges such as a lack of internal capacity and resistance to change, meso-level barriers like poor collaboration along value chains, and macro-level market and legislatory constraints (World Manufacturing Foundation, 2022). CE initiatives often remain within corporate social responsibility departments, risking a lack of buy-in from core functions like finance or operations. To overcome these barriers, a commitment on the management level, a cultural shift from a linear mindset, and establishing interlinked value networks are critical (Tervonen et al., 2023). To start moving toward circularity, Reike et al. (2018) invite businesses to embrace “simplicity in complexity” by using frameworks like R-strategies as a practical starting point to understand their value chain and evaluate circular opportunities.

2.2.3. Applying systems thinking and service design for circular value chain innovation

The transition from linear to circular value chains in the manufacturing sector represents a systemic challenge, demanding a fundamental rethinking of how resources flow, value is created, and how stakeholder collaboration is organised across interconnected systems on micro, meso, and macro levels (Circle Economy, 2024; Kirchherr et al., 2017; Reike et al., 2018). The European Union's commitment to a circular economy is not only an environmental objective but will also accelerate the move towards service-based economies. Policies aimed at designing out waste and extending product life cycles are expected to drive a considerable increase in the services sector's output by 2030 (The World Bank, 2022).

To navigate this multifaceted shift, a thorough understanding of the interconnectedness of value chain actors and the holistic design of circular solutions, in addition to advances in technology, is needed. Systems thinking can provide a supporting mindset for making sense of the systemic nature of circular economy principles (Circle Economy, 2024). When applied together with service design, offering a user-centric approach with practical tools for translating systemic insights into tangible innovations, CVCs can become progressively more reachable.

The systems perspective is increasingly recognised as one of the core principles of the CE (Kirchherr et al., 2017). Charonis (2021) found that a systems perspective was present in 42% of the CE definitions examined, and the systems perspective has been growing since 2012, presumably due to the influence of the formative work of the Ellen MacArthur Foundation (Kirchherr et al., 2017). Although the initial focus of CE systems perspective was directed towards the macro-level, gradually more focus is now on the meso level, especially on creating new collaborations and eco-industrial parks (Conticelli & Tondelli, 2014).

Systems thinking and service design can provide the lens and tools necessary to approach complex transitions, foresee obstacles along the way and create circular solutions that enable taking care of and staying within the planetary boundaries (Circle Economy, 2024; Rockström et al., 2024). The Circularity Gap Report 2024 highlights the role of systems thinking in developing CE solutions. It involves detecting root causes of ecological breakdown, identifying leverage points for impactful change within systems, and setting up systemic enablers such as supportive policies and financial backing, to renew the rules of the "game". Arnold and Wade (2015) analysed systems thinking through various definitions found in the literature and through its application and proposed their own:

> Systems thinking is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them to produce desired effects. These skills work together as a system. (Arnold & Wade, 2015, p. 675)

Therefore, adopting a systems perspective provides companies with a useful framework for understanding the interconnectedness of actors, material flows, and environmental impacts across the value chain. However, a human-centred approach is needed to translate this understanding into practical action and ensure the solutions meet people's needs. This is where the principles and methodologies of service design become particularly relevant for the stages from concept creation to implementation.

To make CVCs work, redefining value creation and delivery through integrated systems of products, services, and interactions is essential. In their co-created book, Stickdorn et al. (2021, p. 54) provide a crowdsourced definition by Megan Erin Miller, where service design is defined as “an approach to designing services that balances the needs of the customer with the needs of the business, aiming to create seamless and quality service experiences”. Service design is based on six core principles: a human-centred, collaborative, iterative, sequential, real, and holistic approach (Stickdorn et al., 2021).

More importantly, service design enables organisations to consider the entire customer journey in a circular context using human-centred and collaborative methodologies. This includes designing not only the service around the core product but also the supporting services that enable circular flows, like take-back systems, repair services, and product-as-a-service models (Harmaala, 2021; Moreno et al., 2016). Furthermore, the emphasis on stakeholder engagement and co-creation ensures that companies “gain true, end-to-end understanding of their services, enabling holistic and meaningful improvements” (Stickdorn et al., 2021, p. 54), making the solutions more suitable for implementation across the value chain.

As mentioned in section 2.2.2, linear value chains need to be transformed not only to closed-loop circular value chains but also into collaborative and integrated circular value networks. Combining systems thinking and service design can facilitate this by mapping and optimising interactions between diverse stakeholders. As Gomes et al. (2024) highlight, effective collaboration across value chain layers is needed to achieve the full potential of CE opportunities. Co-creative tools and frameworks can help visualise these interactions, discover the enablers, and identify the impactful leverage points.

Over the past decade, traditional service design and design thinking approaches have been evolving towards circular design, combining the mindsets and methodologies from the aforementioned, but also moving beyond individual product or service perspectives to designing circular systems (Moreno et al., 2016; Sedini et al., 2024). This evolution is visible in the development of tools and frameworks that support co-creation for circular solutions and the application of design methodologies to circular value chain development (Circulab, n.d.; Danish Design Centre, 2023; Ellen MacArthur Foundation et al., 2022; Harmaala, 2021; Santa-Maria et al., 2022). To better understand how systems thinking and service design can be applied in value chain transitions, an overview of 5 tools and frameworks is provided (Table 3).

Table 3. Tools and frameworks for CVC development

Tool/Framework	Author	Primary focus	Description	Tools/methods applied
Service Design Methodology for circular business models	Harmaala (2021)	Linear to circular business models	Case study-based research to explore how service design methodologies can be used to develop circular economy solutions and understand the willingness to adopt them in the existing customer base.	interviews, observations, shadowing, customer journey mapping, empathy mapping, service safari, user personas, design briefs, prototyping, business model canvas
Circular Business Model Design Guide	Ellen MacArthur Foundation, PA Consulting, Exeter Business School (2022)	Circular business model innovation through value chains	Practical guide for businesses to identify circular opportunities and design circular business models to create, deliver, and capture value.	circular value system mapping, partner mapping, capability checklist, pricing strategy tool, opportunity assessment
The Circular Value Chain Tool	Danish Design Centre, 2023	Circular value chains	Workshop tool to visualise current value chains, identify breakdowns, generate circular initiatives, and plan action to improve circularity.	value chain mapping, stakeholder and resource identification, breakdown analysis, circular scenario generation, action planning
Circular Sprint	Santa-Maria et al., 2022	Circular business models and value chains	Sprint based on design thinking to rapidly create or refine circular economy business models through structured activities and workshops.	problem framing, vision co-creation, context mapping, value chain mapping, customer profiling, ideation, sustainability scan, business model canvas, testing
Value Chain Canvas	Circulab, n.d.	Circular value chains	A canvas-based tool to understand and redesign value chains from a circular and regenerative perspective.	value chain mapping, stakeholder responsibility and resource mapping, opportunity identification

Source: Adapted from various sources as cited in the references.

With several tools, the transition starts with mapping and rethinking the value chain, revealing where resources are used, wasted or lost. Furthermore, business model innovation must align with changes across the value chain to effectively retain value (Ellen MacArthur Foundation et al., 2022; Santa-Maria et al., 2022). As shown in the Circular Value Chain Tool (Danish Design Centre, 2023), mapping and redesigning the value chain helps identify circular opportunities that directly influence how value is created and delivered. Thus, business model and value chain innovations are closely connected, with new business models emerging from a deep understanding of the value chain (Salminen et al., 2016).

An explanation of the main research gaps identified is provided to summarise the literature insights. Despite the increasing interest in CE across academia, industry, and policy, the field continues to face conceptual and practical limitations. One major gap concerns the emphasis on recycling and recovery at the expense of upstream strategies like refuse, reduce, and reuse that hold greater potential for systemic impact (Kirchherr et al., 2017; Potting et al., 2017; Reike et al., 2018). There is a remaining confusion around R-strategies, often reduced to linear extensions of waste management rather than real change in the business practices. The lack of clarity limits the realisation of circular value creation across value chains, particularly in manufacturing, where most efforts stay within conventional operational scopes (Tervonen et al., 2023).

Moreover, the CE literature provides a fragmented understanding of the main concepts. As Ghisellini et al. (2016) and Skýpalová (2024) highlight, inconsistent definitions and overlapping terminology hinder clarity and comparability. Without a cohesive theoretical foundation, efforts to replicate best practices and design effective interventions remain challenging. Kirchherr et al. (2017) argue that better descriptions of good implementation practices are urgently needed to sharpen both scholarly understanding and practical decision-making.

To address these shortcomings, there is a growing call for interdisciplinary approaches. While systems thinking helps uncover root causes and leverage points across complex industrial systems, service design brings structure to co-creation and stakeholder engagement, enabling actionable change. Considering the user perspective and macro-level pressures, these perspectives offer practical tools and mindsets for translating abstract CE principles into value chain innovations (Arnold & Wade, 2015; Harmaala, 2021; Stickdorn et al., 2021). However, their integration into CE research and implementation remains limited. This gap highlights the need for more research that connects theoretical foundations with real-world solutions, especially in manufacturing, where value chains are complicated and still largely follow linear ways of working.

3. RESEARCH DESIGN

Over the years, literature on design research has evolved by offering multiple perspectives for design to tackle different challenges. Frankel and Racine (2010) give insights into Frayling's three categories, a widely used taxonomy, of research for design, through design, and about design (Figure 10). Research for design aims to enable design by offering information and findings for designers to improve their project outcomes (Downton, 2003). Research through design is an approach which aims to create knowledge through an action-reflection logic to explain broader contexts, and it is widely supported by systematic design methodologies (Frankel & Racine, 2010; Jonas, 2007). Research about design explores design processes by researching what designers do, how they think and behave in different contexts (Cross, 2006).

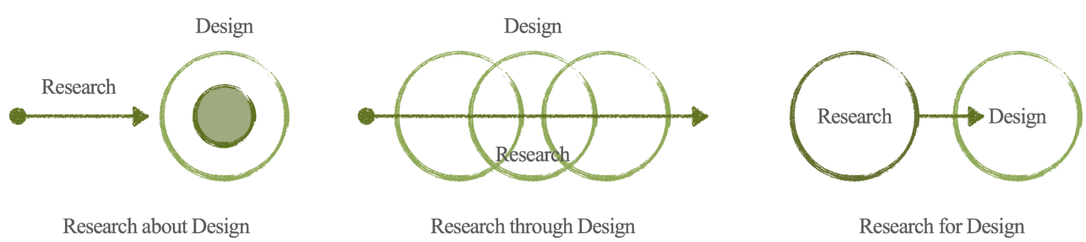


Figure 10. Three approaches to design research
Source: Adapted from Manolakelli, 2023

As the three categories have many intersections regarding their origin and process, it is common to apply a mix of elements. This study primarily focuses on the categories of research for and through design to support future designers and practitioners in achieving better results. The research uses practitioner insights to address the challenge of linear approaches (for design) and develops a framework to guide future design processes (through design).

3.1. Research philosophy

The research philosophy for this thesis is pragmatism. When adopting this philosophy, the practical consequences of the findings become the main aim of the research. A pragmatic study is focused on real-world applications and follows the idea that a single perspective of theory can't offer a complete picture, but there might be different truths (Saunders & Tosey, 2012). Pragmatism aims to balance objectivism and subjectivism, as well as facts and values, by combining theories and concepts with real experiences. The research stems from a problem and research questions that are going to be addressed by emphasising practical outcomes. Pragmatists use different knowledge and methods – qualitative, quantitative, mixed, and action research – while prioritising the collection of credible and relevant data to best address the problem and support future implementation steps (Saunders et al., 2023).

This philosophy is fitting for this thesis to explore practical transitioning and systemic changes in the manufacturing sector's value chains. The research questions are focused on providing practical outcomes: understanding key opportunities and challenges in transitioning from linear to circular VCs, identifying how R-strategies can be applied in this transition and how service design and systems thinking can support the process. The study considers multiple perspectives and different levels to understand complex changing systems. The research brings together different perspectives from the theoretical foundations of CE, R-strategies, value chain management, service design and systemic view. To interpret the findings, the researcher takes an active role in making sense of the data while making connections with the existing viewpoints.

3.2. Research method

The thesis applies a qualitative research approach to explore circular value chain innovations. Qualitative research follows inductive reasoning beginning with observation (literature review, data collection), then recognising patterns from the data (analysis, identifying relationships) to inform the making of conclusions. While the approach is data-driven, the use of existing theory can guide the formulation of research questions and objectives. The research prioritises building new insights from experience and observed patterns (Bernard, 2011; Leavy, 2017). The qualitative approach fits well with the pragmatic philosophy to arrive at solution-oriented insights. For this thesis, an initial overview of relevant literature built the basis for planning data collection and creating interview questions.

From qualitative data collection methods, semi-structured interviews were found most suitable, as they allow for making sense of interviewees' perceptions and experiences by providing an outline of topics to be discussed, while leaving space to explore unexpected directions that emerge organically (Blandford, 2014). Legard et al. (2003) explain the researcher conducting the interview as a traveller who takes the journey into the interviewee's story and interprets it afterwards, thus taking a role in making sense of data and its meaning. While the interviewer is a research instrument, they emphasise the role of establishing a good rapport and being curious to receive knowledge from the interviewee without feeling the need to demonstrate their own.

Successful interviewing involves what Legard and colleagues call effective stage-management, consisting of six steps from the beginning to the end of the interview. The author finds that relationship building starts already when recruiting the interviewees via email, as this is the first point of contact, where the potential interviewee becomes aware of the research aims and objectives. Hence, it's important to communicate the research aim clearly and offer flexible interview times, especially when targeting professionals and experts in the field. The seven steps and aims of each step are visualised in Figure 11.

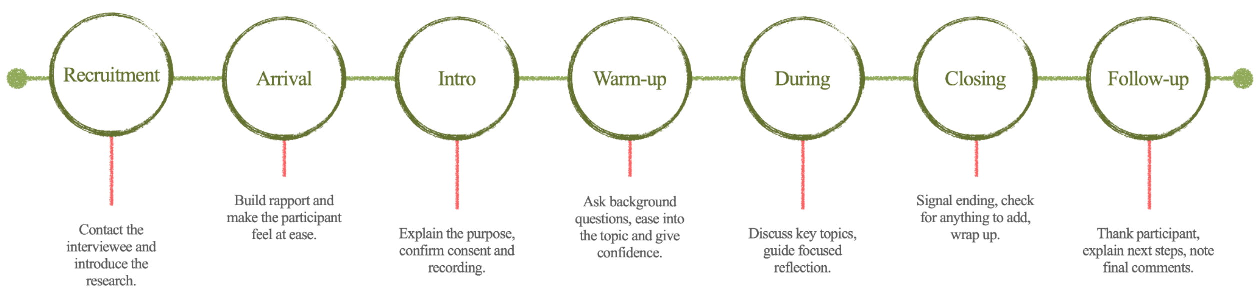


Figure 11. Seven steps of an interview
Source: Adapted from Legard et al., 2003, pp. 145–146

3.3. Research target

The target industry is the Finnish manufacturing sector, and accordingly, the primary research targets for this research are professionals (e.g. sustainability, technology and value chain management) from manufacturing companies and industry experts (researchers and consultants) from research and support organisations. The target group drives the development and implementation of circular economy practices within the Finnish manufacturing sector, making them suitable for this study and ensuring reliable insights. This group was selected as their expertise provides a comprehensive overview across micro (company), meso (network), and macro (policy, government) levels of circular value chains, supporting the study's aim to understand and identify opportunities and challenges for transitioning from linear to circular in the manufacturing industry.

