THE TRANSITION TO SUSTAINABILITY, THE CIRCULAR ECONOMY AND DIGITALISATION

An Operational Framework
for the German Textile and Clothing Industry

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A thesis submitted to The University of Gloucestershire in accordance with the requirements for the degree of Doctor of Philosophy in the School of Business, Computing and Social Sciences

17/10/2025

Word Count: 85,485

ABSTRACT

This study examines how the German textile and clothing (T&C) industry is managing the transition to sustainability, the circular economy (CE), and digitalisation in practice. Although both sustainability and the CE have gained increasing attention in academic debate, empirical research exploring the organisational and technological dimensions of this transformation remains limited. In particular, studies addressing the T&C sector - a key industry in the sustainability and CE discourse - are fragmented, and the German T&C industry has received very little attention in this context. To address this gap, the study pursues three research objectives: (1) To critically explore and analyse the interrelation and implementation of sustainability, the circular economy and digitalisation in an organisational context based on existing literature. (2) To research and analyse the status of the transition to sustainability, the circular economy and digitalisation in the German Textile and Clothing industry. (3) To develop an operational framework for the transition to sustainability and the circular economy, leveraging the potential of digital technologies for the German Textile and Clothing industry. Following an interpretivist and inductive qualitative case study design, data collection combined document analysis and expert interviews. A total of 430 publicly available sustainability-related documents from 29 German T&C companies were analysed and expert interviews were conducted with representatives from 10 of these companies. The analysis, guided by a conceptual framework integrating the dimensions of organisation, products, and processes, suggested, that sustainability is strategically embedded in most companies, supported by value-based management cultures and increasing regulatory and market pressures. CE practices, however, emerged to remain fragmented: while efficiency-oriented narrowing strategies prevail, slowing and closing strategies are still in the early stages due to technological, structural, and market-related barriers. Digital technologies - especially ERP systems and cloud-, AI-, and blockchain-based platforms - emerged as key enablers of transparency, traceability, and data-driven decision-making, yet their use remains largely efficiency-driven and seldom strategically aligned with CE goals. Building on these findings, the study develops an operational framework that integrates changes regarding organisational, product, and process dimensions. It identifies key fields of activity, challenges, influencing factors, and digital technology use cases, providing a structured tool for companies to assess and advance their transition. Overall, the research contributes to knowledge and practice by offering a sector-specific framework for the transition to sustainability, the CE and digitalisation in the German T&C industry. It enhances understanding of the EU's twin (green and digital) transition and provides a foundation for comparative research, further analysis, and practical application in action research approaches.

DECLARATION OF ORIGINAL CONTENT

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas. Parts of the text and selected figures developed in the course of this research have also been used in academic journal articles and book chapters authored or co-authored by the candidate. These publications are fully acknowledged and appropriately referenced.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

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DECLARATION ON THE USE OF DIGITAL TOOLS AND RESOURCES

I hereby declare that I have used various digital tools and resources to support the writing and organisation of this thesis. The tools applied are listed in the table below, together with a precise description of their use cases and scope. These tools were used solely as supportive instruments; the academic content, analyses, and conclusions presented in this thesis are my own independent work and were not influenced by the tools applied.

Tool	Use case	Scope
Zotero	Literature management and referencing	Entire thesis
DeepL	Translation (German/English) and linguistic/grammatical revision	Entire thesis
ChatGPT 4	Translation (German/English), linguistic/grammatical revision, and improving clarity and readability of texts	Entire thesis
NVivo	Data management and thematic analysis / coding	Data analysis

Signed ……

Date 17/10/2025

DOI: 10.46289/XPCW4349

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who have supported me throughout the completion of this thesis. This work would not have been possible without the encouragement, guidance, and assistance of many people to whom I am deeply indebted.

First and foremost, I wish to extend my heartfelt thanks to my first supervisor, Dr Martin Wynn, for his excellent guidance, constructive feedback, and unfailing support. His thoughtful insights, intellectual generosity, and encouragement have been invaluable throughout this research journey. My sincere appreciation also goes to my second supervisor and mentor, Dr Christine Brautsch, for her continuous encouragement, trust, and mentorship. Her thoughtful advice, genuine interest in my progress, and readiness to provide guidance whenever needed have been a constant source of motivation and confidence.

I would also like to thank my colleagues at Hof University for their collegiality, willingness to help, and the supportive working environment that has made this journey both productive and enjoyable.

My deepest gratitude goes to my family for their unconditional love and support during every stage of this process. I am especially grateful to my husband and my son, whose patience, understanding, and encouragement have sustained me through the many challenges of this endeavour.

Finally, I wish to thank my parents, friends and relatives for their continued encouragement and for providing joy, balance, and perspective throughout this demanding journey. Their support has been a vital source of strength and an essential part of the successful completion of this thesis.

„Je mehr ich weiß, desto mehr erkenne ich, wie viel ich nicht weiß.“

(Albert Einstein)

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LIST OF ABBREVIATIONS

AI .....*Artificial Intelligence*
B2B.....*Business-to-Business*
B2C.....*Business to Consumer*
BMI .....*Business Model Innovation*
CBM.....*Circular Business Model*
CBMI.....*Circular Business Model Innovation*
CE.....*Circular Economy*
CLSC .....*Closed-Loop Supply Chain*
CSCM .....*Circular Supply Chain Management*
CSDDD.....*Corporate Sustainability Due Diligence Directive*
CSRD .....*Corporate Sustainability Reporting Directive*
DPP .....*Digital Product Passport*
DTs.....*Digital Technologies*
EPR .....*Extended Producer Responsibility*
ESPR.....*Ecodesign for Sustainable Products Regulation*
EU.....*European Union*
GHG .....*Greenhouse Gases*
IoT .....*Internet of Things*
NGO .....*Non-Governmental Organisation*
OLSC.....*Open-Loop Supply Chain*
P2P.....*Peer-to-Peer*
PCF .....*Provisional Conceptual Framework*
PSS .....*Product–Service System*
SBM.....*Sustainable Business Model*
SCM.....*Supply Chain Management*
SCSCM.....*Sustainable Circular Cupply Chain Management*
SDGs.....*Sustainable Development Goals*
SSCM .....*Sustainable Supply Chain Management*
T&C .....*Textile and Clothing*
TBL.....*Triple Bottom Line*
UN .....*United Nations*

GLOSSARY

Term	Definition
Business Model	Describes how a company creates, delivers, and captures value. Sustainable business model: extends this logic by integrating social and environmental considerations into value creation, delivery, and capture, aiming to generate long-term economic value while reducing negative impacts on stakeholders and the natural environment. Circular business model integrates circular economy principles into value creation, delivery, and capture by narrowing, slowing, and closing material and energy flows through strategies such as reuse, repair, recycling, or product–service systems.
Change Dimension	Refers to core areas of organisational change in which change unfolds as part of a company's transition towards sustainability, the circular economy, and digitalisation. They comprise organisational structures and strategies (Organisation), products and services (Product), and operational and supply chain processes (Processes).
Circular Economy	A system aimed at minimising resource consumption (input) and waste generation (output) by narrowing (reducing resource consumption and increasing efficiency), slowing (extending product and component lifespans through reusing, repairing or remanufacturing), and closing (creating closed material flows through recycling and energy recovery) resource flows to promote sustainability.
Digitisation	The technical process of converting analogue data and information into digital formats.
Digital Technologies	Electronic tools, automated systems, and technological devices that enable the processing, transmission, and storage of digital data.
SMAC and BRAID Technologies	Acronyms referring to two clusters of interrelated digital technologies. SMAC comprises **s**ocial media, **m**obile technologies, **a**nalytics/big data, and **c**loud computing, while BRAID includes **b**lockchain, **r**obotics, **a**rtificial intelligence, **I**nternet of Things, and **d**igital fabrication. Together, these technology groups represent prominent trends in digitalisation, enabling data-driven decision-making, real-time communication, automation, intelligent systems, and new forms of value creation in organisational and industrial contexts.
Digitalisation	The deployment of digital technologies in organisational contexts, leading to modified and newly emerging business and value creation processes.
Digital Transformation	The entirety of socio-technical changes in business and society that emerge from the progressive advancement of digitalisation.
Fields of Activity	Subcategories of change dimensions that group related practices and define specific domains within companies' transition towards sustainability, the circular economy and digitalisation.
German Mittelstand	Refers to predominantly family-owned and owner-managed companies in Germany. Beyond the size criteria for small and medium-sized enterprises as defined by the European Union (including number of employees, annual turnover, and balance sheet total), the concept encompasses the unity of ownership and management. In such firms, entrepreneurs exercise personal managerial control, assume entrepreneurial risk, and derive their primary income from the company.