The selection of the participants was based on the preliminary mapping of leading manufacturing and research organisations involved in circular development and having dedicated positions for researching or managing value chains. Additionally, snowball sampling was used to get recommendations from within the circularity ecosystem to reach the right experts, who are otherwise difficult to reach. Snowball sampling is a non-probability sampling method based on referrals from primary participants to identify others who might be relevant for the study. The method is useful for accessing specialised or hard-to-reach populations, but the limitations include a lack of random selection, potential bias due to network size, and reliance on participants' subjective judgment in evaluating the eligibility (Johnson, 2014). For this particular research, the method is suitable, as a specific expert group is in focus and the research benefits from expert referrals, as the researcher is not local and as well-connected as the study participants.

The number of interviewees wasn't predetermined, and recruitment took place throughout the data collection phase. Each interview offered a unique perspective on their company's initiatives and examples. Yet, in the second half of the process, it became evident that data saturation had been reached regarding the big-picture questions, challenges, and opportunities. This meant that new interviews no longer provided substantially new information (Guest et al., 2006), supporting the conclusion that a sufficient number of interviews (N=9) was reached.

3.4. Data collection

The data collection took place from February 17th to April 1st, conducting semi-structured online interviews. In total, 9 interviews were conducted in English with a duration of 45–60 minutes. The recruitment and preliminary communications took place via email. In the first email, the aim of the thesis was explained to the participants, and after confirmation to participate in the research, the interview questions and a consent form were sent to the participants. The interview plan also included the main definitions that the research followed to ensure all participants had the same starting point for the discussion. For example, R-strategies framework by Potting et al. (2017) was provided to avoid any confusion or unclarity, as R-strategies have different approaches. Sending the interview questions in advance worked well for this study, as the topic of circularity and value chains might touch on the work of several departments, so some of the interviewees had prepared for the interview to provide more insights.

The interview started with an introduction of the researcher and a reminder of the research aim. The interviewees had an opportunity to ask questions before the actual interview started. The interview questions followed the logic of RQs, and as the interviews were semi-structured, additional questions were asked throughout the interviews. The interview plan is provided in Appendix 1. After the interview ended, the interviewees were informed how the research process would continue. Some of the interviewees followed up via email to share links to examples discussed during the conversation. Table 4 gives an overview of all the interviewees.

Table 4. Overview of interviewees

Role	**Sector & organisation type**	**Expertise area**	**Years of experience**
CE expert	Public sector support organisation	Manufacturing, microelectronics	20+ years
CE expert	Public sector support organisation	Forestry, bioeconomy	15+ years
CE expert	Public sector support organisation	Heavy industry, CE-based business ecosystems	20+ years
Senior researcher	Public sector research organisation	CE policy, LCA, critical materials	10+ years
Senior researcher	Public sector research organisation	Data-driven manufacturing, industrial engineering	25+ years
Industry expert	Manufacturing company in the automotive industry	Supply chain coordination, CE practices	5+ years
Industry expert	Manufacturing company in surface finishing and the precision industry	Technology management, ecodesign, circular innovation	15+ years
Industry experts	Manufacturing company in the forest industry	Corporate sustainability, production	20+ years
		Waste, side-streams, nutrient recycling	15+ years
Circular actor, intermediary	Startup in circular construction & built environment	CE in construction, civil engineering	20+ years

The interviews were recorded and transcribed into Miro on post-it notes for analysis purposes. Listening and transcribing the interviews on Miro worked as an effective way of becoming more familiar with the data. After the research, all the recordings of the interviews were deleted, with only the anonymised transcribed input kept.

All interviews were conducted individually, except for one case where two representatives from the same company participated in the interview. One of the interviewees proposed this before the interview to better understand the company's approach and perspectives. One of the interviewees had a high-level view on environmental management, and the other focused specifically on circularity topics, creating opportunities to build on each other's ideas. As they were representing the same company, their answers were analysed under the same umbrella and named P8.

All interviews were conducted with Finnish manufacturing companies or research and support organisations directly connected to the Finnish CE landscape, except for one company. Although this company was originally founded in Denmark, it operates across Northern Europe and was selected for its relevance as a born-circular actor. The company offers an example of a role model, enabling value chain collaboration and acting as a connector between different stakeholders. This example was used to give recommendations for the future when transitioning value chains.

4. RESULTS AND FINDINGS

This chapter presents the empirical findings of the study, which were based on interviews with the Finnish manufacturing sector. The analysis explores how CVC innovations are perceived, initiated, and implemented by applying a multi-level perspective. The findings reveal enablers, barriers, and trends that shape the transition from linear to circular practices.

4.1. Data analysis

In this study, data gathered from semi-structured interviews were analysed using thematic analysis within the MLP framework. Thematic analysis identifies and interprets patterns and themes across a dataset. It focuses on mapping shared meanings and experiences, helping to make sense of how a topic is commonly discussed or perceived (Braun & Clarke, 2012). The method is suitable for a pragmatist philosophy focusing on practical outcomes and real-world applications to understand how experts perceive and implement circular practices across value chains. Braun and Clarke (2012) divide the process of thematic analysis into 6 phases: familiarising with the data, creating initial codes, identifying themes, refining themes, defining and labelling themes, and compiling and presenting findings.

The MLP has proven to be an effective analytical tool for interpreting socio-technical transitions and their complexities in sustainability (Ahmadov et al., 2025; Geels, 2011; Walrave et al., 2018). Socio-technical transitions refer to systemic changes needed to overcome societal challenges and address environmental problems, such as climate change and resource depletion. These transitions require changes in policies, markets, consumer behaviours, and infrastructures, involving a wide range of actors and resulting in long-term processes (Geels, 2011).

The MLP views transition processes as the outcome of interactions between developments on three analytical levels: micro, meso and macro. The micro-level perspective focuses on company-level activities and innovations, including factors such as strategy, culture, processes, and structures, which, for example, shape how a company creates and delivers value in CE (Ahmadov et al., 2025; Geels, 2006). At this level, radical innovations challenging existing norms are developed within niches, such as R&D departments or subsidised projects, planting the seeds for systemic change (Geels, 2011).

The meso level represents the socio-technical regime – the valid and established rules and practices that guide the behaviour of markets and supply chain partners. This includes laws, standards, business models, and consumer habits. While providing stability, regimes also create lock-ins, making change difficult, requiring collaboration within industrial ecosystems and regional networks to influence each other (Geels, 2006, 2011). At the macro level, the sociotechnical landscape provides the broader societal, political, economic, and environmental context, making changes slow. It includes drivers, like cultural values, regulatory changes, and global trends (e.g. resource scarcity) that shape regimes and niche transitions (Geels, 2006).

Figure 12 illustrates the MLP, showing how transitions arise and evolve through the interaction of three levels. Niche innovations (micro level) develop momentum, while pressures from the socio-technical landscape (macro level) challenge existing systems. This results in meso-level destabilisation, creating opportunities for new developments to break through. These changes are driven by interconnected processes across levels rather than a single cause (Geels, 2002, 2011).

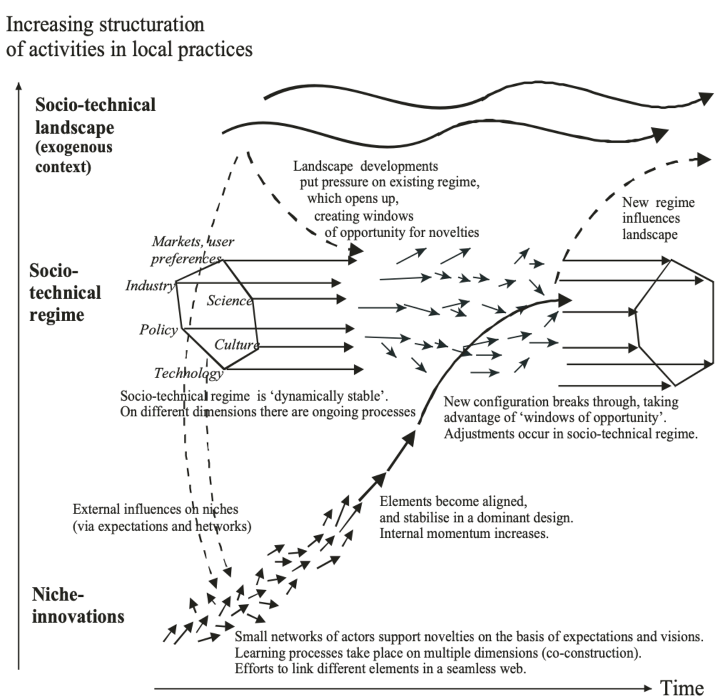


Figure 12. Multi-level perspective on transitions

Source: Geels, 2011, p. 28

Ahmadov and colleagues (2025) analysed articles focusing on SMEs' transition to a CE using the MLP framework. They concluded four themes for each level:

- micro level: strategies, resources and capabilities, management and leadership, innovation and digitalisation;
- meso level: supply chain practices, the role of consumers, the role of associations and networks, engagement and collaboration;
- macro level: taxation and incentives, regulatory policy, collaboration and partnerships, advocacy and awareness.

The systematic literature review and case study analysis by Trevisan et al. (2023) targeted the multi-level nature of barriers to CE adoption, revealing eight categories of barriers: knowledge management, financial, process management and governance, technological, product and material, reverse logistics infrastructure, social behaviour, and policy and regulatory.

The data analysis process was as follows, applying thematic analysis and MLP. The data were familiarised with, and initial coding was done by listening to the interview recordings and transcribing them to Miro, where one idea was inserted per post-it and followed the general topics outlined during the interview. Then, re-reading the data points helped to dive deeper into the content and start noticing themes connected to the main research questions. Themes were reviewed in alignment with existing research that applied the MLP framework.

Then, a clear structure for themes was established on all three levels of MLP about the study's current aims. Finally, findings were formed by synthesising patterns across interviews and contextualising them within existing literature to highlight relevant circular value chain drivers and transition barriers.

4.3. Findings through a multi-level perspective lens

In this section, the insights from expert interviews are analysed to offer a multi-level view of how circular value chain transitions are unfolding in the Finnish manufacturing sector. Based on the MLP, the findings are structured to move from macro-level forces to meso-level developments within value chains, and then to micro-level company strategies and mindset shifts. This approach helps understand how broader systems, inter-organisational practices, and internal behaviours shape progress toward circularity. The chapter concludes with synthesising enablers, barriers, and evolving trends.

4.3.1. Macro-level forces shaping circular transitions

First, policies and regulations are central in shaping circular value chains. The interviewees view regulation as a driving force and a necessary tool to encourage companies to move towards greater circularity. Regulatory mechanisms, such as ESPR and CSRD, help establish clear rules for making products more recyclable, reusable, and resource-efficient while promoting transparency. Importantly, regulation is viewed as a tool to align market behaviour with broader societal and environmental goals, and thus help companies plan for the future.

However, many interviewees highlight the downside of regulations, specifically their complexity and how they overlap or even conflict with existing national laws. A recent study on the cumulative effects of EU sustainability legislation (CEULA) on Finnish companies noted similarly that companies often interpret regulatory obligations differently, leading to overcompliance or inconsistent implementation across sectors (Cambou et al., 2025). For example, waste and chemical regulations (e.g. REACH regulation) often hinder material reuse and productisation efforts. Long and rigid environmental permitting processes can be major bottlenecks, limiting the application of circular practices.

> Companies can't realise many good ideas due to overlapping regulatory frameworks and slow permitting processes. So even if a construction company is interested in our side streams, they might not have the right permit, and the opportunity is lost. – Industry expert from a forest industry company

Furthermore, politics and public opinion affect how strict the regulations are. Because political systems depend on votes, some changes take a long time or don't happen. "Some companies complain that regulations are unfair," explains a CE expert from a public sector support organisation. Within the EU, excessive regulation can reduce competitiveness, especially compared to the US and China. While regulations are essential to guide systemic shifts, they must be more transparent, straightforward, and better aligned to support companies in making real progress.

> Some things that need to be done are extremely unpopular, but we have a moral obligation not to give in to them. We must believe that our system is correct and more aligned with nature. – Industry expert from the construction industry

Secondly, the role of economics and geopolitics surfaced at the macro-level discussions. One interviewee suggested that pricing issues should be considered a substantial portion of the challenge in transitioning to circular value chains. For example, the price of recycled materials is often connected with the resources needed for their processing. “If recycling demands a lot of energy, chemicals, or water, it's only fair that the price is higher, and shouldn't be artificially suppressed by regulation,” explained a senior researcher focusing on LCA and policy-related issues. With the support of product design and advancements in recycling technologies, the long-term goal should be to develop products and materials that are easy to recycle and require fewer resources, resulting in lower costs and high-quality outputs.

Geopolitical dynamics come into play in the context of raw materials and circularity, and were mentioned by all the interviewees. Concerns were raised about Europe's critical raw materials, as “we don't want to be reliant on others”, explained a senior researcher. The issue of exhausting certain raw materials is also connected to price increases, further underscoring the importance of circular solutions. Interviewees highlighted how global powers strategically position themselves to secure access to vital resources, like potential conflicts over minerals in Greenland and the strategic importance of Ukraine's subsurface resources.

The turbulent global landscape, in turn, augments the topic of supply chain security. A CE expert focusing on manufacturing and microelectronics highlighted that the energy crisis triggered by the war provided a financial incentive to explore more resilient and circular alternatives.

> If we look at the geopolitical situation, it's really about securing the supply of critical raw materials. Circularity is one way of creating that security by becoming more dependent

> on internally generated and secondary material flows. – CE expert in forestry and bioeconomy

The 2024 World Manufacturing Report (Romero et al., 2024) also reflects on this concern, with resource nationalism and supply disruptions becoming major tipping points that affect global manufacturing. The report notes that the demand for critical materials is expected to double in the coming years, while geopolitical conflicts and export restrictions (e.g. for lithium and nickel) are intensifying. As countries seek to reduce reliance on foreign suppliers and protect domestic access, circular practices are increasingly viewed as strategic tools to manage risks and create competitive advantage through resource efficiency.

Financial institutions increasingly influence the shift towards circularity through investment and lending decisions. “Once again, we get back to money, as more and more private banks, investors, and grant providers are asking how sustainable your business is,” a public sector CE expert shared. With local banks increasingly posing questions about sustainability when considering loan applications, even for smaller businesses, companies’ access to capital is directly affected. Financial viability is becoming increasingly intertwined with environmental responsibility, encouraging the adoption of more circular business models.

Thirdly, the roles of societal pressure and responsibility allocation were also mentioned as macro-level considerations. Several interviewees highlighted a paradox: while Finland performs well in CE listings regarding activities and awareness, its high welfare status often correlates with overconsumption, a characteristic of the Shift countries. In 2024, Finland scored 25% on the Circular Business Index (CBI), the highest among Nordic countries, but still indicates substantial room for improvement (Bajuk & Linder, 2024).

> If we look at how much waste we are producing and our circular materials use rate, then the situation is really bad. We are wasting a lot, consuming a lot, and using many resources to meet our consumer needs. – CE expert in forestry and bioeconomy

While Finland has the potential to become a leader in circular solutions and technologies for the global market, a degree of humility is essential to maintaining and providing localised approaches.

Interviewees also raised concerns about public perception and the credibility of sustainability claims. “We need to build fair and credible mechanisms to prove the worth of sustainability and avoid greenwashing. We have to build a system where everybody is happy, which takes time,” addressed a CE expert from a public sector support organisation.

The question of who should take the primary responsibility for driving this transition gathered varied responses. The complexity of the current linear system, in which consumers are “trapped”, was highlighted, as one interviewee pointed out, many consumers in high-cost-of-living countries might opt for cheaper, less sustainable goods to optimise their personal finances. “Many people have Temu installed on their phones and purchase from there, but they should not do it; it's not sustainable. People are optimising their own lives and needs,” said an industry expert. Furthermore, the economic realities often make environmentally conscious purchasing a significant financial burden for average consumers. A shift towards more sustainable consumption patterns requires a broader systemic change addressing individuals' economic constraints.

Beyond consumer behaviour, the responsibility for adopting circularity extends across the entire value chain and involves multiple stakeholders. While some argued that companies should proactively invest in sustainable R&D, others emphasised the necessity of concrete legislation across industries and that “responsibility cannot be put on one player”. An automotive industry expert pointed out that “for large and profitable companies, customers can only do so much, and there should be governmental force that incentivises or punishes the use of raw materials.”

Achieving real impact needs equal responsibility from producers, service providers, brand owners, and subcontractors. When discussing the role of manufacturing companies, a technology manager at a manufacturing company specialising in surface finishing explained that “we have limited capacity in our organisation and don’t have the knowledge on all the specifics”.

Ultimately, a collaborative approach across the entire value chain, where everyone does their part, is deemed essential, but “to be fair, it sounds a bit like utopia”.

The macro-level landscape presents a mix of drivers and constraints for the circular transition. While supportive policies and regulations are essential, their implementation is put to the test by complexity and potential conflicts. Economic aspects, particularly the pricing of recycled materials and geopolitical events that influence raw material availability and supply chain security, also affect the external environment. Moreover, societal pressures and the ongoing debate about responsibility distribution underscore the need for a shift in consumption patterns and a collaborative approach throughout the value chain. However, these macro-level forces impact the existing practices within industrial ecosystems and value chains – the meso-level. The following section will explore the evolving value chain practices and the role of collaboration among stakeholders in facilitating this move towards circularity.

4.3.2. Evolving value chain practices and collaborations

On the meso-level, B2B customers and end-consumers play a crucial role in driving demand and influencing companies’ actions. Interviewees feel pressure from their customers, particularly larger corporations, who increasingly demand that their suppliers take steps towards environmental responsibility. A senior researcher focusing on data-driven manufacturing used Outokumpu, a producer of sustainable stainless steel, as an example, asking their subcontractors to report on their sustainability actions and environmental impact.

While cost-effectiveness remains a significant factor in purchasing decisions, sustainability is becoming an important criterion, with companies seeking more sustainable suppliers. However, this can cause difficulties for companies as they might not have enough resources or the right capabilities to meet the requests. A technology manager of a surface finishing solutions manufacturer explains:

> Our sales and customer service receive questions from customers about how our products can help them lower their GHG emissions. Every now and then, I also get long Excel

> sheets with product information to fill in, but we don't always have the resources to answer them.

The challenge for suppliers in meeting these demands, especially regarding limited resources for data provision, points to a need for support mechanisms and standardised reporting frameworks. Equally important is the companies' awareness, as “not all companies have woken up to this issue that we are expecting the data,” emphasised a CE expert in forestry. This finding is supported by the CEULA project, which identified a strategic divide (Cambou et al., 2025). Some Finnish companies are already well-prepared and investing in tracking tools, certifications, and long-term planning. Others, however, remain reactive, focusing on compliance and reporting rather than proactively redesigning products or processes. Additionally, the demand for environmental data highlights the importance of transparency and traceability in circular supply chains, which can be facilitated by technologies like blockchain and digital product passports (Awan et al., 2022; Lin & Chu, 2024).

On the upside, more and more collaborations are emerging in the Finnish market, supporting circularity efforts. A senior researcher, focusing on CE policies and critical materials, said, “In the Finnish market, as it is relatively small, companies find collaborating with domestic value chain partners rather easy and are quite open to discuss their problems”. However, companies are also often part of global supply chains, making it a challenge to find new circular collaboration opportunities. “For now, it feels like all the companies are in the dark and looking for each other blindfolded; sometimes they bump into the correct partner and sometimes not,” noted an automotive industry expert. This highlights the need for meeting places and platforms that connect businesses to develop CE initiatives.

A CE expert focusing on manufacturing and microelectronics and a circular construction industry expert stated that closed-loop circular models are challenging to achieve. “Your own demolition material might not make sense to use in your next building, due to the way infrastructure is set up, it will be way too expensive,” the industry expert explained. For this reason, networks where one company uses another's waste or by-products are more realistic, resulting in industrial symbiosis. A CE expert pointed out that Wärtsilä, a company developing innovative technologies and life cycle solutions for the marine and energy markets, demonstrates a good symbiotic relationship by utilising waste materials from the Central European automotive industry. “They buy all waste steel because it's very high quality and its properties are well known, so they can melt it down and build engine blocks.” Another example of value chain collaboration comes from the forest industry – Betolar reduces CO2 emissions in concrete production by utilising cross-industry materials, like mining and forestry, demonstrating an innovative mix of value chains. “We need to support the entrepreneurship element in circularity to have more of these examples,” a public sector CE expert recommended.

Collaboration and co-creating solutions with customers can be problematic, as contact is often limited to situations involving problems or price negotiations. A CE expert discussed their experience working on CE-based ecosystems, stating, “If the product is working and the price is good, customers are seldom willing to change anything – they just want to keep it as it is. They're happy, so why take the risk?”

Moreover, subcontractors often face difficulties securing research funding and may lack the same influence as larger contractors. One opportunity is to build strong customer relationships and form strategic partnerships to gain more influence. Another way for subcontractors is to diversify by developing their own product and running two business models in parallel.

> As a subcontractor, you produce for the customer and answer their requests. But how to affect your level? If you don’t have your own product, getting funding from Business Finland is more difficult. – Senior researcher in data-driven manufacturing

At the meso level, programs and co-innovation projects that support collaboration among diverse stakeholders significantly boost CE advancements and niche innovations. In Finland, leading companies actively participate in shaping these innovation ecosystems, partnering with consultants, universities, research companies, and other public sector support organisations. Interviewees provided examples of programs such as the SHAPE ecosystem, the Finnish Circular Design Program, the Sustainable Manufacturing Finland program, the Bio and Circular Finland program, and the Nordic Circular Accelerator. A CE expert in forestry and bioeconomy said,

> Leading companies like Mirka and Valmet collaborate within their innovation ecosystems. They need partners from Finland to join their projects – sometimes, there are over 100 companies in these ecosystems. The SHAPE ecosystem, for example, is a great one, considering many R-strategies.

A former program manager expressed concerns that while these programs demonstrate a strong commitment to circularity, significant challenges remain in securing funding and scaling up the solutions. One of the program's main goals is to make companies think about what sustainability means for them and how they can realise the business opportunities. "The program also introduced the carbon handprint thinking to broaden the perspective from managing one's own environmental impact to exploring how we can help other companies," elaborated a CE expert in manufacturing and microelectronics. Additionally, several interviewees highlighted the exchange of ideas and sharing best practices as a strong benefit of these programs and collaborative projects. "The circular infrastructure is still developing, and collaboration networks make it possible to hear who is working with whom in terms of recycling and reusing," an automotive industry expert noted.

Due to the increasing awareness of environmental impacts and the consequences of wasteful processes, entirely new actors and businesses are taking on the role of intermediaries in material loops. Interviewees from manufacturing companies are generally positive about these specialised businesses. An environmental manager from forestry believes these new partnerships will be a game-changer, but acknowledges that the service provider ecosystem is still developing.

> Our focus is on producing our products in a sustainable and recyclable way. Still, we also generate various process waste that we cannot use ourselves or don't understand on the technical side. We hope these service providers will make it their core business and can make a good business from it. But we are not there yet.

While most interview insights came from Finnish companies, one exception was a Denmark-based circular actor included for its pioneering business model. This company connects waste producers, manufacturing partners and end-customers, using waste flows to design new products. Their work covers three types of material flows: manufacturing defects, post-consumer waste, and demolition waste. “We work hard to ensure that we have a steady inflow of waste,” the company representative explained. “Sometimes we’re just working on connecting the dots,” referring to the need to educate building owners, architects and other partners.

The company sees clear business potential where others might overlook it. “What we call waste here, you wouldn't call waste outside Europe. Very fantastic materials are being incinerated and discarded, and much value remains unused.” They design and develop circular products and then work with producers, sometimes even co-investing in production setups. However, building a market for these products isn’t always easy. “We are working heavily on creating the market demand,” they shared.

Many of the materials they work with could be reused by the original producers, but internal limitations often block this. “Some of the things we do or sell could be done by the companies we work with themselves, but they have a different strategy and mindset,” the interviewee noted. These new actors help shift thinking, reduce waste, and create business opportunities within circular systems by stepping in as intermediaries.

The emergence of new circularly born actors allows traditional manufacturers to concentrate on their main focuses while relying on others for end-of-life management. A senior researcher focusing on LCA and policy-related issues pointed out that “not all manufacturing companies need to become service providers, it's just not the intrinsic value that all companies need to own their products all the time.” The interviewee then also underlined the role of product design and feedback loops to, so that insights on user needs from the use phase would get back to the manufacturer or product designer, so they could, in turn, refine the design and material choices, making sure products are designed to be disassembled, repaired and built to last.

As mentioned, value networks can be formed by finding new applications for unused waste streams and by-products, so that one company’s waste becomes another’s input. “So far, such symbiotic situations are rather unique, because supply and demand have to match to make economic sense, meaning that there is a constant supply coming in,” mentioned a CE expert in manufacturing and microelectronics.

Additionally, assessing the technical suitability of materials, ensuring compliance with environmental standards, and having clear pricing and contractual agreements are particularly important in these collaborations. “In general, as long as something is waste from a regulatory perspective, an environmental permission is needed to receive and handle that waste,” a CE expert in forestry pointed out. Several interviewees emphasised the importance of having clear written agreements on pricing and a supply guarantee. “We have seen that in some cases companies get jealous because somebody started to do business from the waste,” a CE expert working on CE-based ecosystems explained. Another industry expert added that “people are always optimising…and the problem is, when a CFO sees that what they used to pay €1000 per tonne to burn might now be worth €1000, it can obstruct the green transition”.

Moreover, logistics plays a critical role in shaping these value networks. As several experts pointed out, access to service providers and recycling technologies is highly location-dependent, meaning that the same circular solution might be feasible in one area but not another. The distance materials need to travel strongly influences a circular business case's economic and environmental viability. Several interviewees shared that a reasonable transportation radius is from a few tens of kilometres to a hundred kilometres, depending on the weight and value of the side stream. Beyond 100 kilometres, the costs and environmental impacts start to outweigh the benefits. For plastics and textiles, longer transport distances are acceptable, but the viable radius shrinks significantly for heavier materials such as glass. Interviewees highlighted that planning logistics must be integrated early in the design of circular systems. According to a senior expert focusing on LCA and critical materials, one option is to “integrate logistics into an existing transportation system, rather than building additional transportation capacities.”

In conclusion, successful circular value networks are both material- and location-specific, as every material stream requires a case-by-case assessment. Among others, cost efficiency, regulatory aspects, a combination of weight, packaging efficiency, transport distance, available technology, and the balance between constant supply and demand need to be considered. An industry expert concluded, “it's not so simple to put circularity first yet”. In contrast, a public sector CE expert sees the need for “developing long-term thinking, as companies are still very focused on the next quarter”.

The meso-level analysis points to the existing linear socio-technical regime. With company and network initiatives, as well as developing regulatory frameworks and infrastructure, circular disruptions might break through. Recent studies also highlight strong value chain collaboration as an enabler of circularity, promoting systemic change towards sustainability (Gomes et al., 2024; Ortiz-de-Montellano et al., 2023). The following section will explore circular strategies and the necessary mindset shifts within manufacturing companies at the micro level.

4.3.3. Circular strategies and mindset shifts in manufacturing companies

On a micro level, the transition towards circularity requires changes in company mindsets, business strategies, and operations. According to the interviewees, circularity in manufacturing is gaining visibility and is primarily driven by regulations, customer expectations, and cost-efficiency goals. Larger companies and listed firms are leading the development of circular practices, according to a CE expert from a public sector support organisation. “Mostly, companies are thinking of their emissions and energy usage, and looking increasingly into circular materials.”

As Finland has a versatile group of companies, the adoption of CE varies quite a bit. On one hand, “traditional large companies are quite conservative but have a lot of money to invest in sustainability; it just takes time to change the direction of this large ship, but they are doing their best,” notes a senior researcher focusing on CE policy and critical materials. On the other hand, startups and SMEs are more flexible. Still, they need to balance sustainability actions with answering their customers using minimal resources,” explains a senior researcher focusing on data-driven manufacturing. Compliance is a given for larger companies, and they have built the necessary capabilities for ongoing monitoring. “Compliance is crucial, and we started several years back – we have a separate compliance department continuously monitoring the emerging issues and taking care of certifications and product safety,” explained a technology manager in surface finishing manufacturing. So, both sides have advantages and challenges, but interviewees say that companies understand the meaning and importance of the topic but struggle with choosing the right direction.