Term	Definition
Operational Framework	Organises the key change dimensions of a company's transition towards sustainability, the circular economy and digitalisation, and describes their main fields of activity as well as specific practices, challenges, and influencing factors. It provides orientation for practice without constituting a prescriptive implementation model.
Sustainability	A normative concept referring to development that meets present needs without compromising the ability of future generations to meet their own needs, integrating economic, environmental, and social dimensions. Corporate sustainability applies this logic at the organisational level by embedding economic viability, environmental responsibility, and social considerations into business strategy, decision-making, and operational practices.
Textile and Clothing Industry	The textile industry comprises the production and processing of textile fibres, yarns, and fabrics, as well as the manufacture of industrial, technical, and home textiles. The clothing industry refers to the manufacturing of apparel, including outerwear, underwear, sportswear, and workwear.
Transition	Refers to ongoing, multi-dimensional changes through which companies adapt to key trends and dynamics shaping their environment. In this study, these trends refer to sustainability, the circular economy, and digitalisation.

1 INTRODUCTION

1.1 Introduction

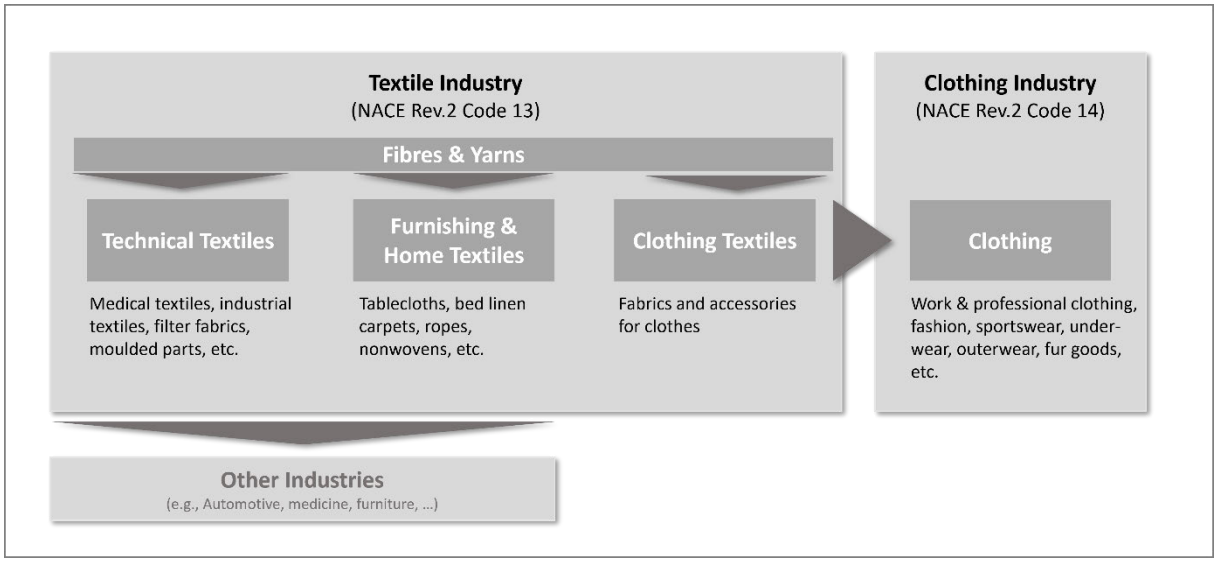
The textile and clothing (T&C) industry is more than just an economic sector – it reflects culture, identity, and technological progress. For centuries textiles and clothing have played a central role in shaping societal developments and trends. The industry can be seen as a mirror of human kind: flexible, creative, and always evolving. Few other industries are as deeply influenced by the interplay of tradition, innovation, and globalisation. It drives innovation, whether through new products, materials, production methods, or technologies. At the same time, it continually responds to societal changes, from fashion trends to global challenges such as climate change and resource conservation. These factors make the sector an exciting field for both work and research.

This study examines the changes currently underway or imminent for companies in the German T&C industry: the transition from a resource-intensive, linear, “dirty”, and analogue to a sustainable, circular, and digital industry.

While textiles and clothing are frequently treated as synonymous terms, this study differentiates between them for analytical clarity (Figure 1).

Figure 1

Classification of the T&C industry and product examples

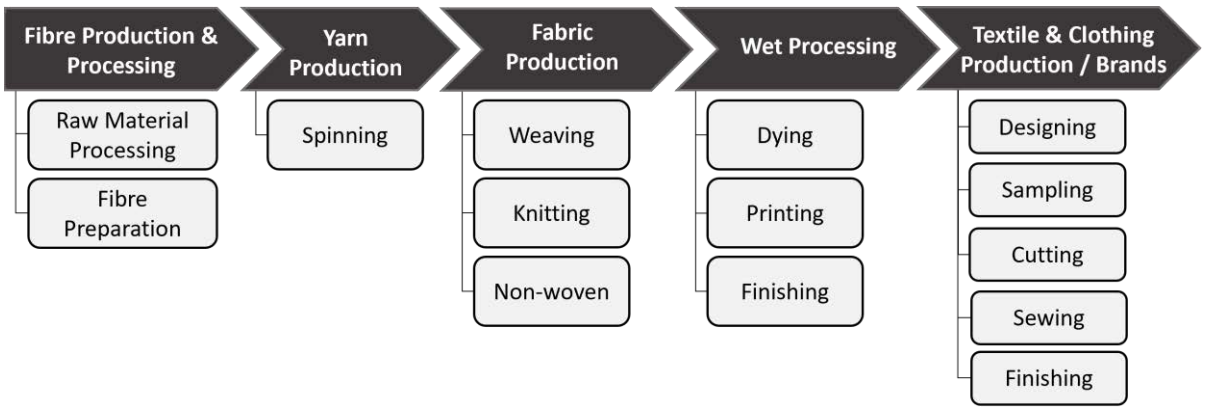


Source: Wynn & Wiegand, 2025, based on Euratex, 2024; Neugebauer & Schewe, 2015

In NACE[1] revision (Rev.) 2, the textile industry is classified under code 13 and comprises activities related to the manufacture and processing of fibres, yarns, fabrics, and a range of technical, industrial, and home textiles. By contrast, the clothing industry is listed under code 14 and includes the manufacture of apparel products such as outerwear, underwear, sportswear, and workwear (European Parliament, 2006).

This study focuses on the five core manufacturing stages within the T&C sector (Figure 2). The process begins with the conversion of raw materials into fibres, followed by the spinning of fibres into yarns. In the next stage, the yarns are processed into fabrics through weaving, knitting, or nonwoven production. Wet processing then applies treatments such as dyeing, printing, and finishing. Finally, the materials are manufactured into marketable end products or supplied as intermediate goods for further industrial use (Euratex, 2024).

Figure 2
The textile value chain



Source: Adapted from Wiegand & Wynn, 2024, based on Euratex, 2024; Stamm et al., 2019 and UN Environmental Programme, 2020

This chapter provides the background for the research study. The relevance and value of the thesis build on the unique characteristics of the T&C industry in Germany, which has been undergoing profound structural change for decades, as well as its specific business environment and the impacts of current and emerging global and European developments on competitiveness and potential strategies for its preservation. The chapter is divided into five sections. Following this introduction, Section 1.2 provides

[1] The term NACE is derived from the French (**N**omenclature statistique des **a**ctivités économiques dans la **C**omunauté **e**uropéenne) and stands for the “classification of economic activities in the European Union”

an overview of recent global and European developments and their impact on the German sector and its stakeholders. Section 1.3 presents the theoretical background to the study, outlines the research motivation, defines the research objectives and summarises the study's contributions to both knowledge and practice. Section 1.4 offers an overview of the methodology employed. Finally, Section 1.5 highlights the core aspects of the research and provides an overview of the study's overall content and structure.

1.2 Background to and Overview of the German Textile and Clothing Industry

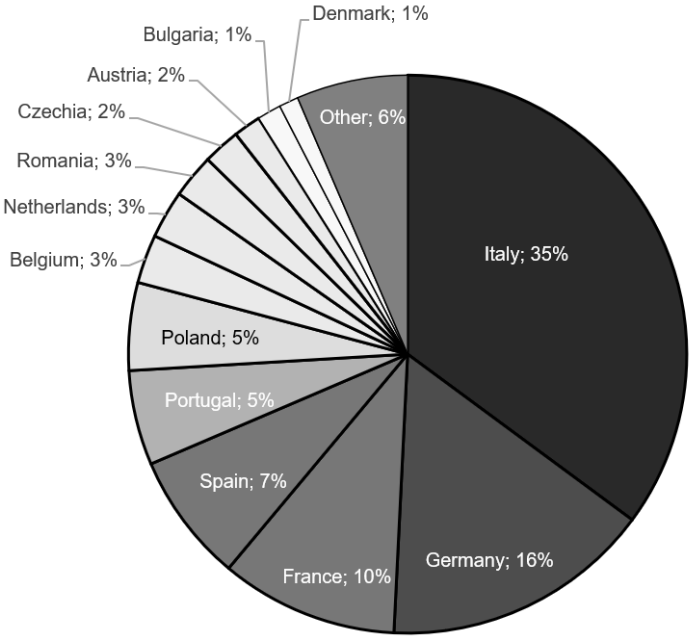
This section provides an overview of Global and European developments shaping the German T&C industry. Furthermore, this section outlines the size and global interconnectedness of the German T&C industry and gives an overview of its historical development as well as current and future megatrends shaping the industry.