Interviewees notice that the circular mindset is somewhat ingrained in the manufacturing sector's DNA. Continuously improving processes and quality while reducing inefficiencies is nothing new to manufacturing companies within the lean thinking framework. This mindset is evolving through new engineering approaches that consider circular design practices. "For instance, people have started complaining that home appliances are almost impossible to repair, and now, there's a growing shift back to designing items that can be disassembled, fixed, and reassembled," noted an industry expert. A difficulty from a continuous improvement mindset is that materials have been designed with the best performance in mind. "The shift to mono-material solutions has a long development curve, as design choices have been optimised for performance rather than circularity," the technology manager added.

Several interviewees highlighted the role that leadership plays in shaping the overall mindset. Sometimes, the push for circular initiatives comes from the management or owners, as business continuity is in their interest. "The management saw that single-use products are under the radar in the EU, and although not directly impacting our products, they have a short life cycle, and we saw it as something to tackle," explained a technology manager in surface finishing manufacturing. Leaders also play an important role in shaping the organisational culture. An automotive industry expert explained how cost-cutting initiatives are always welcomed, but "by cutting costs, you should also minimise the negative impact on the environment."

Companies are largely driven by cost-saving opportunities, such as optimising warehouse energy use, minimising material loss during production, or extending equipment lifetime through maintenance and repair. These decisions are often purely economic. "Of course, you repair and maintain your equipment so their lifetime is as long as possible," a CE expert in manufacturing explained, "and if the maintenance of old machines costs the same or more, that's the moment companies bring in the new equipment." While circularity is advancing and has been included in some companies' strategic targets, companies will act based on a clear business case. "You can think big, but everything comes down to money," admitted a CE expert from a public sector support organisation. An environmental manager in forestry added, "in all this, we want to grow as a company, so sometimes we produce more side streams because we are increasing our production."

While legislation, customer demands and cost-cutting dominate as drivers, some companies see circularity as a source of competitive advantage. This includes opportunities for market differentiation, brand image, and creating value through new business models. As a public sector support organisation, CE expert noted, “Some companies want to be pioneers and prepare for the upcoming changes – there is a risk of putting some technologies to use too early, but they see potential to take some future markets.” Additional motivation comes from investor pressure, and in some cases, from internal sustainability values, where environmental responsibility and long-term resilience are seen as strategic imperatives. These overlapping forces show that while the transition may begin with compliance or cost, it can grow into a broader business value and identity transformation. “Creating new added value for the end-customer should be the main driver,” says a CE expert in bioeconomy and forestry.

When discussing R-strategies' application in Finnish manufacturing companies, interviewees introduced many examples from their experience and the industry. Some R-strategies are more relevant and feasible than others – while optimising (reduce, reuse) is seen as “a common practice” or “a question of great engineering”, more radical strategies, such as refuse and rethink and service-focused approaches are more difficult to apply or not so familiar to the companies yet, especially when requirements around quality and safety are strict, like in electronics or machinery. Among the Nordic companies, the most common circular strategies are reduce (85%) and recycle (74%), mainly since application is possible without changing the business model, organisational structure, or logistics (Bajuk & Linder, 2024).

Interviewees agreed that sector- and product-specific dynamics dictate, to some extent, R-strategies' applicability. For example, metals are well-suited for efficient recycling, as their value remains high. In contrast, recycling textiles is resource-intensive and loses value with every round, making it less economically viable. “The automotive industry is investing in R&D efforts to use alternative fuel and reuse materials, not to tip into natural resources as much, but when talking about cars – the most dangerous way of transportation – the regulations for quality are extremely high to make the most dangerous transportation as safe as possible,” described an automotive industry expert. Additionally, interviewees expressed that some R-strategies are simply outside their control when the value chain gets too long or complex. “We can't influence much if someone decides to reuse or not the timber we have manufactured, it's not in our hands anymore," said an industry expert from forestry.

Entirely refusing production, materials, or components was seen as one of the least visible strategies in manufacturing. Many interviewees admitted that it's difficult to apply or recognise, as companies typically produce what the market demands. "One where I haven't got any examples is this refuse model – where does it work?" asked a senior researcher focusing on LCA and critical materials. However, some companies implement refusal indirectly by avoiding harmful substances. "We have long lists of forbidden chemicals not used in our products, because otherwise it might produce hazardous waste that cannot be recycled," explained a CE expert in forestry. Refusing product lines based on weak business cases was also mentioned, guided by economic reasons, not circularity principles.

Rethinking business models, products, and usage patterns is slowly evolving in the manufacturing industry. Leasing models and shared production capacity appear in some contexts, such as high-cost machinery. "Some companies are selling the production time, so if someone has a part they're not producing that often, it doesn't make sense to own the machine," elaborated a CE expert working on CE-based ecosystems. Transitioning to service models raises questions about ownership, maintenance responsibility, and internal capacity.

> To rethink their products, manufacturers would need to become service providers. It's difficult because the sector is still quite traditional, and many companies aren't sure if they want to manage multiple business models or whether it would be profitable. – Senior researcher in data-driven manufacturing

The Circular Economy Outlook Nordics 2024 report shows that Finnish companies apply the rethink strategy more than their Nordic peers (41% in Finland vs 20–26% in Norway and Denmark). Still, its overall execution remains low, and business case uncertainty is a significant barrier (Bajuk & Linder, 2024).

Philips rethought its product and business model by launching a rental system for its IPL Lumea device, supporting its circularity goals. Since it wasn't designed for refurbishment, the company faced hygiene, quality, and logistics challenges. Philips addressed this by co-developing a strict refurbishment protocol with supply chain partners, enabling a high-standard, service-based model (Ellen MacArthur Foundation, 2023).

A senior researcher in LCA and critical materials pointed out that similar service models in other sectors, like textiles, may come with unintended environmental trade-offs. “Worst case scenario is that it's a European company that sends the clothes to another country to be cleaned and then to another country again; this comes with a very high additional environmental footprint.” This highlights the importance of a system perspective, considering the full life cycle and logistics when rethinking products as services.

Reduction strategies are deeply rooted in manufacturing, thanks to long-standing efficiency practices. Companies actively reduce energy and material use, optimise packaging, and minimise process waste, as well as their heating and transportation footprint. Driven by cost-saving and environmental targets, many interviewees viewed reduction as the most natural and widely adopted strategy. “Reducing is about optimising processes that are in focus anyway, as the price of electricity and water is growing; it's the normal way of doing things,” a senior researcher in data-driven manufacturing stated. This is strongly supported by existing research. According to previous research, the reduction strategy has the highest rate (46%) and is also accompanied by clear targets for business operations. Strategies with defined and measurable goals are implemented six times more likely than those without. (Bajuk & Linder, 2024).

However, interviewees questioned whether any business would truly benefit from reduced overall demand and supply, suggesting that deep reductions in consumption may still conflict with traditional growth models. A senior researcher focusing on LCA and critical materials shared a service-based model from the metal industry, where customers paid based on material throughput, incentivising both seller and buyer to minimise resource use. In such setups, profitability is linked to process efficiency rather than the volume of products.

Reuse strategies vary across sectors and are often constrained by value chain visibility. According to the interviewees' examples, reuse is mainly applied through returnable packaging systems and the continued use of production equipment. “Buying and reusing other manufacturers' old equipment is standard practice, and has always been there," noted a CE expert in manufacturing and microelectronics. However, companies often lose control of their products after sale, limiting their influence over downstream reuse, due to a lack of traceability or customer willingness.

Life extension strategies, such as repair, refurbish, remanufacture, and repurpose, were often discussed together by interviewees. In equipment-heavy sectors, repair is a common practice – for example, an interviewee mentioned Valmet, which remanufactures tractor engines, and spare parts are routinely offered to extend machinery lifespan. The Circular Economy Outlook 2024 Nordics report confirms that repair is the strategy where Finland leads the Nordics, with 62% application and strong revenue or cost savings reported by 54% of companies (Bajuk & Linder, 2024). In consumer electronics, new circular actors like Swappie enable refurbishment, giving products a second life through resale. And sometimes, it can even be the case that manufacturers don't have the information on repairing or remanufacturing. "Again, we come to the lack of data – manufacturers are in the dark about who and how is using the products," noted a senior researcher in data-driven manufacturing.

While remanufacturing is gaining traction in industrial contexts for high-value components, it requires careful planning and scale to succeed. Repurposing wasn't widely referenced, but dependence on cross-industry collaboration and lack of a systematic approach were highlighted. "Life extension strategies are more relevant for B2C products," an industry expert in forestry noted. "The challenge is in collection – how to gather second-hand items, whether consumers will accept them, and how to price them." Repurposing was not widely referenced, suggesting that it remains an informal approach highly dependent on collaboration and case-specific creativity.

Recycling is one of the most common and mature strategies in manufacturing. Metals are a clear success story due to their high value and ease of recovery, while plastics and textiles remain challenging due to the loss of quality over time. Many companies support recycling through sorting systems and investments in infrastructure. However, several interviewees noted that recycling is often over-relied on, seen as the default solution, even when higher-value strategies would offer better environmental outcomes. "In my mind, it is the last option of CE that you merely recycle the materials; you should catch the CE value much earlier than recycling," criticised a senior researcher focusing on LCA and critical materials.

Market conditions sometimes drive incineration. "Some of our products have a (too) high energy value, making incineration quite attractive in the current energy market," explained an environmental manager in forestry. This highlights how economic incentives can sometimes work against circular hierarchy principles, favouring low-value recovery over strategies that preserve materials in use.

Energy recovery through incineration is widespread in Finland. In 2022, energy recovery through incineration was the most common waste treatment method, making up 56% of the total (European Environment Agency, 2025). Several interviewees questioned whether it aligns with long-term circular goals. "I'm not sure it fits under the circular economy in the future; CE wants to maintain the value in materials, and when we burn the materials, we lose the value in them," stressed a technology manager in surface finishing manufacturing. Some suggested that recovery should be a last resort rather than a strategic focus. Despite its efficiency in terms of energy, recovery is increasingly seen as a linear fallback rather than a truly circular option.

Companies are beginning to move beyond end-of-pipe strategies, such as recycling and recovery, towards deeper changes in how they source, produce, and create value. A clear circular vision and specific goals are a strong starting point for a company's transition toward circularity. One manufacturing company said, "Two years ago, we established a sustainability vision that includes cleaner environments, social impact, and circularity." This kind of top-level commitment creates alignment across departments. However, according to the Circular Economy Outlook 2024 Nordics (Bajuk & Linder, 2024), only 4 in 10 companies across the Nordics have set measurable goals, highlighting a common struggle in moving from ambition to execution.

Interviewees reflected on struggling to "choose the right direction" despite understanding the topic's importance. A public sector CE expert emphasised, "The starting point needs to be that there is strategic will and the idea that we want to create competitiveness there."

Companies begin by mapping their existing operations and analysing material flows to better understand the existing value chain and inefficiencies. An industry expert recommended reading through R-strategies and then starting to think about what your circular future could look like. This early reflection is supported by creative foresight tools, like the three horizons model, to discuss long-term shifts and visualise the change process.

Additionally, interviewees stressed that there is “no one way” and that “nobody knows these answers, but we are part of the answer.” In practice, this means engaging others: “we are educating our purchasing department so they can have better discussions with our suppliers' and “finding the right partners in the value network”. Referring to some successful program experiences, a public sector CE expert recommended that “companies need to come together and think with suppliers and customers – is there a chance to make the supply chain circular?”

Understanding the regulatory landscape early in the process is key to avoiding setbacks. As one interviewee said, “Start the regulatory dialogue early and think about whether you need productisation, certifications, or an environmental permit.” Companies can also take an active role in shaping the regulation. But at the end of the day, almost all the interviewees mentioned the importance of collaboration, with an industry expert highlighting that “you can’t do this alone; real redesign needs facilitation, a team, and support”.

4.3.4. Main enablers, barriers, and future directions for circular value chains

While linear value chains remain the default in manufacturing, their limitations are becoming increasingly visible. They offer predictability, stable pricing, and well-established supplier networks. “Linear value chain is straightforward – you know the best suppliers, logistics is clear, go on Google and check the average price, where to get a better price,” described an automotive industry expert. However, their downside lies in heavy reliance on finite virgin materials and a lack of traceability after the product is sold. One expert noted, “If we continue using non-renewables, we’ll reach the end.”

As an answer to the issue, circular value chains offer increased resilience, reduced resource dependency, positive brand positioning, and unlock insights to move towards product life extension and new business models. “Circular value chains are more valuable,” said a senior researcher in data-driven manufacturing. But these benefits come with the need to resolve complex issues – ensuring the quality and consistency of secondary materials, managing short transport radii and figuring out new collaboration models and agreements. “Waste flows are opportunities, but they’re still waste – the challenge is who ensures the quality stays stable and fits your process,” questioned a CE expert working on CE-based ecosystems. Also, logistics can be a deal-breaker in remote regions, as “in Lapland, the sources are too far, 200 to 300 km north, and then it's not economically reasonable already,” a CE expert noted.

For CVCs to scale, companies must adopt circular design principles, strengthen local ecosystems, and rethink value creation. As a CE expert in bioeconomy and forestry explained, “The approach where we focus on creating new kinds of value, not just selling something once, but offering a solution, is a big advantage, but it requires strong customer understanding and good branding.” Circular business models demand not only design for reuse or other life extension strategies but also a shift in mindset and practices in how companies connect with their customers and communicate value.

The main enablers and barriers identified across three levels are visualised in Figure 13 to better understand the complexity of circular value chain transitions. Barriers to implementing circular value chains span across all levels, from companies’ priorities to complex regulatory frameworks. On a micro level, companies struggle to balance a planet-centred mindset with ensuring profitability and meeting customer demands. A public sector CE expert noted, “Companies don't understand what circular economy actually is, they might already be doing parts of it without realising.” Some companies lack clarity on who owns the topic internally, and the “willingness to change” must come from the management level.