1.2.1 Global and European Context Shaping the German T&C Industry

The production and consumption of T&C products have increased markedly over recent decades. Global fibre production for textile applications rose by 113% between 2000 and 2023, while the world population grew by only around 30% over the same period (Textile Exchange, 2024; World Bank, 2024). At the same time, the T&C value chain has become highly internationalised, involving a large number of actors and interconnected production processes (see Figure 2) (European Commission & CSIL, 2021). Within the EU, annual textile production amounts to around 7 kg per person, whereas per capita consumption is close to 26 kg, indicating a strong reliance on imports, particularly clothing products sourced from Asia (EEA, 2019). In addition, around 15 kg of textiles are discarded per person each year in the EU, while recycling rates remain low (Hedrich, et al., 2022). In economic terms, the EU remains a major actor in the global T&C industry. In 2023, the sector comprised around 197,000 companies, employed more than 1.3 million people, and generated approximately €170 billion in turnover (Euratex, 2024). Germany ranks second after Italy in terms of turnover within the EU (Figure 3), accounting for 16% of the European total (Eurostat, 2023). Beyond its position in the EU market, Germany also plays a prominent role globally, ranking as the world’s second-largest importer and third-largest exporter of T&C products (World Trade Organisation, 2023). This underlines the internationally fragmented nature of

T&C value creation and its close connection to social, environmental, and waste-related challenges across different world regions (Gözet & Wilts, 2022). In this context, Gözet and Wilts (2022, p. 9) describe Germany as a “key player and changemaker” in driving solutions.

Figure 3
Member state share of total turnover in the EU´s T&C industry



Source: Eurostat, 2023

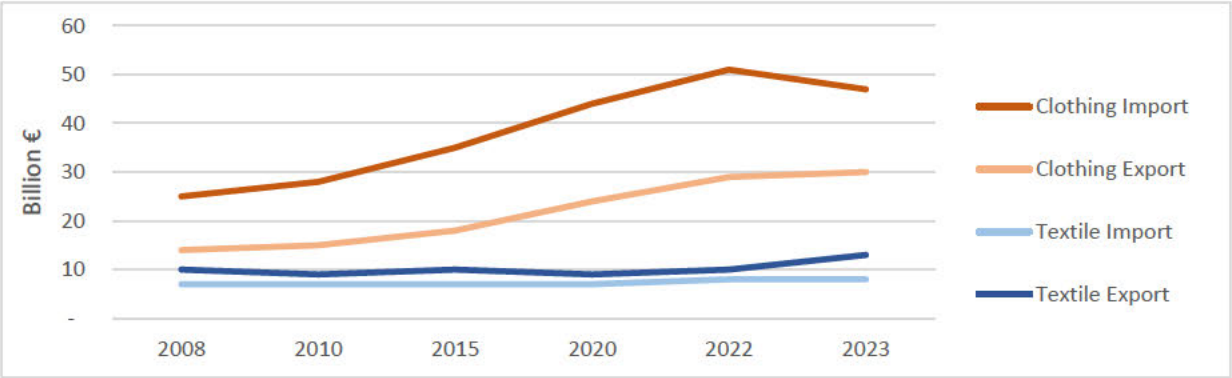
1.2.2 History and Development of the German Textile and Clothing Industry

The German T&C industry has a rich historical background, evolving from small workshops to the emergence of textile factories during industrialisation in the 19th and 20th century, particularly in the German uplands (Breitenacher, 1981). The industry played a significant role in the country's industrial development, with Saxony being the most industrialised region in the early 20th century (Heimann, 1997). However, the World Wars led to substantial damage to many textile factories and the division of Germany after World War II led to divergent developments in both German states (Breitenacher, 1989). In the western part, the industry expanded strongly during the 1950s and 1960s (Schneider, 2003). In the eastern part, by contrast, T&C production was reorganised under state ownership and integrated into large centrally controlled combines (Sachsentextil, 2014). From the 1970s onward, increasing international competition led to far-reaching structural change, particularly in West Germany. Labour-intensive stages

of clothing production were increasingly relocated abroad, whereas the textile sector proved more resilient due to its greater capital intensity and technological orientation (Neuhoff et al., 2024). A major source of growth in this transformation was the expansion of technical textiles, which found applications in sectors such as automotive manufacturing, medical technology, and lightweight engineering. Following reunification, parts of the East German textile industry were successfully modernised, and the region has since developed into an important centre for technical textile innovation and production (Dispan, 2009; Marschall et al., 2020). However, in terms of gross value added (adjusted for inflation), clothing production in Germany decreased by around 90% between 1980 and 2020 (Neuhoff et al., 2024). The activities that remain in Germany are concentrated less on large-scale manufacturing and more on higher-value functions, including product development, design, sourcing, marketing, distribution, logistics, and administrative tasks (Dispan, 2009). Some firms still operate sewing facilities for prototypes, customised orders, or small production runs (Dispan, 2009), but large-volume production is mainly carried out in countries such as China, Bangladesh, India, and Turkey (Statistisches Bundesamt, 2024b). As a result, clothing consumption in Germany is largely met through imports. In 2023, the value of clothing imports exceeded €47 billion, almost twice the level recorded in 2008 (Figure 4). Although German T&C firms constitute the unit of analysis in this study, the industry can only be understood adequately by considering its globally interconnected supply chains and internationally fragmented value creation processes. At the same time, parts of the textile sector continue to maintain domestic production, and both imports and exports of these textile products remain comparatively limited relative to clothing products, as shown in Figure 4 (Statistisches Bundesamt, 2024b).

Figure 4

Import and export of textiles and clothing in Germany 2008 - 2023 (in € billion)



Source: Statistisches Bundesamt, 2024c

The current structure of the German T&C industry reflects these developments: In 2023, the sector comprised 879 companies with approximately 79,000 employees. Of these, 689 firms were classified in the textile sector (NACE Code 13), while 190 belonged to the clothing sector (NACE Code 14) (see Table 1). The industry is dominated by small and medium-sized enterprises (SME), which account for around 95% of all companies (Statistisches Bundesamt, 2024a).

Table 1
Characteristics of the German T&C industry

Textile Industry (NACE Code 13)	Clothing Industry (NACE Code 14)
• 689 companies in Germany (78%) • 12,379,560 € Revenue (63%)	• 190 companies in Germany (22%) • 7,382,069 € Revenue (37%)
• Capital-intensive	• Labour-intensive
• Manufacturing in Germany	• Manufacturing mainly outsourced

Source: Based on data from Statistisches Bundesamt, 2024a

1.2.3 Key Trends and Dynamics Shaping the German T&C Industry's Environment

As outlined before, the German T&C industry has always been a dynamic sector. Driven by technological, geopolitical, regulatory and fashion-related trends and developments, the industry has been undergoing far-reaching changes for decades (Dispan, 2009; Schneider, 2003). However, the impacts of globalisation, current crises and emerging megatrends, as outlined hereafter, require an active transition to a more sustainable, circular and digitalised industry.

1.2.3.1 Sustainability

Global competitive pressures on the German T&C industry have led to new trends and fashion collections at ever shorter intervals. To remain competitive, companies in the clothing sector have relocated production to developing and emerging economies. These regions offer lower labour costs and less stringent environmental and social standards compared to Germany, enabling companies to reduce sales prices and encourage more frequent consumer purchases (Dispan, 2009; Schneider, 2003). One of the first studies on the impact of the German fashion industry by Oxford Economics (2022) estimated that the global greenhouse gas emissions caused by the German industry amounted to a value of 38 million tons, with only about two million tons (5%) attributed to Germany. Globalisation of the T&C supply chain has also led to social

impacts, especially in the production countries of the so-called Global South. These include unacceptable working conditions such as child labour, the use of harmful chemicals, safety issues in factories, forced labour, and low wages (Köksal et al., 2017). Public reporting on the social impacts along German T&C companies global value chains, as well as high-profile actions and campaigns by non-governmental organisations (NGOs) have led to increased awareness in society and politics. A prominent example is Greenpeace's Detox Campaign (Kopp et al., 2021) which exposed the use of toxic and hazardous substances in textile production and intensified demands for clean and socially responsible textiles.