> It's much safer to use conventional materials instead of recycled materials. We need to have enough good and encouraging examples, and that way, we can build the confidence to use these materials more widely. – CE expert in forestry

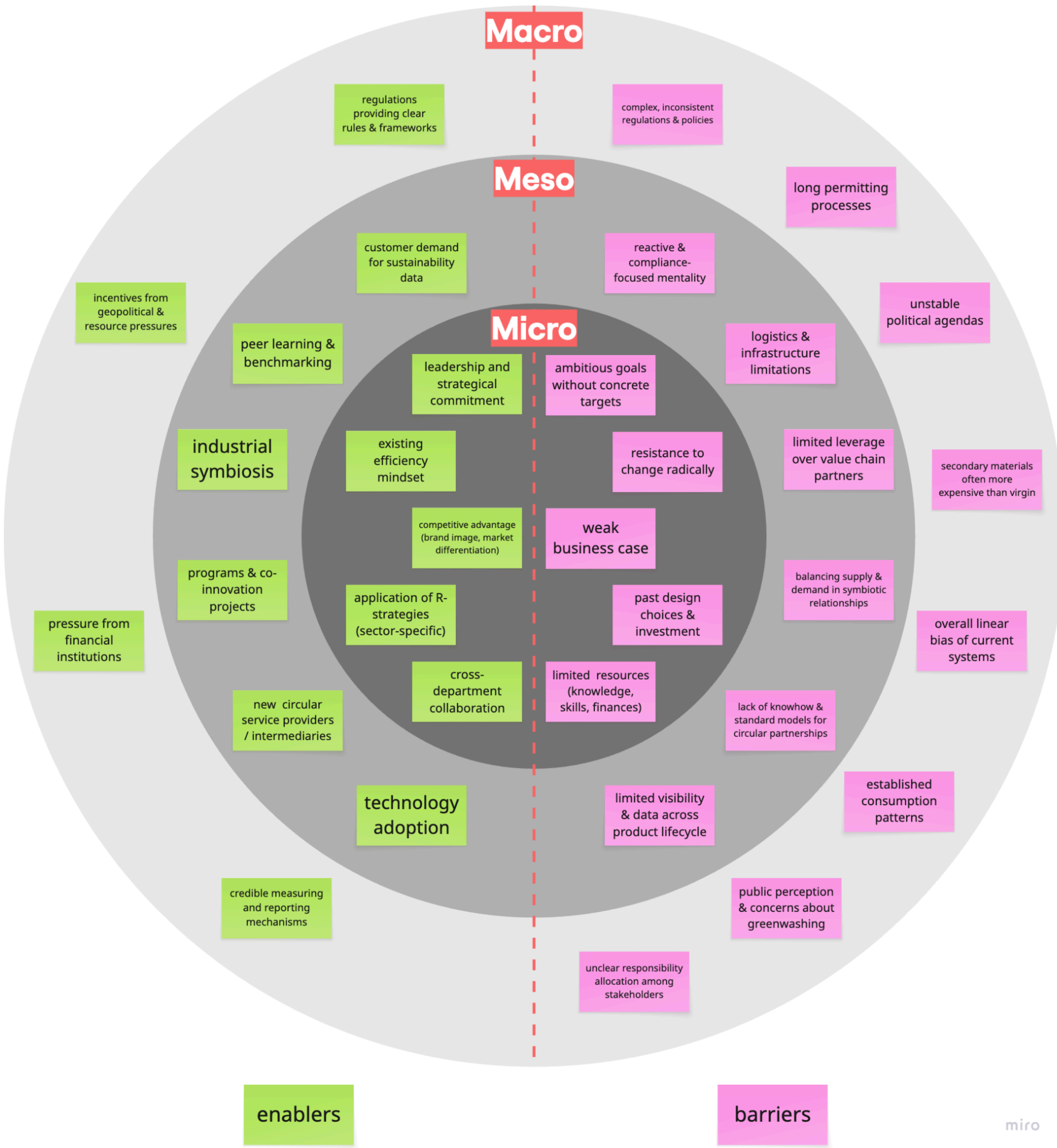


Figure 13. Multi-level perspective on enablers and barriers for CVC transition

On the meso level, building circular value chains is still challenging. "It's not that easy to search for the circular suppliers, and there aren't that many," an automotive industry expert pointed out, referring to weak market infrastructure. Logistics challenges and high upfront investments add more complexity, especially when securing consistent secondary material flows. “Everything needs to align: material value, partner, regulation, transportation, storage, the whole logistics chain,” an industry expert listed.

At the macro level, policy ambiguity slows down progress. Voluntary reporting, a lack of incentives, and market volatility also make it hard for companies to commit to long-term changes, as “a volatile environment makes companies delay decision-making,” explains a senior researcher in CE policy and critical materials. “In too many cases, you have to fight for the circular economy, and then you start to lose motivation,” said an environmental manager in the forest industry, highlighting how disconnected sustainability goals can be from operational realities.

Despite the challenges, there are signs of the changing linear regime and growing support structures for circular value chains. Many companies are already testing circular ideas, both from the ground up and through leadership-led programmes. “Sometimes development comes from within – from a logistics team noticing we can switch to fully reusable packaging,” shared one expert. Others noted how top-down commitment also plays a role, with “the board making decisions on where and how to source.”

At the meso level, collaboration is crucial, but it is still in the early stages. One interviewee noted that “finding partners is tough; having a circular matchmaker would greatly help.” Practical examples and peer learning are particularly valuable with interviewees expressing “the need to see the business case”, “need for more education on how to replace raw materials” and “practical examples on how to proceed, and could they look into”. Leading companies set a good example for others and raise awareness about circularity. “We need more small companies, born-circular startups that could create some new value for the end customers,” a public sector CE expert believes.

At the macro level, regulation can act as both a barrier and a catalyst. “Maybe the regulator could take a more supportive role, and rather than only setting limits, help discover new opportunities”, an industry expert suggested. In contrast, others called for stronger rules in public procurement and non-negotiable CO2 limits. Finland’s strong infrastructure in green energy, availability of funding, and sector-specific programmes were seen as strong national enablers. The shift to circular value chains can become more tangible and preferred with the right incentives, knowledge, and collaboration.

Several trends are reshaping the manufacturing sector toward more circular, resilient, and localised value chains in response to material scarcity, climate pressures, and policy changes. A senior researcher in data-driven manufacturing summarised this trend by noting, “I think the value chains will get shorter”, reflecting the broader move towards decentralisation and regional production. This localisation is considered necessary for biodiversity, though climate challenges demand “both local and global solutions,” said a CE expert in bioeconomy and forestry. Growing interest in critical raw materials, especially metals, drives urgency around circular economy (CE) solutions. “We will see a growing interest in critical raw materials … meaning that we have to implement CE solutions quite quickly,” explained a senior researcher in CE policy and critical materials. At the same time, data and transparency are gaining importance, with expectations that “all the products will have some type of DPP (Digital Product Passport) that end users would have the know-how on how to proceed with the products”. These trends point to a future where value chains are more efficient, flexible, and better aligned with circular principles.

5. DESIGN WORKS

As an outcome of the research process, a practical design intervention was developed to translate insights from literature and interviews into a practical format for industry practitioners and facilitators supporting the circular transition process. The outcome is a visual and action-oriented tool, called "Circular Value Chain Blueprint", aimed at helping manufacturing companies better understand, assess, and redesign their value chains through a circular lens (Appendix 2).

The tool is grounded in academic frameworks, including R-strategies, systems thinking, service design, and the multi-level perspective framework, and is based upon empirical insights from industry experts. The tool supports companies in mapping their current value chain setup, identifying untapped potential, and exploring new circular opportunities. Structured around three system levels: micro (company-level operations and strategies), meso (value chain collaboration), and macro (regulations and systemic trends), the tool enables practitioners to reflect on both internal processes and broader contextual factors.

The Circular Value Chain Blueprint tool can be applied across different organisational and ecosystem contexts. It can serve as a workshop tool for manufacturing companies that brings together cross-functional teams, from product development to sales and sustainability management. Additionally, the tool can be used in facilitated sessions with external stakeholders, such as suppliers, logistics partners, and facilitators, to bring in expert knowledge. Involving value chain partners early supports identifying leverage points that might go unnoticed. For public sector actors from research and support organisations, such as regional development agencies and innovation programmes, the tool can help anchor discussions and serve as a basis for co-creating circular journeys.

What makes this tool distinct is its comprehensive approach to a linear-to-circular process, guided by co-creative methods and exercises. The tool was created as a template in the visual workspace Miro to enable a collaborative approach, while maintaining a digital version of the outcome that can be iterated throughout the transition process. Next, a step-by-step process for using the tool is provided with illustrations of the tool itself. Each step helps practitioners collaboratively assess, rethink, and redesign their value chain through a circular lens.

1. Why does circularity matter to us?

Start with individual reflection using the 5 Whys method (Figure 14) to explore the deeper meaning of circularity for your company. This will build alignment and purpose before diving into action.

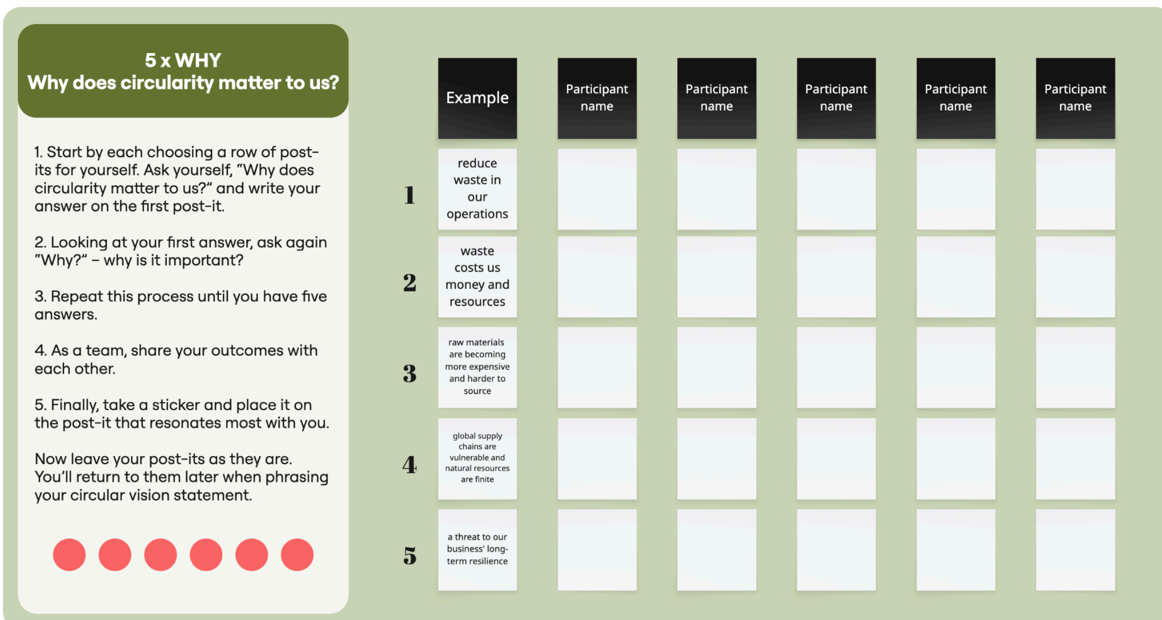


Figure 14. Five Whys method: "Why does circularity matter to us?"

2. What would success in circularity look like?

Individually brainstorm and then discuss as a team what circular success could look like (Figure 15). Cluster ideas and vote on the most important ones.

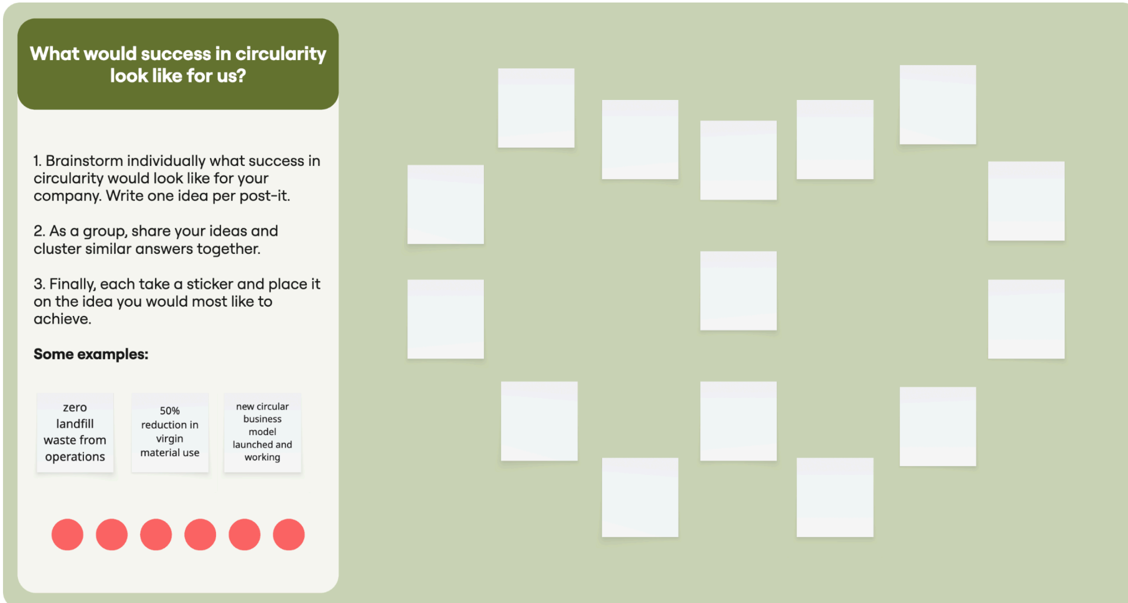


Figure 15. Exercise: “What would success in circularity look like for us?”

3. Create your circular vision

Use the most voted ideas from previous steps to draft vision statements individually. Then, combine them into one shared, inspiring circular vision to guide the process (Figure 16).

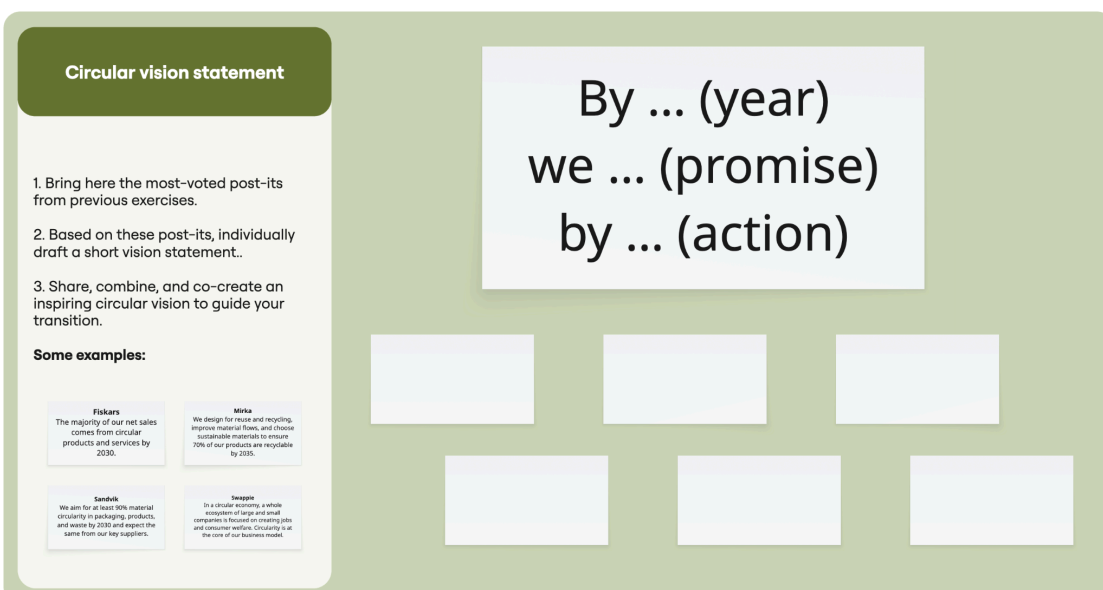


Figure 16. Creating a circular vision statement

4. Map your current value chain

List key value chain steps together or in smaller groups (Figure 17). For each step, document resources, stakeholders, inefficiencies, and external forces influencing operations.