As the largest economy in the EU and the fourth-largest economy globally, Germany has one of the world's most significant consumer markets for T&C products (Oxford Economics, 2022). According to a representative study by Greenpeace (2022), greater proportion of people in Germany prioritise sustainability (35%) over price (29%) when purchasing textiles. This represents a notable shift compared to the survey results from a previous study (Greenpeace, 2015) and suggests a growing shift in consumer awareness and buying behaviour.

In addition to changing consumer behaviour, regulatory pressure on the German industry is also increasing. The State of Fashion Report by McKinsey & Co. (2023a) highlights that the era of self-regulation in the T&C industry regarding sustainability is coming to an end, with new regulations expected to have significant and far-reaching impacts on the sector.

1.2.3.2 Resource Efficiency and Circularity

"*If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years*." (Meadows et al., 1972, p. 23)

This conclusion was reached five decades ago in a Club of Rome-commissioned study on the limits to growth on earth (Meadows et al., 1972). Yet global resource use and waste generation continue to increase, with serious consequences for the environment, including greenhouse gas emissions, biodiversity loss, and air, soil, and water pollution (United Nations Environment Programme, 2024). The T&C sector serves a prominent example of these developments. Over the past decades, the production and

consumption of T&C products have undergone a rapid escalation (Gözet & Wilts, 2022) globally. At the same time, T&C products are disposed of after an increasingly short use, with low recycling rates, which results in environmental damage and an enormous resource loss (Hedrich, et al., 2022). Consequently, the global T&C industry has evolved into the world's fourth-largest consumer of primary raw materials and water and the fifth largest emitter of greenhouse gas emissions (EEA, 2019). In light of these impacts, the prevailing linear “cradle-to-grave” model of production and consumption is increasingly being questioned (Gözet & Wilts, 2022).

The circular economy (CE) is widely regarded as a promising alternative because it seeks to reduce the dependence of economic development on ever-increasing resource consumption (Stahel, 2016). A CE refers to an “economic system that targets zero waste and pollution throughout materials lifecycles” (Nobre & Tavares, 2021, p. 10) by replacing “the end-of-life concept with reducing, alternatively reusing, recycling, and recovering of materials throughout the supply chain” (Kirchherr et al., 2023). Although the concept itself is not new, it has gained considerable political and strategic importance in recent years. This is reflected in major international and European policy frameworks, including the United Nations (UN) Sustainable Development Goals (SDGs) (United Nations, 2015), the European Green Deal (European Commission, 2019) or the European Circular Economy Action Plan, which T&C states a key value chain for increased circularity (European Commission, 2020a).

Almost 7 million tons of textile waste are generated annually within the EU, equivalent to 16 kg per capita, of which an average of only 12% is collected (Deckers et al., 2024). Germany accounts for 1.7 million tons of this waste, achieving one of the highest collection rates in the EU at nearly 60% (BVSE, 2020). According to a study by McKinsey, household-discarded textile waste constitutes approximately 85% of total textile waste in the EU, while the remaining 15% originates from post-industrial, commercial, and pre-consumer waste (Hedrich, et al., 2022). Although no specific data is available for these waste categories in Germany, applying the EU share of 15% to Germany’s total textile waste suggests an estimate of approximately 250,000 tons. More than half of which is typically incinerated or landfilled, resulting in the loss of valuable resources (Shamsuyeva, 2022). While domestic material recycling remains low, approximately 62% of the German textile waste is exported to other regions (BVSE, 2020). Information on what happens to textiles in the export countries remains scarce. A report by

the European Environment Agency (EEA, 2023) suggests that in many regions of Africa and Asia - where a significant share of used textiles from Germany is exported to - there are no established collection or recycling systems. As a result, discarded textiles from Germany often end up in landfills or incineration in other parts of the world, leading to resource loss and environmental concerns. However, notable shifts in consumer behaviour in industrialised countries are emerging. In recent years, growth has been observed in alternative business models such as second-hand fashion retail and rental services. A PwC study estimates that the second-hand textile market will more than double from approximately USD 90 billion in 2021 to over USD 200 billion by 2026 (PwC, 2023), potentially leading to changes in both demand patterns and waste streams.

1.2.3.3 Political and Regulatory Developments

As outlined previously, T&C companies are facing growing pressure from regulators, investors, consumers, and other stakeholders to reduce their environmental and social impacts and to strengthen sustainable and circular practices. At the EU level, these developments are reflected in a growing number of policy and regulatory initiatives under the European Green Deal (European Commission, 2019). Several of these are highly relevant to the T&C industry. Among the most important policy frameworks in this context are the European Industrial Strategy (European Commission, 2020b) and the EU Strategy for Sustainable and Circular Textiles (European Commission, 2022b). Together, these frameworks are expected to reshape the regulatory conditions under which T&C companies operate.

One important development is the revision of the Waste Framework Directive (European Commission, 2023d), which requires EU member states to establish separate textile collection systems by 2025. This measure is intended to expand collection, sorting, reuse, and recycling capacities and to stimulate further progress in sorting and recycling technologies. It also introduced the instrument of extended producer responsibility (EPR), under which T&C companies are expected to assume greater responsibility for the full life cycle of their products. In practical terms, this is meant to reduce textile waste and to encourage reuse and recycling instead of disposal, incineration, or export. Another key piece of legislation is the Ecodesign for Sustainable Products Regulation (ESPR) (European Commission, 2024b). This regulation is expected to introduce product-specific ecodesign requirements, including for T&C products, with the

aim of improving environmental performance, durability, and recyclability. It also provides the basis for a digital product passport (DPP), which is intended to make sustainability-related product information digitally accessible. This may include information on durability, reparability, recycled content, and the availability of spare parts. In this way, the DPP is designed to improve transparency across product life cycles and to support more informed purchasing decisions.

Further regulatory initiatives affect the financial, reporting, and supply chain responsibilities of companies. The EU Taxonomy Regulation (European Commission, 2023a), for instance, establishes criteria for environmentally sustainable economic activities and is intended to channel investments towards more sustainable business practices. For German T&C companies, this may influence access to finance and future investment conditions. In addition, the Corporate Sustainability Reporting Directive (CSRD) (European Commission, 2022a) expands sustainability reporting obligations, while the Corporate Sustainability Due Diligence Directive (CSDDD) (European Commission, 2024a) strengthens due diligence requirements across supply chains. The Regulation on Deforestation-Free Supply Chains (European Commission, 2023c) adds another layer of responsibility by requiring companies to demonstrate that relevant products are not linked to deforestation or forest degradation. Although many of these measures do not yet impose fully sector-specific obligations on all T&C firms, they clearly indicate a tightening regulatory environment that will increasingly affect the industry.

Rules and regulations are also being adapted at national level. In December 2024, Germany adopted the National Circular Economy Strategy (BMUV, 2024) aimed at reducing primary raw material consumption and largely closing material loops through circular and resource-efficient product design, production processes, and business models. The T&C industry also plays an important role here. The targets include to

- increase the number of companies that sell or rent clothing and textiles primarily for reuse, as well as their turnover and employment figures,
- increase sales of durable clothing and in circular business models and
- increase the use of recycled fibres in textile production.

The German National Circular Economy Strategy also provides for corresponding research funding and the promotion of innovations with the aim of making sustainable and recyclable textiles the standard. Such developments are not only reshaping the market and competitive dynamics but also challenging traditionally linear supply chains

and logistics concepts. Changing consumer behaviour, coupled with increasing regulatory interventions, is driving dynamic market transformations and posing new challenges for the industry. It is to be assumed that companies that are aware of these diverse changes and can adapt quickly and flexibly will be able to establish and expand their competitive advantage in the future.

1.2.3.4 Digitalisation

Digitalisation is considered one of the central megatrends of the 21st century and is leading to profound changes in business and society (Verhoef et al., 2021). However, the term has increasingly become a buzzword that is used across a wide range of contexts and is often applied interchangeably with related concepts such as digital transformation. To avoid conceptual ambiguity, this section briefly introduces and differentiates between the relevant terms and provides an overview of key technologies and developments. In this context, three concepts are distinguished: digitisation, digitalisation, and digital transformation.

Digitisation refers to the technical process of converting analogue data and information into digital formats and represents a core principle underlying computing technologies (Legner et al., 2017). Building on this principle, digital technologies (DTs) can be understood as electronic tools, automated systems, and technological devices that enable the processing, transmission, and storage of such digital data (Wynn & Jones, 2022a).

Digitalisation refers to the use of DTs within organisational contexts, leading to modified and newly emerging business and value creation processes - such as robot-assisted manufacturing or platform-based market transactions - and enabling digital products, services, and business models (Verhoef et al., 2021).