5. Ideate on your circular value chain

Explore positive and negative impacts (environmental, social, economic), apply R-strategies to spot circular opportunities, identify potential new partners, and prioritise key actions by voting on the most critical elements to change (Figure 17).

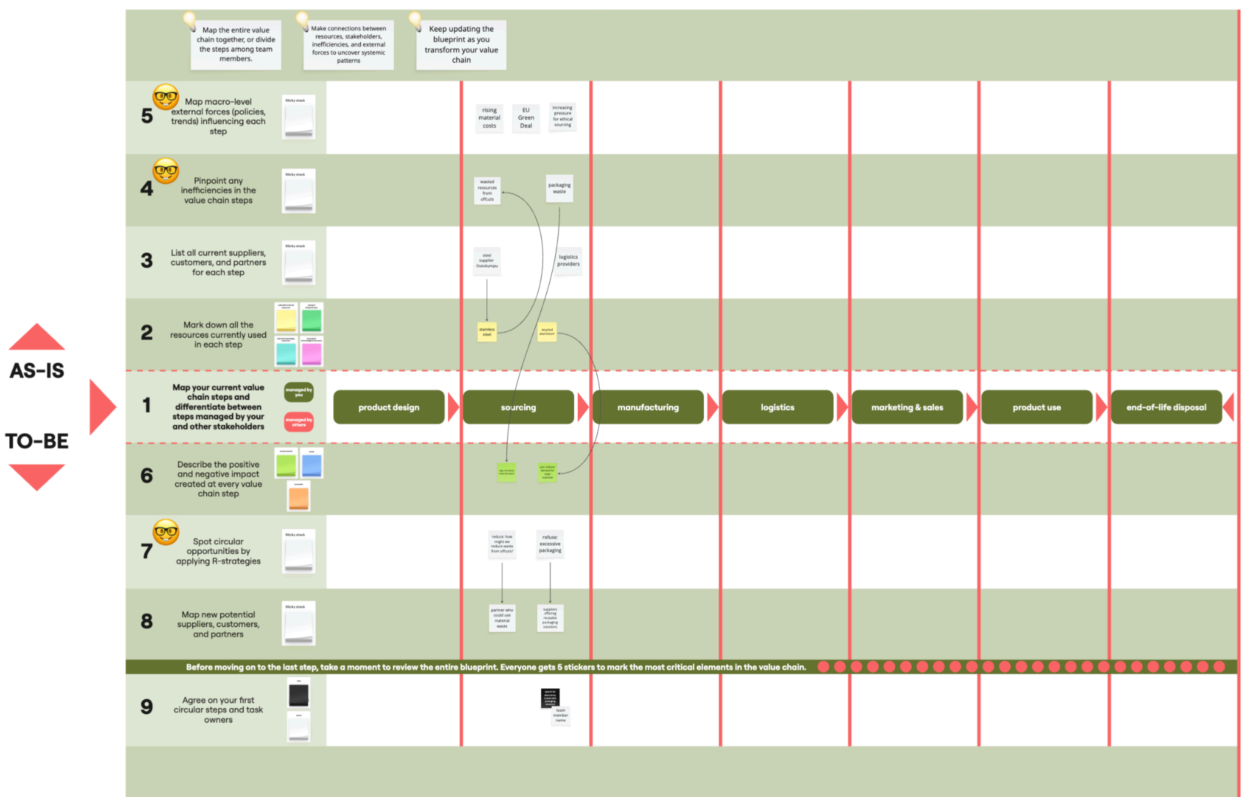


Figure 17. Mapping the as-is value chain and ideating on the to-be value chain

Throughout the process, refer to the Quick Info Kit for theoretical background and supporting materials (Figure 18). It includes an introduction to the circular economy, an overview of common value chain inefficiencies, a summary of relevant regulatory developments, and a clear explanation of R-strategies to help guide your thinking and decision-making.

Figure 18. Quick Info Kit

While thorough testing and large-scale validation were not within the scope of this thesis, an initial review of the tool was conducted with two design leads, each with over 30 years of experience in service design and circular design. After being introduced to the research background, they individually reviewed the tool and provided feedback using post-its. Their suggestions focused on adding more detailed instructions and examples for each exercise and incorporating more theoretical context where needed. Overall, the tool was positively received, and both experts found the structure logical and the flow intuitive. The detailed blueprint and numbered steps were especially appreciated for improving clarity and usability.

6. DISCUSSION AND IMPLICATIONS

6.1. Discussion

This study set out to analyse circular value chain innovations, with a focus on the application of R-strategies, and to explore how service design and systems thinking can support the transition from linear to circular thinking in Finland's manufacturing industry. Drawing on expert interviews, the findings offer a multi-level perspective on the enablers and barriers of moving from linear to circular and a launch pad for the transition. This section discusses how the research findings respond to its three starting-point questions while contributing to the broader discussion around circular value chain transition in the Finnish manufacturing sector.

The first research question (RQ1) explored how manufacturing companies can integrate R-strategies into their value chain. This study confirms that many Finnish manufacturing companies already apply several R-strategies, particularly reduce, reuse, repair, recycle, and recover. These strategies are most feasible when aligned with existing business logic, such as cost-saving, efficiency, and lean operations. For example, reduction of resource use through process optimisation and energy efficiency is considered "just the normal way of doing things," with 66% of Nordic companies linking reduction to cost savings and 75% to reduced emissions (Bajuk & Linder, 2024). Repair and reuse are more common in equipment-heavy sectors. At the same time, recycling and energy recovery, still closely related to the linear economy, remain the most popular strategies due to regulatory compliance and existing infrastructure.

Research findings confirm that sector-specific dynamics influence the applicability of R-strategies. For example, strict product performance requirements, particularly in industries like automotive and electronics, limit the adoption strategies, such as rethinking or refurbishing. Bajuk and Linder (2024) highlight that in the Finnish context, life cycle extension strategies are often limited by a lack of partners and supportive infrastructure.

Regardless of genuine interest, implementing more radical strategies such as refuse, rethink, remanufacture and repurpose is less widespread due to uncertainties around profitability, potential conflicts with established business models, unclear legislation, and limited availability of product use data. This indicates a varied level of maturity among R-strategies, as seen from the manufacturing industry's perspective. While the more radical strategies pose bigger risks and face additional challenges, their implementation is still at the level of early-stage pilot projects rather than systemic changes (Bajuk & Linder, 2024). Overall, while manufacturing companies show growing interest in R-strategies, complete integration depends on enablers and barriers at all macro, meso, and micro levels.

Secondly, this research aimed to uncover the key enablers and barriers in transitioning value chains from linear to circular (RQ2). The question was explored by applying a multi-level perspective framework to better comprehend the complexity of value chain transition. At the micro level, cost-efficiency and leadership commitment often drive initial action. Unclear targets, limited resources, and lack of internal alignment were identified as barriers. These findings support the previous recommendations from existing literature for setting measurable circularity goals and following the action-oriented approach, rather than waiting for new legislatory requirements (Bajuk & Linder, 2024; Cambou et al., 2025).

A strong foundation of lean thinking and operational efficiency creates a natural entry point for implementing reduce and reuse strategies in the manufacturing sector. In addition to leadership commitment, internal collaboration across departments (e.g., between sales, product design, and compliance) helps identify sustainable improvement opportunities. These findings support Salminen et al.'s (2016) argument that circular economy work must go beyond silos and be owned across functions.

At the meso level, collaboration can pose more difficulties than enablers for the transition. Finding suitable partners, establishing circular agreements, and securing reliable secondary material flows remains challenging for the still-evolving systems. These findings resonate with Salminen and colleagues' (2016) emphasis on the importance of formalised value networks and industrial symbiosis to reducing inefficiencies and supporting innovation.

Because collaboration is crucial for successful circular transition, further emphasis should be placed on industrially symbiotic initiatives, co-innovation programmes, and new circular actors who act as intermediaries between value chain partners. The success of this transformation depends on supportive infrastructure, customer demand, and clear regulations. The circular actors help close the loop by turning side streams into valuable material inputs, and reduce barriers for manufacturers who wish to participate in circular ecosystems without establishing all circular capabilities internally. This study's respondents mentioned sharing best practices and benchmarking as key motivators.

At the macro level, geopolitical pressure, resource scarcity, and EU legislation are seen as both push and pull forces. Policies' fragmented and overlapping nature creates significant administrative and compliance burdens, hindering value chain collaborations at the meso level. Industry experts expressed confusion about interpreting regulations, consistent with CEULA's findings (Cambou et al., 2025) of widespread uncertainty and risk of overcompliance.

Nonetheless, these same macro-level drivers also create strategic opportunities. For example, resource scarcity and security are pushing companies to consider circularity as a means of shifting to secondary materials and reducing dependency on global supply chains. Additionally, financial institutions' sustainability demands incentivise companies to review their environmental impact and consider transitioning, for example, through the use of R-strategies.

Thirdly, this study explored how service design and systems thinking can be applied to develop circular value chains across the Finnish manufacturing industry (RQ3). As the shift requires rethinking value creation and delivery, the study combined systems thinking and service design to uncover the best possible approaches. Systems thinking helps companies to understand interdependencies across their value chain, identify leverage points, and address structural barriers such as material inefficiencies and collaboration gaps (Arnold & Wade, 2015; Circle Economy, 2024). Systems thinking is particularly useful at the meso level, where industrial practices, market norms, and collaboration models shape the opportunities for further value creation. For example, the interviewees highlighted the importance of intermediary actors and cross-sectoral partnerships in enabling circular networks. However, as the multi-level analysis showed, all levels are interconnected, and considering the multi-level enablers and barriers can greatly affect the circular transition's success.

Service design, in turn, offers an empathic mindset and practical tools for designing human-centred and feasible circular solutions (Harmaala, 2021). It can be particularly useful in creating prototypes for iterative testing and, later, implementing service-based models (e.g. leasing, product-as-a-service) that rethink ownership and enable life extension strategies. Together, these approaches support the transition by aligning business models with stakeholder needs and providing a holistic view of the system. In summary, systems thinking reveals which areas of manufacturing change are most needed, while service design helps to turn that change into an achievable reality.

6.2. Practical implications

The transition to CVCs is a demanding and complex journey that no company can undertake alone. Collaboration across departments, between companies, and with public actors is a prerequisite and is increasingly gaining momentum. For manufacturers, this means moving beyond internal process optimisation and actively engaging their value chain partners to co-create circular solutions and processes. The possible actions include improving transparency, applying R-strategies, aligning goals between partners, and building up new capabilities internally. The nuances and outcomes of this multi-actor collaboration are different for every company, based on their sector and operating area. To succeed, it's important to plan for the transition by first understanding what it means for any specific company, because "it's a huge optimisation between the environment, money, legislation, and organisational capacity for business continuity," as one of the industry experts explained.

To support the linear-to-circular transition, a practical tool named "Circular Value Chain Blueprint" was developed as part of this thesis. The tool combines the best practices and recommendations from all the interviewed experts. Additionally, the Circular Value Chain Blueprint is grounded in academic frameworks and empirical findings to help companies visualise, assess, and redesign their value chains through a circular lens. The tool guides users through several steps to set in motion a strong circular journey by:

- setting the stage by deconstructing the meaning of circularity and putting it back together as a clear circular vision statement for a specific company;
- understanding the company's existing value chain through mapping its step-by-step processes, resources, inefficiencies, partners, and influencing forces;

- ideating and identifying the key impact points, applicable R-strategies, and potential collaborators to identify the first action points;
- supporting the transformative process with theoretical background and practical guidelines.

The Circular Value Chain Blueprint tool can be used in internal workshops involving diverse groups across teams or by including external facilitators and existing value chain partners to build a shared understanding of circularity. Public sector actors can also benefit from the tool when supporting manufacturing companies in building circular capabilities within regional ecosystems or co-innovation programs.

6.3. Future studies

This study provides the foundation for understanding CVC transitions in the manufacturing sector across micro, meso, and macro levels and proposes a practical tool for initiating the transition process. In conclusion, the selected research design and data collection methods effectively supported the aim and scope of the study. The findings align well with the interdisciplinary nature of this research, combining service design and systems thinking with CE principles to support value chain transitioning. The interviewees reflected this interdisciplinary lens, drawing on insights from diverse industry roles and organisations to enrich the empirical understanding. However, building a coherent literature review across complex topics – circular economy, circular value chains, systems thinking, and service design – proved challenging initially, particularly in keeping a sharp focus and creating connections between concepts. As Ahmadov et al. (2025) point out, CE research has often leaned too heavily on quantitative or qualitative methods. A more integrated approach would have facilitated research and supported the development of holistic and scalable circular solutions.

Further research is needed to expand on this study's insights on circular transition. One potential direction would be to test and iterate on the practical tool developed to complement this study. Empirical studies applying the Circular Value Chain Blueprint tool in varied manufacturing contexts would help to assess its usability and impact on value chain decision-making and collaboration. Additionally, further research on the interactions between system levels, e.g. how macro-level pressures might influence meso-level collaboration and micro-level actions, could lead to new insights and monitor how the actual change unfolds across the landscape-regime-niche dimensions over the coming years.

Another direction for further investigation could be analysing the specific factors that shape circular transition. Future studies could examine how leadership, employee engagement, and organisational culture affect the adoption of R-strategies and service-based models. Research into digital enablers like data-sharing infrastructure, digital product passports, and transparency tools would offer valuable insights, particularly for operationalising CE across value chains. Finally, long-term design-led processes such as company or ecosystem development programs could be tested across different value chain settings and measured to evaluate their impact as enablers of systemic circular transformation.

7. CONCLUSION

This study has explored the transition from linear to circular value chains in the Finnish manufacturing sector, focusing on the application of R-strategies and the role of service design and systems thinking in facilitating this shift. By addressing the three core research questions, the study aimed to uncover how manufacturing companies can integrate circular practices, consider the enablers and barriers in this transition, and explore how service design and systems thinking can support value chain transformation. The findings have provided insights into the complex and multi-faceted nature of circular value chain transitions that lie ahead for Finnish manufacturers.

The first research question asked how manufacturing companies can integrate R-strategies into their value chains. This study found that many Finnish manufacturing companies are already implementing some R-strategies, particularly those aligned with existing business logic, cost-saving and efficiency, such as reduce, reuse, repair, recycle, and recover. However, adopting more radical strategies, such as refuse, rethink, remanufacture, refurbish, and repurpose, is still in its early stages due to uncertainties around profitability, business model alignment, and regulatory barriers.

The second question focused on identifying the key enablers and barriers in transitioning to circular value chains. The analysis was conducted from a multi-level perspective, which revealed that cost efficiency, measurable goals and leadership commitment are key drivers at the micro level. At the same time, collaboration and customer demand are essential at the meso level. Macro-level drivers such as resource scarcity and EU legislation push companies towards circular practices, but also create compliance burdens that complicate value chain collaborations.

Thirdly, the research examined how service design and systems thinking can be applied to facilitate the transition. The findings showed that systems thinking can help identify interdependencies and leverage points across value chains. At the same time, service design offers practical tools for developing human-centred, circular solutions that can be tested and iterated.

This research contributes to the growing body of knowledge on circular economy in the manufacturing sector by providing theoretical insights and a practical tool for initiating circular value chain transitions. The development of the Circular Value Chain Blueprint tool is a key contribution, offering a step-by-step guide for companies to assess, visualise, and redesign their value chains through a circular lens. The tool integrates academic insights with practical industry experiences, providing manufacturers with a resource to begin their transition towards circularity in a systematic and collaborative way.

Further research is needed to test and refine the Circular Value Chain Blueprint in various manufacturing contexts to assess its effectiveness in driving decision-making and collaboration. Additionally, exploring how pressures from different levels influence each other could provide valuable insights into the dynamics of circular transition. Future studies could also focus on how individual micro-level forces, like leadership or digital enablers, affect the adoption of R-strategies and service-based models. Finally, longitudinal research into the impact of design-led processes and ecosystems would help measure their effectiveness in advancing systemic change towards circularity.

The path to circular value chains is complex. However, with the right mindset, partnerships, and tools, the transition is both achievable and essential for the future of the manufacturing sector. Last but not least, it’s worth remembering an industry expert’s remark on the challenge ahead, “It will be a great mess!”

LIST OF REFERENCES

Abrahão. (2024). *Transforming human systems to safeguard the Global Commons: A report by PIK and CGC*.

Accenture. (2014). *Circular Advantage. Innovative Business Models and Technologies to Create Value in a World without Limits to Growth*. https://sharingcitiesalliance.knowledgeowl.com/help/circular-advantage-innovative-business-models-and-technologies-to-create-value-in-a-world-without-limits-to-growth

Ahmadov, T., Durst, S., Gerstlberger, W., & Kraut, E. (2025). SMEs on the way to a circular economy: Insights from a multi-perspective review. *Management Review Quarterly*, *75*(1), 289–322. https://doi.org/10.1007/s11301-023-00380-2

Arnold, R. D., & Wade, J. P. (2015). A Definition of Systems Thinking: A Systems Approach. *Procedia Computer Science*, *44*, 669–678. https://doi.org/10.1016/j.procs.2015.03.050

Awan, U., Sroufe, R., & Bozan, K. (2022). Designing Value Chains for Industry 4.0 and a Circular Economy: A Review of the Literature. *Sustainability*, *14*(12), 7084. https://doi.org/10.3390/su14127084

Ayres, R. U., & Kneese, A. V. (1969). Production, Consumption, and Externalities. *The American Economic Review*, *59*(3), 282–297.

Baccini, F. (2024, July 30). *The right to repair has become EU law starting from today*. https://www.eunews.it/en/2024/07/30/eu-directive-right-repair-products/

Bajuk, M., & Linder, M. (2024). *Circular Economy Outlook 2024 Nordics* [RISE report 2024:92]. Cradlenet, RISE Research Institutes of Sweden.

Batista, L., Bourlakis, M., Smart, P., & Maull, R. (2018). In search of a circular supply chain archetype – a content-analysis-based literature review. *Production Planning & Control*, *29*(6), 438–451. https://doi.org/10.1080/09537287.2017.1343502

Benayad, A., Hagenauer, A., Holm, L., Jones, E. R., Kämmerer, S., Maher, H., Mohaddes, K., Santamarta, S., & Zawadzki, A. (2025). *Landing the Economic Case for Climate Action with Decision Makers*. BCG.

Bernard, H. R. (2011). *Research Methods in Anthropology* (5th ed.). AltaMira Press.

Berndt, A. D. (2003). Leadership in the value chain. *Acta Commercii*, *3*(1), 1–8. https://doi.org/10.4102/ac.v3i1.35

Blandford, A. (2014, January 1). *Semi-structured qualitative studies. Interaction Design Foundation*. https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/semi-structured-qualitative-studies

Blom, M. (2020). *Rethinking the road to the circular economy*. https://think.ing.com/uploads/reports/Rethinking_the_road_to_the_circular_economy_FINAL_RB1.pdf

Bourguignon, D. (2016). *Closing the loop – new circular economy package*. European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573899/EPRS_BRI%282016%29573899_EN.pdf

Braun, V., & Clarke, V. (2012). Thematic Analysis. In *APA handbook of research methods in psychology* (Vol. 2, pp. 57–71).

Bressanelli, G., Adrodegari, F., Pigosso, D. C. A., & Parida, V. (2022). Towards the Smart Circular Economy Paradigm: A Definition, Conceptualization, and Research Agenda. *Sustainability*, *14*(9), 4960. https://doi.org/10.3390/su14094960

Cambou, Dorothée, Fougère, Martin, Herlin, Heidi, Komba, Neema, Maghsoudi, Amin, Rajavuori, Mikko, Sagne-Ollikainen, Elina, Saloranta, Juho, & Solitander, Nikodemus. (2025). *The Cumulative Effects of EU Sustainability Legislation (CEULA): Impacts on Finnish firms*. Ministry for Foreign Affairs. https://julkaisut.valtioneuvosto.fi/handle/10024/166062

Charonis, G.-K. (2021). Degrowth, Steady State And Circular Economies: Alternative Discourses To Economic Growth. *Society Register*, *5*(3), 75–94. https://doi.org/10.14746/sr.2021.5.3.05

Chirumalla, K., Reyes, L. G., & Toorajipour, R. (2022). Mapping a circular business opportunity in electric vehicle battery value chain: A multi-stakeholder framework to create a win–win–win situation. *Journal of Business Research*, *145*, 569–582. https://doi.org/10.1016/j.jbusres.2022.02.070

Circle Economy. (2021). *The Circularity Gap Report 2021*. https://www.circularity-gap.world/2021

Circle Economy. (2024). *Circularity Gap Report 2024*. https://www.circularity-gap.world/2024

Circulab. (n.d.). *Value Chain Canvas User Manual*. https://circulab.academy/circular-economy-tools/value-chain-canvas/

CircuLaw. (2024). *EU legislation and regulations for a circular economy*. https://www.circulaw.nl/eu-wetgeving

Conticelli, E., & Tondelli, S. (2014). Eco-Industrial Parks and Sustainable Spatial Planning: A Possible Contradiction? *Administrative Sciences*, *4*(3), 331–349. https://doi.org/10.3390/admsci4030331

Cross, N. (2006). *Designerly Ways of Knowing*. Springer-Verlag. https://doi.org/10.1007/1-84628-301-9

Danish Design Center. (2023). *The Circular Value Chain Tool*. https://ddc.dk/tools/the-circular-value-chain/

Doughnut Economics Action Lab. (2024). *Scott Bader: Doughnut Design Case Study*. https://doughnuteconomics.org/stories/scott-bader-doughnut-design-case-study

Downton, P. (2003). *Design research*. RMIT University Press.

EFIS Centre, Technopolis Group, & OldContinent. (2024). *European Innovation Scoreboard 2024 – Country profile Finland*. European Commission.

EFRAG. (2023). *EFRAG IG 2: Value chain implementation guidance*. European Financial Reporting Advisory Group. https://www.efrag.org

Eljas-Taal, K., Mikheeva, O., Beckers, D., Väljaots, K., & Hein, T. (2019). *Ringmajanduse strateegia koostamise metoodika väljatöötamine*. https://ringmajandus.envir.ee/sites/default/files/Strateegia%20-%20fotod/1.2%20Ringmajanduse%20indikaatorid%20l%C3%B5pparuanne%20050719.pdf

Ellen MacArthur Foundation. (2012). *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition.* https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-vol-1-an-economic-and-business-rationale-for-an

Ellen MacArthur Foundation. (2021, February 12). *The butterfly diagram: Visualising the circular economy*. https://www.ellenmacarthurfoundation.org/circular-economy-diagram

Ellen MacArthur Foundation. (2022a, May 23). *The biological cycle of the butterfly diagram*. https://www.ellenmacarthurfoundation.org/articles/the-biological-cycle-of-the-butterfly-diagram

Ellen MacArthur Foundation. (2022b, May 23). *The technical cycle of the butterfly diagram*. https://www.ellenmacarthurfoundation.org/articles/the-technical-cycle-of-the-butterfly-diagram

Ellen MacArthur Foundation. (2023). *Building a circular supply chain*. https://www.ellenmacarthurfoundation.org/circular-supply-chains

Ellen MacArthur Foundation, PA Consulting, & Exeter Business School. (2022). *Circular Business Model Design Guide*. https://www2.paconsulting.com/Sustainability-EMF-BDG-2020-download.html

European Commission. (2020). *A new circular economy action plan: For a cleaner and more competitive Europe (COM(2020) 98 final)*. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN

European Commission. (2022). *Corporate sustainability reporting*. https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

European Commission. (2023). *The Green Deal Industrial Plan*. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en

European Commission. (2025a, April 30). *Green claims*.

https://environment.ec.europa.eu/topics/circular-economy/green-claims_en
European Commission. (2025b, April 16). *Packaging waste*. https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste_en
European Commission, Directorate General for Enterprise and Industry. (2012). *Ecodesign your future: How ecodesign can help the environment by making products smarter.* Publications Office. https://data.europa.eu/doi/10.2769/38512
European Environment Agency. (2016). *Circular economy in Europe: Developing the knowledge base.* Publications Office. https://data.europa.eu/doi/10.2800/51444
European Environment Agency. (2025). *Waste management country profile with a focus on municipal and packaging waste, Finland*. https://www.eea.europa.eu/en/topics/in-depth/waste-and-recycling/municipal-and-packaging-waste-management-country-profiles-2025/fi-municipal-waste-factsheet.pdf/@@download/file
European Parliament. (2022). *Green Deal: Key to a climate-neutral and sustainable EU*. https://www.europarl.europa.eu/topics/en/article/20200618STO81513/green-deal-key-to-a-climate-neutral-and-sustainable-eu
European Parliament & Council of the European Union. (2024a). *Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020*. http://data.europa.eu/eli/reg/2024/1252/oj
European Parliament & Council of the European Union. (2024b). *Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC*. http://data.europa.eu/eli/reg/2024/1781/oj.
Frankel, L., & Racine, M. (2010). The Complex Field of Research: For Design, through Design, and about Design. *In Durling, D., Bousbaci, R., Chen, L, Gauthier, P., Poldma, T., Roworth-Stokes, S. and Stolterman, E (Eds.)*. Design and Complexity - DRS International Conference 2010, Montreal, Canada. https://dl.designresearchsociety.org/drs-conference-papers/drs2010/researchpapers/43
Gatewood, A. K., & Drake, M. J. (2024). *ASCM Supply Chain Dictionary* (18th ed.). Association for Supply Chain Management. https://www.ascm.org
Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8
Geels, F. W. (2006). Multi-Level Perspective on System Innovation: Relevance for Industrial Transformation. In X. Olsthoorn & A. J. Wieczorek (Eds.), *Understanding Industrial Transformation* (Vol. 44, pp. 163–186). Kluwer Academic Publishers. https://doi.org/10.1007/1-4020-4418-6_9
Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions*, *1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002
Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007
Gomes, G. M., Pigosso, D. C. A., & McAloone, T. C. (2024). Design and collaboration strategies for circular economy implementation across the value chain. *Proceedings of the Design Society*, *4*, 1259–1268. https://doi.org/10.1017/pds.2024.128
Guest, G., Bunce, A., & Johnson, L. (2006). How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. *Field Methods*, *18*(1), 59–82. https://doi.org/10.1177/1525822X05279903
Harmaala, M.-M. (2021). *Transition from linear to circular business models with service design methodology to drive innovation and growth*. http://urn.fi/URN:NBN:fi-fe2021101451012
Horn, S. (2014). *Sustainability Strategies for Business – An Integrated Approach with a Life Cycle Perspective*.