The increasing diffusion and accelerated development of internet-based technologies, frequently grouped under the acronyms SMAC (social media, mobile technologies, analytics/big data, and cloud computing) and BRAID (blockchain, robotics, artificial intelligence, Internet of Things, and digital fabrication), have for several years formed the cornerstones of digitalisation in organisations and society (Legner et al., 2017; Wiener et al., 2025; Wynn & Jones, 2022a). Digital transformation extends beyond the mere

digitalisation and automation of organisational processes and tasks, entailing a fundamental reconfiguration of business logics and processes that is accompanied by profound socio-organisational changes. (Legner et al., 2017; Verhoef et al., 2021).

Importantly, these technologies do not operate as standalone innovations but derive their transformative potential from their interconnected use. For instance, social media enable new forms of real-time interaction, communication, and value creation between companies and customers. In 2025, more than 5.4 billion people worldwide used social media (Statista, 2025) As such, social media primarily offer companies opportunities for direct interaction, customer observation and influence over consumer behaviour. They are therefore predominantly used for marketing and communication purposes, while increasingly evolving into social commerce channels (KPMG, 2024). At the same time, their use is associated by consumers with high expectations regarding speed, transparency, and service quality, meaning that social media can represent not only strategic opportunities but also significant reputational risks for companies (McKinsey & Co., 2023b), and therefore requires organisational adaptation and the development of new capabilities. Mobile technologies, in particular mobile devices and applications, are ubiquitous and ensure the continuous availability of digital services - such as social media - across time and space. This leads to changes in communication and consumption behaviour, information search, as well as in work spaces and conditions (Verhoef et al., 2021). The systematic collection of the large volumes of data (=big data) generated through these technologies and processes, together with their processing and analysis, forms the foundation for data sharing and monetarisation e.g., through data-driven business models, informed managerial decision-making, personalised offerings, or far-reaching forecasting capabilities. At the same time, these developments give rise to new challenges related to data protection and data security. Cloud computing, in turn, provides the necessary and scalable IT infrastructure to use, distribute, and deploy data and applications flexibly and independently of location, while enabling workflow monitoring and remote collaboration (Calderon-Monge & Ribeiro-Soriano, 2024; Quach et al., 2022).

Further applications, which can be grouped under the acronym BRAID (Wynn & Jones, 2022a) extend these developments into industrial and manufacturing contexts and are therefore often subsumed under the concept of Industry 4.0 (Calderon-Monge & Ribeiro-Soriano, 2024; Culot et al., 2020), These technologies build on the foundational

technologies described above or extend them into new contexts. For instance, blockchain technologies combine several other DTs to create novel decentralised databases (distributed ledgers) that record transactions and other information through chains of time-stamped and cryptographically secured digital entries, thereby enabling reliable and decentralised data exchange. They are applied across a wide range of sectors, including supply chain and logistics as well as banking and finance (Tripathi et al., 2023). Robotics and digital fabrication technologies transform production and service processes through automation, efficiency gains, and new forms of customised manufacturing, such as digital twins and additive manufacturing (= 3D printing). Artificial intelligence (AI) enables automated decision-making, pattern recognition, and learning systems that are applied in areas such as production, logistics, and customer service. Finally, the Internet of Things (IoT) connects physical objects via sensors, enabling the real-time monitoring and control of processes (Tripathi et al., 2023; Verhoef et al., 2021). In this context, the scope of DTs extends beyond individual firms to include the vertical integration of production systems and the horizontal integration of partners along the value chain. Interoperability and interconnectivity are therefore key prerequisites for the functional integration of IoT, cloud computing, data-driven analytics, and higher-level technologies such as artificial intelligence, robotics, and additive manufacturing.(Culot et al., 2020).

Taken together, these technologies drive profound changes in business models, manufacturing processes, competitive structures, and consumer behaviour. They are likely to enable efficiency gains, new value creation logics, and innovative offerings, while simultaneously increasing the pressure on companies to adapt. Despite their transformative potential, DTs should not be understood as universally beneficial or independently deployable solutions, as their effective use depends on organisational capabilities, appropriate data and IT governance, and, in particular, a high degree of interoperability and interconnectivity across technological systems and organisational units (Verhoef et al., 2021) and is associated with substantial investments for companies (Quach et al., 2022). Moreover, the integration of data-driven technologies raises critical issues related to data ownership, cybersecurity, transparency, and accountability that extend beyond individual firms and affect entire value networks, underscoring

that digitalisation represents a systemic process in which the coordination of technologies, organisational structures, and stakeholder relationships becomes a central managerial task.

These considerations are particularly reflected when examining the sector-specific developments in the T&C industry. For example, the shift of marketplaces in the T&C retail sector to the virtual sphere through e-commerce and social media illustrates how DTs reshape competition, consumer behaviour, and supply chains (Amed et al., 2022; McKinsey & Co., 2024). A 2020 study by the German Textile and Fashion Association (Peters & Goluchowicz, 2020) highlights that industry representatives perceive digitalisation as a major opportunity for the entire T&C sector. These range from automation and efficiency improvements in design and manufacturing processes to greater supply chain transparency and traceability, as well as the development of smart, digitalised products and business models. The use cases of DTs are manifold. For example, a McKinsey study presents 20 different use cases for the application of generative AI in the fashion value chain (Harreis et al., 2023). Various studies and surveys among managers in the German and European T&C industry indicate that the development of the industry and its companies is strongly linked to successful and continuous digital and technological innovation (Interreg SUDOE, 2020; Neuhoff et al., 2024). McKinsey summarises it as follows:

> *"[…] fashion brands and manufacturers will need to not only embrace digital tools across their value chain, but also prioritise process redesign, data quality enhancement and the integration of planning systems to provide visibility for all parties across the value chain*" (McKinsey & Co., 2024, p. 24).

Industry associations in Germany also emphasise the importance of digitalisation on their websites and actively support their members by organising advisory and information events, networking initiatives, and funding programs to facilitate the adoption of DTs e.g., The German Fashion academy or the German Textile and Fashion Association (German Fashion, n.d.; Textil+Mode, n.d.). Furthermore, political initiatives, such as the upcoming DPP for textiles and new reporting obligations, will impact the German companies (Legardeur et al., 2024). These regulations will accelerate the need for data collection and traceability, as well as the efficient restructuring of key processes, forcing companies to adapt quickly to remain competitive.

In summary, the trends and developments described in this section are impacting and challenging the German T&C industry in multiple ways, which will lead to further transformative changes in the sector. Digitalisation is increasingly discussed in different fields of research as an essential catalyst for orchestrating the comprehensive transformation from a linear to a more sustainable and circular industry, thereby functioning as a central enabler for realising circular strategies and practices. Previous studies have shown that the developments described in this section exert institutional pressure (both coercive and normative) on companies in the T&C industry, prompting them to adapt accordingly (Abbate et al., 2023; Stål & Corvellec, 2018).

However, empirical research on how sustainability and circularity are implemented in organisational practice and what role DTs play in this context remains limited, with the existing literature being largely conceptual. There appears to be a lack of empirical and industry-specific studies (Neri et al., 2024) that address the practical and operational aspects of this developments. This study therefore seeks to examine how companies in the German T&C industry perceive and pursue sustainability and circularity in practice and what role DTs play in supporting these efforts, while deriving practice-oriented implications from the findings.

1.3 Theoretical Background, Research Motivation and Objectives

In the previous section an overview of economic and political developments and relevant megatrends impacting the German T&C industry was given and an overarching objective for this study was derived. In this section the study is set within a theoretical background. Furthermore, the research motivation and specific research objectives are presented.

1.3.1 Theoretical Background

The primary and overarching goal of every company is to ensure its own survival and to achieve long-term economic success. There are various theories and explanatory approaches from a wide range of research fields as to how this success is achieved and why some companies are more successful than others. The future success - and ultimately the survival - of German T&C companies is expected to depend to a considerable extent on how effectively they are able to maintain and strengthen their competitive position by adapting to complex regulatory and socio-economic developments and by leveraging technological advancements to their advantage. Institutional theory

can help explain the driving forces and contextual factors resulting in intended organisational change initiatives (DiMaggio & Powell, 1983). However, it primarily provides an external perspective on organisational change and offers only limited insight into how change processes unfold within organisations.

Therefore, the phenomenon will be viewed through the lens of organisational change. Organisational change is understood as a “difference in form, quality, or state over time in an organisational entity” (Van De Ven & Poole, 1995, p. 512). These can refer to individual units (e.g., a department, a product) as well as to the organisation as a whole or its relationships with other organisations. In the field of organisational change and transformation, different research directions have emerged (Stouten et al., 2018).