University of Jyväskylä.
ISO. (2016). *ISO. (2016). Life cycle perspective – what ISO14001 includes*. https://www.iso.org/iso/home.html
Jamadagni, A., Aurisicchio, M., & Nybom, L. (2024). Modelling an ecosystem of business models in a circular value chain: The circular business ecosystem model canvas. *Proceedings of the Design Society*, *4*, 1309–1318. https://doi.org/10.1017/pds.2024.133
Johnson, T. P. (2014). Snowball Sampling: Introduction. In R. S. Kenett, N. T. Longford, W. W. Piegorsch, & F. Ruggeri (Eds.), *Wiley StatsRef: Statistics Reference Online* (1st ed.). Wiley. https://doi.org/10.1002/9781118445112.stat05720
Jonas, W. (2007). Design Research and its Meaning to the Methodological Development of the Discipline. In R. Michel (Ed.), *Design Research Now* (pp. 187–206). De Gruyter. https://doi.org/10.1007/978-3-7643-8472-2_11
Kirchherr, J., Reike, D. & Hekkert, M. P. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources Conservation and Recycling*. https://doi.org/10.1016/j.resconrec.2017.09.005
Kivikytö-Reponen, P., Orko, I., Muukkonen, R., & Valtanen, K. (2022). *Data-driven circular design*. VTT Technical Research Centre of Finland. https://doi.org/10.32040/2022.CircularDesignGuide
Lacy, P., & Rutqvist, J. (2015). *Waste to Wealth*. Palgrave Macmillan UK. https://doi.org/10.1057/9781137530707
Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guilford Publications.
Legard, R., Keegan, J., & Ward, K. (2003). *In-depth interviews. In: Ritchie, Jane and Lewis, Jane (eds.). 'Qualitative research practice: A guide for social science students and researchers'.* (pp. 138–169). Sage.
Lin, K.-Y., & Chu, I.-T. (2024). A design thinking approach to integrate supply chain networks for circular supply chain strategy in Industry 4.0. *Industrial Management & Data Systems*. https://doi.org/10.1108/IMDS-04-2024-0369
Madani, B., Saihi, A., & Abdelfatah, A. (2024). A Systematic Review of Sustainable Supply Chain Network Design: Optimization Approaches and Research Trends. *Sustainability*, *16*(8), 3226. https://doi.org/10.3390/su16083226
Manolakelli, A. (2023, May 29). *Integrating insights from Psychology into Design: Three facets of Design Research in Architecture.* ArchPsych. https://www.archpsych.co.uk/post/integrating-insights-from-psychology-into-design-three-facets-of-design-research-in-architecture
Martikainen, V. (2020). *Sustainable Manufacturing*. https://www.businessfinland.fi/en/for-finnish-customers/services/programs/ended-programs/sustainable-manufacturing-finland
Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., De Meester, S., & Dewulf, J. (2019). Circular economy indicators: What do they measure? *Resources, Conservation and Recycling*, *146*, 452–461. https://doi.org/10.1016/j.resconrec.2019.03.045
Moreno, M., De Los Rios, C., Rowe, Z., & Charnley, F. (2016). A Conceptual Framework for Circular Design. *Sustainability*, *8*(9), 937. https://doi.org/10.3390/su8090937
Murray, A., Skene, K., & Haynes, K. (2017). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *140*(3), 369–380. https://doi.org/10.1007/s10551-015-2693-2
Ortiz-de-Montellano, C. G.-S., Ghannadzadeh, A., & Van Der Meer, Y. (2023). The CIRCULAR pathway: A new educational methodology for exploratory circular value chain redesign. *Frontiers in Sustainability*, *4*, 1197659. https://doi.org/10.3389/frsus.2023.1197659
Porter, M. E. (2001). *The value chain and competitive advantage. Understanding business processes.* (2nd ed.).
Potting, J., Hanemaaijer, A., Delahaye, R., Hoekstra, R., Ganzevles, J., & Lijzen, J. (2018). *Circular economy: What we want to know and can measure. Framework and baseline assessment for monitoring the progress of the*

circular economy in the Netherlands. PBL Netherlands Environmental Assessment Agency.
Potting, J., Hekkert, M. P., Worrell, E., & Hanemaaijer, A. (2017). *Circular Economy: Measuring innovation in the product chain.*
Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, *179*, 605–615. https://doi.org/10.1016/j.jclepro.2017.12.224
Raudaskoski, A. (2025). *Circular strategies for success*. Professional Publishing Finland.
Raworth, K. (2022). *Doughnut economics: Seven ways to think like a 21st-century economist*. Penguin Books.
Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options. *Resources, Conservation and Recycling*, *135*, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37), eadh2458. https://doi.org/10.1126/sciadv.adh2458
Rockström, J., Donges, J. F., Fetzer, I., Martin, M. A., Wang-Erlandsson, L., & Richardson, K. (2024). Planetary Boundaries guide humanity's future on Earth. *Nature Reviews Earth & Environment*, *5*(11), 773–788. https://doi.org/10.1038/s43017-024-00597-z
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S. I., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., Van Der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, *14*(2), art32. https://doi.org/10.5751/ES-03180-140232
Romero, D., Taisch, M., Acerbi, F., Andersen, A.-L., Braun, G., Bressanelli, G., Chari, A., Henrique de Sousa Mendes, G., Ebel, M., Frank, A., Gonzales, C., Hankammer, S., Khan, M., Kyriakoulis, N., Lenz, J., Marchetti, S., May, G., Medini, K., Müller, J., … Wuest, T. (2024). The 2024 World Manufacturing Report: New Perspectives for the Future of Manufacturing: Outlook 2030. In *The 2024 World Manufacturing Report* [Report]. World Manufacturing Foundation.
Roos, G. (2014). Business Model Innovation to Create and Capture Resource Value in Future Circular Material Chains. *Resources*, *3*(1), 248–274. https://doi.org/10.3390/resources3010248
Salminen, K., Viljakainen, A., Virkkunen, R., Helaakoski, H., Kokkonen, A., Vita Costa, J. C., & Alahuhta, P. (2022). *Towards Sustainable Manufacturing: How is autonomy paving the way towards a sustainable industry?* VTT Technical Research Centre of Finland.
Salminen, V., Ruohomaa, H., & Pöykkö, T. (2016). *From Supply Chain To Digital Circular Value Chain.* https://www.researchgate.net/publication/338502243_FROM_SUPPLY_CHAIN_TO_DIGITAL_CIRCULAR_VALUE_CHAIN
Santa-Maria, T., Vermeulen, W. J. V., & Baumgartner, R. J. (2022). *The Circular Sprint: User Guide*. Unpublished. https://doi.org/10.13140/RG.2.2.36829.69607
Saunders, M. N. K., Lewis, P., & Thornhill, A. (2023). *Research methods for business students* (Ninth edition). Pearson.
Saunders, M. N. K., & Tosey, P. (2012). *The Layers of Research Design.* https://www.academia.edu/4107831/The_Layers_of_Research_Design
Schaeper, J. (2023). Reimagining Service Design Beyond Neoliberal Economics. *Touchpoint*, *14*(2), 6–11. https://doi.org/10.30819/touchpoint.14-2.01
Sedini, C., Bianchini, M., Maffei, S., & Cautela, C. (2024). Shifting Design Thinking to a Circular Design Perspective: Reframing the Process of Circular Innovation. *The International Journal of Design Management and Professional Practice*, *18*(1), 31–57.

https://doi.org/10.18848/2325-162X/CGP/v18i01/31-57
Senge, P. M. (2006). *The fifth discipline: The art and practice of the learning organization* (Rev. and updated ed). Currency Doubleday.
Shtarkman, N., & Ménard, B. (2024). *Biocubes*. https://www.biocubes.net
Singer, M., & Donoso, P. (2008). Upstream or downstream in the value chain? *Journal of Business Research*, *61*(6), 669–677. https://doi.org/10.1016/j.jbusres.2007.06.043
Sitra, Technology Industries of Finland, & Accenture. (2018). *Circular economy business models for the manufacturing industry: Circular Economy Playbook for Finnish SMEs*. https://www.sitra.fi/en/publications/circular-economy-business-models-manufacturing-industry/
Skýpalová, J. (2024, August 29). *The concept and development of the circular economy*. 14th International Scientific Conference „Business and Management 2024", Vilnius Gediminas Technical University, Lithuania. https://doi.org/10.3846/bm.2024.1276
Stickdorn, M., Hormess, M., Lawrence, A., & Schneider, J. (Eds.). (2021). *This is service design doing: Applying service design thinking in the real world ; a practitioners' handbook* (10. Nachdr). O'Reilly Media.
Tervonen, P., Leppänen, T., Lind, V., Longi, H., & Haapasalo, H. (2023). The blue bioeconomy—The creation of a healthy fish farming business ecosystem. *International Journal of Environment and Sustainable Development*, *22*(4), 425–442. https://doi.org/10.1504/IJESD.2023.10057959
The World Bank. (2022). *Squaring the Circle: Policies from Europe's Circular Economy Transition © World Bank.*
Trevisan, A. H., Lobo, A., Guzzo, D., Gomes, L. A. D. V., & Mascarenhas, J. (2023). Barriers to employing digital technologies for a circular economy: A multi-level perspective. *Journal of Environmental Management*, *332*, 117437. https://doi.org/10.1016/j.jenvman.2023.117437
Van Buren, N., Demmers, M., Van Der Heijden, R., & Witlox, F. (2016). Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments. *Sustainability*, *8*(7), 647. https://doi.org/10.3390/su8070647
Walrave, B., Talmar, M., Podoynitsyna, K. S., Romme, A. G. L., & Verbong, G. P. J. (2018). A multi-level perspective on innovation ecosystems for path-breaking innovation. *Technological Forecasting and Social Change*, *136*, 103–113. https://doi.org/10.1016/j.techfore.2017.04.011
Winquist, E., Horn, S., Tuovila, H., Lavikko, S., Sorvari, J., Joutsjoki, V., Karhu, M., Slotte, P., Kautto, P., Kivikytö-Reponen, P., & Ilvesniemi, H. (2023). *R-strategies in circular economy: Textile, battery, and agri-food value chains*. Natural Resources Institute Finland.
World Manufacturing Foundation. (2022). *2022 World Manufacturing Report: Redesigning supply chains in the new era of manufacturing*. https://worldmanufacturing.org/

APPENDICES

Appendix 1. Interview plan

Intro

1. Please talk about your professional background and current role in your organisation.
2. How many years have you been in the sustainability/circular economy/manufacturing field?
3. In your opinion, how is Finland's manufacturing sector doing on its sustainability journey?

Key enablers & barriers in transitioning value chains from linear to circular

A supply chain is a network of suppliers that deliver products from raw materials to end customers through either an engineered or transactional flow of information, goods, and money (Gatewood & Drake, 2024, p. 190). A value chain consists of the functions, activities, resources, and relationships within and beyond a company that add value to its goods or services, from conception to delivery, consumption, and end-of-life (Gatewood & Drake, 2024; EFRAG, 2023). A circular value chain is the coordinated forward and reverse supply chains via purposeful business ecosystem integration for value creation from products/services, by-products, and useful waste flows through prolonged life cycles that improve the economic, social and environmental sustainability of organisations (Batista et al., 2018, p. 18).

4. What are circular value chains' main strengths and weaknesses compared to linear ones?
5. What are the main drivers pushing companies toward circular value chains?
6. What are companies' biggest challenges when transitioning from linear to circular value chains?
7. What kind of support do companies need to transition from linear to circular value chains?

R-strategies

R-strategies can be grouped into three main approaches (Winquist et al., 2023):

- Smarter product use and manufacture (R0 Refuse, R1 Rethink, R2 Reduce)
- Life extension strategies (R3 Reuse, R4 Repair, R5 Refurbish, R6 Remanufacture, R7 Repurpose)
- Maximising material usefulness (R8 Recycle, R9 Recover)

10 R-strategies in order of priority

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

Source: Ellen MacArthur Foundation, 2023; Potting et al., 2017; Winquist et al., 2023

8. In your experience, which R-strategies are most relevant for manufacturing companies?
9. What are the biggest barriers to integrating R-strategies in manufacturing?
10. What are some successful cases where companies have effectively redesigned their value chains using R-strategies? What was the key to success in your opinion?

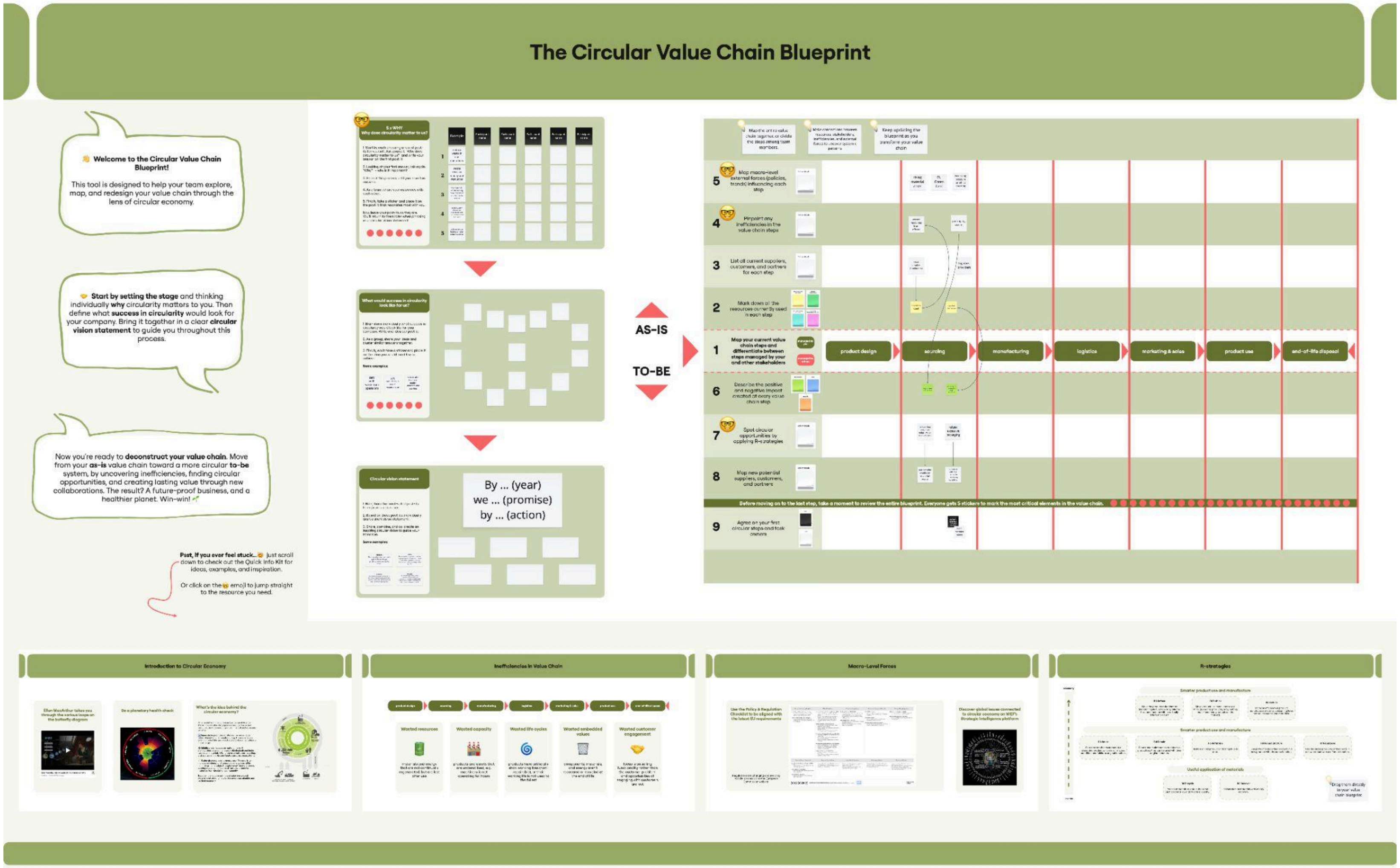
The process of developing circular value chains

11. Could you share specific examples or experiences of how manufacturing companies have transitioned to circular value chains? What methods or tools were useful in the process?
12. What advice would you give to companies looking to redesign their value chain? What are the critical first steps?

Outro

13. What do you see as the future trends in manufacturing and value chains?
14. Is there anything else you think is important to discuss that we haven't covered?

Appendix 2. The "Circular Value Chain Blueprint" tool



Link to Miro board: https://bit.ly/circular-value-chain-blueprint