Pettigrew (1987) developed a holistic analytical framework for the study of organisational change by suggesting that any change consists of three aspects, namely the content, the process and the context of change. Hence, the organisational change to sustainability, circularity and digitalisation must take all these aspects into account. The content dimension characterises the “what” of a change, such as products or processes of an organisation. The process dimension characterises the “how” of change. It is concerned with the actions required to move the organisation from the current to the future state. The context dimension characterises the forces or conditions in an organisation`s internal and external environment that are both drivers and influencing factors of change (Armenakis & Bedeian, 1999; Pettigrew, 1987). Using such a broad theoretical framework as a starting point for the study allows for a structured approach to mapping, classifying and discussing the existing literature and to deriving specific research objectives related to the T&C industry´s transition. It is broad enough not to limit creativity for the research and provides scope for making a valuable contribution to knowledge and practice.

1.3.2 Research Motivation, Objectives and Contribution

The author has two professional backgrounds. Firstly, she was working in the German T&C industry for many years and was involved in organisational change processes in various companies. Secondly, she is working as a lecturer in business administration at a university of applied sciences, where she is particularly interested in economic and societal megatrends, and associated organisational change. This dual perspective, combining practical industry experience with academic reflection, resonates strongly with current debates in management research. One of the most influential journals in

the field of business and management research, the *Academy of Management Journal*, has chosen "*Transformational Times for Management and Organisations*" as an overarching topic for the journal (Gruber, 2023, p. 1). Gruber (2023) highlights the massive changes that characterise our times. He argues that companies are facing a wide range of new opportunities and challenges resulting from general social and technological developments. Of course, there have been changes in the past - it must be said that change and development are inherent in the anthropocentric age - but the intensity, rapidity and therefore the complexity seem to be accelerating nowadays. At the same time, and this is a new phenomenon, Gruber points to the urgent need to make organisations more sustainable in response to global crises. The motivation for this research stems from the intersection of the two professional spheres in which the author operates. The study, therefore, examines how organisations in the German T&C industry implement sustainability, with a focus on circular economy practices, and the role DTs play. This study addresses the following research objectives:

RO1: To critically explore and analyse the interrelation and implementation of sustainability, the circular economy and digitalisation in an organisational context based on existing literature.

RO2: To research and analyse the status of the transition to sustainability, the circular economy and digitalisation in the German Textile and Clothing industry.

RO3: To develop an operational framework for the transition to sustainability and the circular economy, leveraging the potential of digital technologies for the German Textile and Clothing industry.

The thesis builds upon and extends interim findings published by the author during the conduct of the research study (Wiegand & Wynn, 2023, 2024; Wynn & Wiegand, 2025)

This study aims to contribute to both knowledge and practice by identifying and addressing a gap in existing literature. A review of prior research suggested that, while sustainability, the CE and digitalisation are increasingly discussed, few studies examine how these are jointly addressed and enacted in organisational practice. Moreover, existing frameworks tend to remain fragmented and lack sector-specific grounding, resulting in a limited understanding of how companies in the German T&C industry interpret, organise, and operationalise sustainability- and CE-related initiatives, and what role digital technologies are playing in supporting and shaping these efforts.

To address this gap, the study provides a comprehensive empirical analysis of how sustainability and CE initiatives are interpreted and enacted in organisational practices of German T&C companies. The resulting operational framework offers a practice-oriented contribution that supports organisational sense-making and operationalisation by helping practitioners to reflect on existing approaches, identify context-specific challenges and opportunities, and navigate ongoing digitally enabled sustainability and CE initiatives. This study constitutes an initial step in this area of research. The findings provide a foundation for subsequent research that engages more directly with organisations to examine the application and feasibility of the operational framework in practice. In particular, future studies adopting action-oriented or participatory research approaches may generate practice-based insights that support the iterative development and contextual adaptation of the framework.

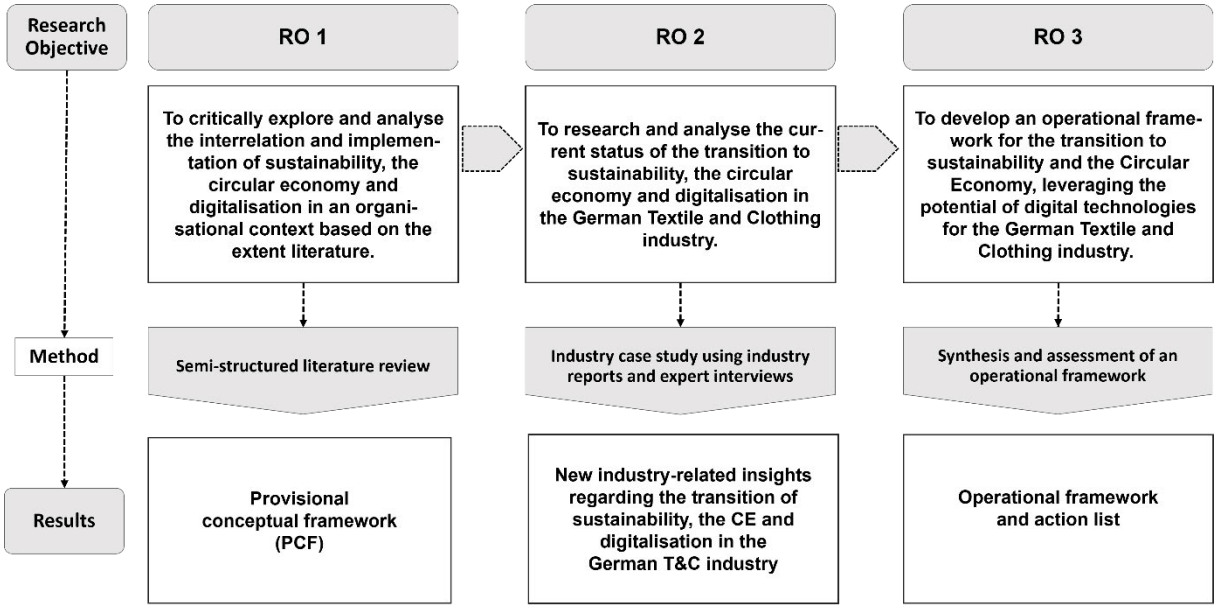
Although empirically grounded in the German context, the insights generated by this research extend beyond the specific setting of the study. They offer an analytically transferable basis that may inform comparative research and practice-oriented inquiry in other regional or industrial contexts undergoing similar sustainability- and digitalisation-related change processes.

1.4 Research Methodology

This study employs a combined research approach to address the research objectives (Figure 5). Firstly, in addressing RO1, a semi-structured literature review was conducted, from which a provisional conceptual framework was derived. Second, to address RO2, the study followed a qualitative, inductive case study approach informed by an interpretivist philosophy, examining the German T&C industry as a clearly defined and context-specific empirical setting. Data collection combined document analysis and expert interviews. A total of 430 publicly available sustainability-related documents (e.g. reports, corporate websites, and trade journal articles) from 29 German T&C companies were analysed, complemented by semi-structured interviews with decision-makers from 10 of these companies. Data were analysed using thematic analysis following Braun and Clarke (2006), enabling patterns of practices and meanings to be identified across the empirical material. Finally, addressing RO3, an operational framework and associated action list were developed through an iterative synthesis of insights from the case study findings and the literature. These outputs were reviewed through a complementary online questionnaire involving eight practitioners from the

participating companies providing an initial assessment of the framework's plausibility, clarity, perceived usefulness, and practical applicability. The trustworthiness of the study was supported through several measures, including the use of multiple data sources, reflexive research practices, transparent reporting, and adherence to established ethical standards.

Figure 5
Research diagram



1.5 Summary and Thesis Structure

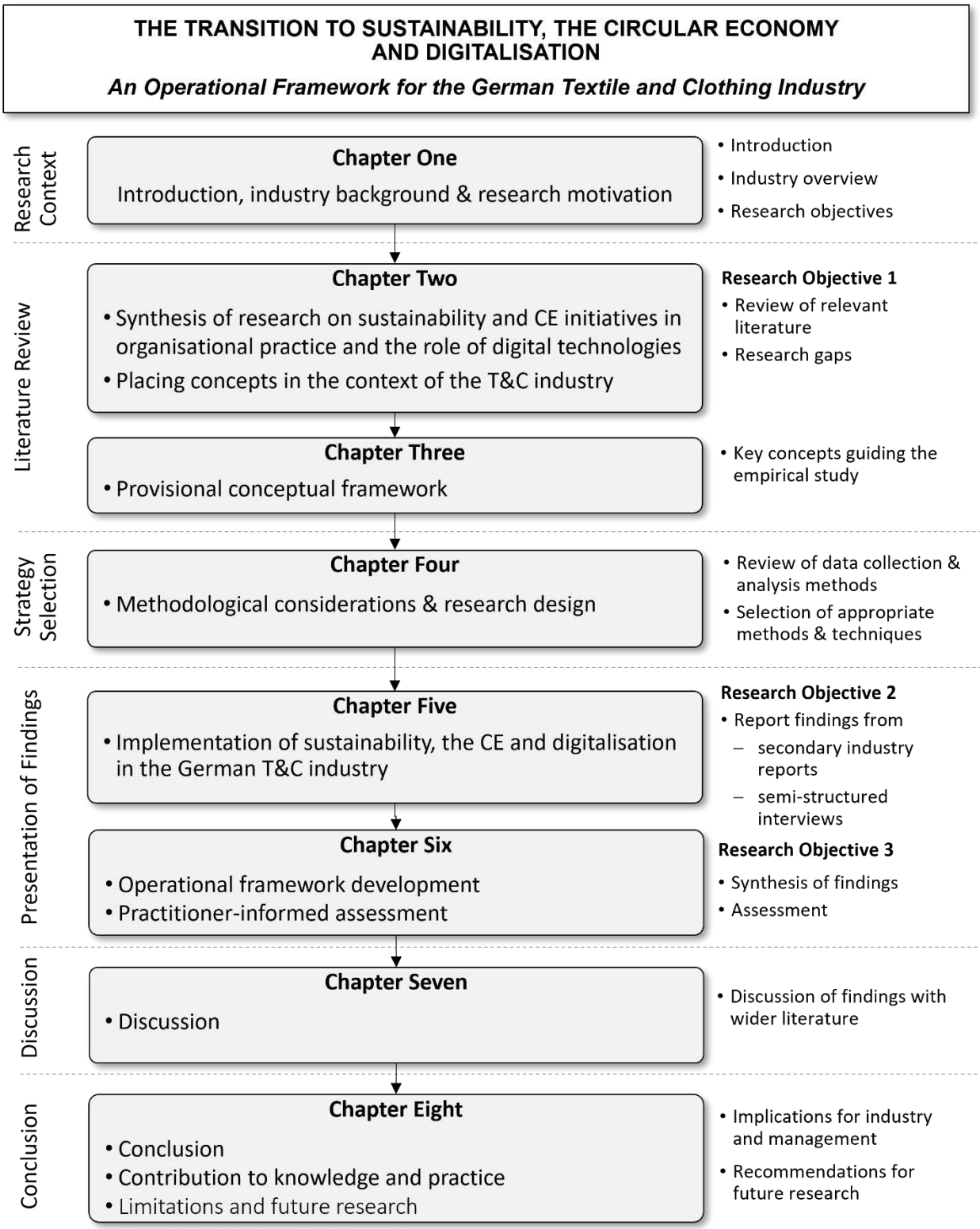
This chapter has outlined the background to and scope of the study and clarified the key parameters of the research. The current legal, socio-economical, and technological developments in the fields of sustainability and the CE, along with the role of the DTs in this context, serve as the starting point and define the need for sector-specific, practice-related research at the intersection of sustainability, the CE and digitalisation in the German T&C industry. **Chapter Two** aims to address RO1. The semi-systematic literature review synthesises empirical insights from prior studies on how sustainability and CE-related initiatives are implemented in organisational practice and what role DTs are playing in this context.

Additionally, it discusses the related previous research in the field of the T&C industry, identifies research gaps, and defines the research questions for the empirical industry investigation. Based on the results and insights from the literature analysis a provi-

sional conceptual framework is developed in **Chapter Three**, which serves as the basis and guide for data collection and analysis. It evolves throughout the study based on collected data and supports the interpretation of results, the development of practical implications, and the generation of empirically grounded insights within the research field. **Chapter Four** serves as a link between the theoretical part with the resulting research questions, and the empirical part addressing those questions. In this chapter, relevant methodological approaches are discussed, an appropriate method is selected, and its choice and implementation in the context of the research questions are explained. The processes of data collection and analysis are also described. **Chapter Five** reports the findings on how sustainability- and CE–related change processes are understood and implemented in the German T&C industry, based on a thematic analysis of industry reports and semi-structured interviews with industry representatives, thereby addressing RO 2. **Chapter Six** addresses RO3 by developing a sector-specific operational framework based on a synthesis of insights from the literature and the empirical findings. The framework supports organisational sense-making and operationalisation around sustainability- and CE-related initiatives while leveraging the potential of DTs in the German T&C industry and was assessed through practitioner engagement. **Chapter Seven** critically discusses the developed framework by comparing it with existing studies as well as related frameworks and models. The concluding **Chapter Eight** summarises the main findings of the study and synthesises the responses to the research objectives. In addition, it outlines the implications for practitioners and researchers, transparently acknowledges the study's limitations, and identifies directions for future research.

In summary, this study aims to narrow the gap between organisational practice in the German T&C industry and academic research by building on insights generated through the empirical analysis to derive practice-oriented implications that support organisational sense-making and the operationalisation of sustainability- and CE-related initiatives, leveraging the potential of DTs. A visual overview of the study's structure and chapter content is provided in Figure 6.

Figure 6
Structure and overview of the thesis



2 LITERATURE REVIEW

2.1 Introduction

A literature review is an integral component of any research endeavour, as “a researcher cannot perform significant research without first understanding the literature in the field” (Boote & Beile, 2005, p. 3). Addressing RO1 this chapter aims to critically explore and analyse the interrelation and implementation of sustainability, the CE and digitalisation in an organisational context based on the existing literature. It highlights relevant fields of activity and their integration, while also addressing industry-specific aspects and characteristics. In addition, the chapter identifies existing research gaps and derives pertinent research questions for further empirical investigation.

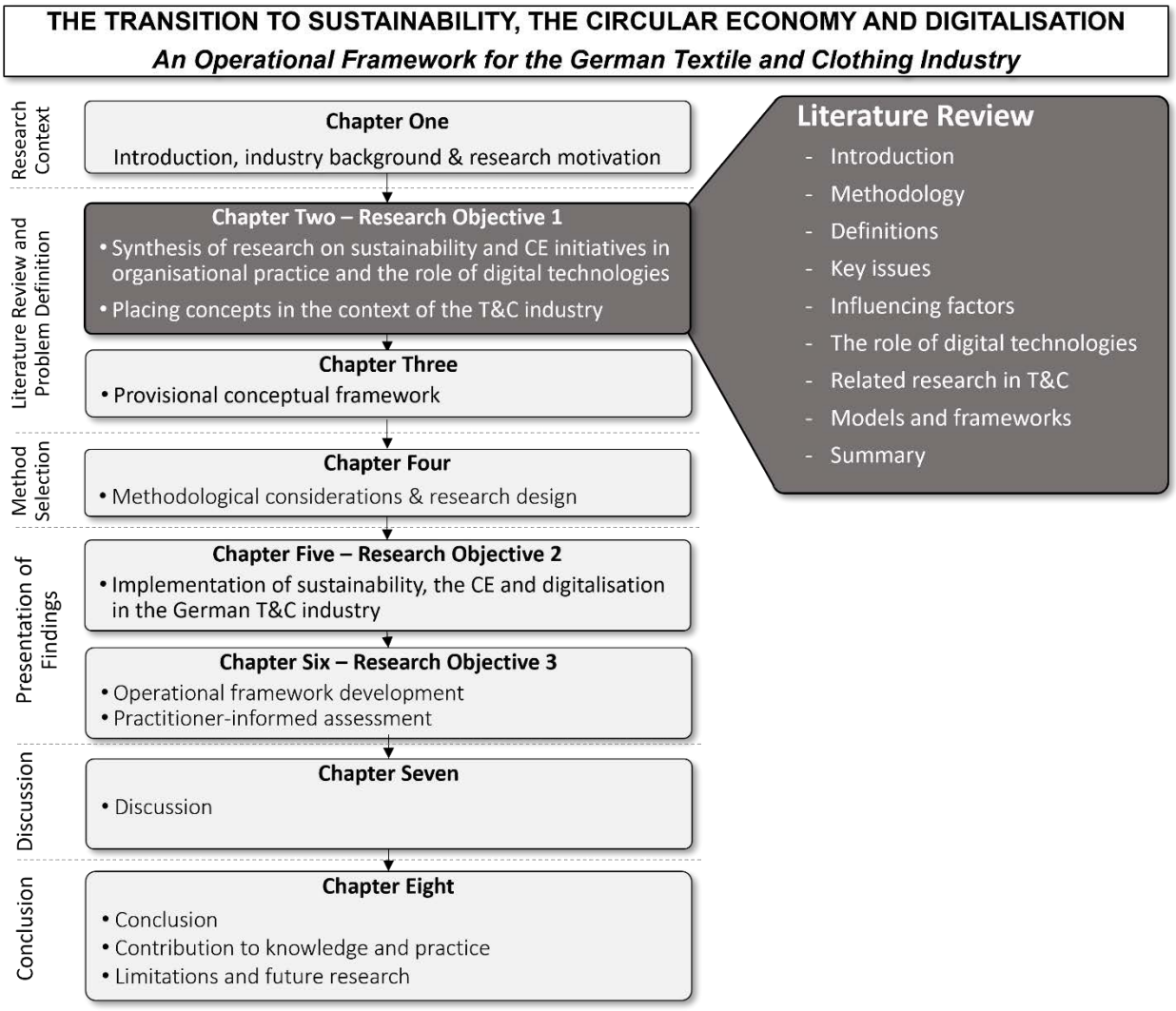
The following research questions form the basis for the literature analysis:

From an analysis of the existent literature,

a) **What are the key issues and challenges in the implementation of sustainability and the CE in an organisational context,**
b) **What role do digital technologies play in this implementation?**
c) **What models and frameworks exist for the transition of organisations to sustainable and circular practices?**

The remainder of this chapter is structured as follows (Figure 7): Section 2.2 outlines the methodology and process of the literature review, providing a transparent justification for the selection of relevant sources. Section 2.3 defines and conceptualises sustainability and the CE and discusses how these concepts are linked in the literature. Section 2.4 discusses key issues related to the organisational implementation of sustainability- and CE-related initiatives as addressed in the literature. Section 2.5 identifies and synthesises the main challenges and influencing factors and Section 2.6 examines the role of DTs discussed in prior research in relation to sustainability- and circularity-related change processes. Section 2.7 reviews relevant research on sustainability, the CE and digitalisation in a T&C context, with the aim of highlighting sector-specific characteristics and identifying research gaps. Section 2.8 focuses on the discussion of relevant models and frameworks. Finally, Section 2.9 summarises the key insights from the literature review, identifies research gaps and outlines the research questions that guide the empirical study.

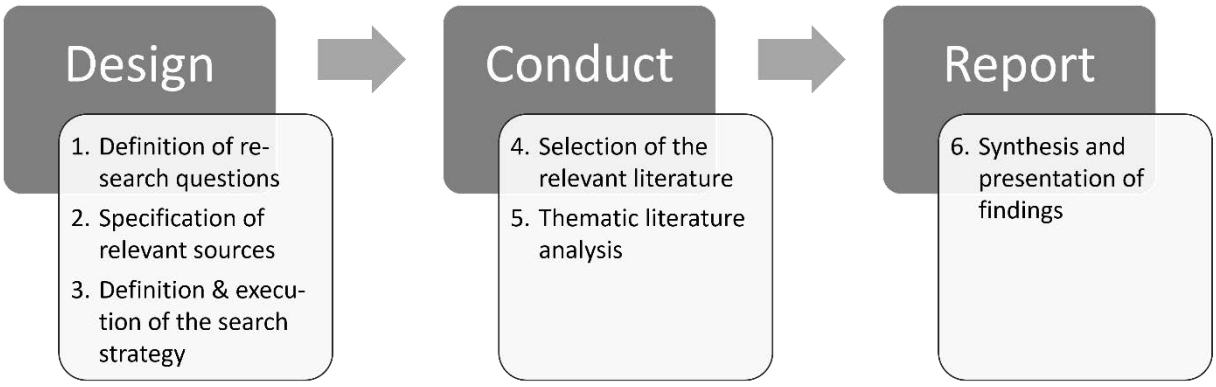
Figure 7
Structure and overview of Chapter Two in context of the thesis



2.2 Literature Review Methodology

A literature review serves to comprehend and critically engage with research in a given domain in order to understand how key issues have been examined and to identify areas where ambiguity, limited empirical insight, or unresolved questions remain (Boote & Beile, 2005; Snyder, 2019; Tranfield et al., 2003). Therefore, a literature review must be based on a structured, consistent, and reproducible approach to locate, evaluate, and synthesise relevant literature (Fink, 2020). This process can be divided into three main phases: designing, conducting, and reporting the review (Snyder, 2019; Tranfield et al., 2003) (Figure 8).

Figure 8
Main phases and steps of the literature review process



Source: Based on Snyder, 2019 and Tranfield, 2003

The research questions to be examined in this literature review have already been introduced in the introduction section to this chapter.

The literature review followed a semi-systematic literature review (Snyder, 2019; Turnbull et al., 2023), which allows for a more open and flexible research and analysis compared to a systematic literature review, while still ensuring a transparent and systematic process for literature selection and review, in contrast to a purely narrative approach. First, it was necessary to determine which types of literature to include in the analysis, as this determines the sources from which relevant literature is retrieved. In addition to peer-reviewed academic literature, other sources such as books, conference proceedings, and grey literature were considered. To ensure a high-quality literature analysis, only peer-reviewed scientific sources were ultimately included. The process for identifying relevant sources comprised the following two steps:

1) Search for scientific peer-reviewed literature
2) Snowballing based on references in the analysed literature

Comparative studies on various academic databases consistently indicate that Scopus and Web of Science are the largest bibliographic databases, each containing more than 80 million entries, with significant content overlap (Gusenbauer, 2022; Pranckutė, 2021). For this study Scopus was used for the initial literature search.

The following search string was applied to the Scopus database: ((sustainability AND “circular economy”) AND *(business OR organi* OR industr**) AND (implement* OR integrat* OR transform* OR transit*). Further filtering was applied by restricting results to English and German and limiting the selection to journal publications to ensure the quality of the included academic literature through peer review.

An initial review of the results revealed that a significant number of studies focused on organisations operating in developing countries. However, as outlined in the introduction, this study examines the T&C sector in Germany, an industrialised country, where organisational practices are shaped by distinct institutional, regulatory, and market conditions. Given this context, findings from developing country settings were considered to offer limited analytical relevance for addressing the research objectives of this study. Consequently, these studies were excluded to ensure contextual alignment with the research focus.

New publications were regularly reviewed based on a search alert using the aforementioned search strings.

The literature analysis adopted a qualitative approach, synthesising key concepts and thematic clusters related to the key issues, challenges and influential factors for the implementation of sustainability- and CE-related initiatives in companies, and the role DTs are playing in this initiatives.

2.3 Definition and Interrelation of Sustainability and the Circular Economy

At the beginning of this section, the key concepts of sustainability and the CE are defined and conceptualised. This provides a working understanding for the purposes of this study and a basis for examining how these concepts are addressed in organisational practice.

2.3.1 Sustainability

Sustainability is a term that is widely used today in various contexts. Purvis et al. (2019) examined the origins of the sustainability concept and concluded that there is still no consistent understanding or single definition of sustainability, but rather the concept is used by different schools of thought and in different contexts. Against this background, this subsection seeks to clarify how sustainability and related terms are understood in the literature and to develop a working understanding of sustainability as it relates to corporate actions for the purpose of this study.

Sustainable Development

The most influential and frequently referenced understanding of sustainability is that of sustainable development, defined as development that "*meets the needs of the present without compromising the ability of future generations to meet their own needs*" (World Commission on Environment and Development, 1987, p. 24).

In a global context, the concept of development refers to the political goals of economic growth and the associated improvement and global equalisation of the socio-economic living conditions of all people (Figge & Hahn, 2004; Ruggerio, 2021).

Building on the Brundtland definition, various authors have proposed core principles of sustainable development, which are articulated and interpreted in different ways across literature. Drawing on the contributions of Mebratu (1998), Kuhlman and Farrington (2010) and Kanning (2022), the following principles are outlined to inform the understanding of sustainable development adopted in this study:

- Sustainable development is guided by human needs with the aim of ensuring the long-term survival of the human species.
- The environment and development are viewed as inseparable entities, as the quality of both present and future life depends on satisfying the basic needs of all people without destroying the environment upon which all life depends. This perspective underpins integrative understandings of sustainability that encompass ecological, social, and economic dimensions.
- Given the finite nature of resources on planet earth, sustainable development is commonly associated with principles of fair and equitable resource distribution, to ensure that all people are equally able to meet their needs (intragenerational equity).
- A long-term temporal perspective is regarded as central to sustainable development, highlighting responsibilities towards future generations and the principle of intergenerational equity (intergenerational equity).

After publication of the Brundtland Report, sustainable development has increasingly become a core element of the environmental discourse. However, the definition is highly abstract and allows for various interpretations (Mebratu, 1998). Rogall et al. (2021) see this abstract nature as the key to the widespread acceptance of the concept of sustainable development by nearly all UN members during the first UN Conference on Environment and Development in Rio de Janeiro in 1992. Rooted in diverse ecological, economic, and social challenges that were addressed inadequately and continued to worsen (von Hauff, 2020), the paradigm of sustainable development was adopted by the global community as a new paradigm for the 21st century.

However, this abstractness also leads to controversy regarding the necessary political, societal, and economic actions and changes that sustainable development requires. The concept of sustainable development can therefore be understood more as a normative concept and guiding principle for politics and society rather than a concrete concept from which clear implementation strategies or measurement criteria can be derived (Grunwald & Kopfmüller, 2012; Müller-Christ, 2023; Robinson, 2004; Sneddon et al., 2006). Following this concept, the UN SDGs came into effect in January 2016 as the “2030 Agenda for Sustainable Development”, aimed at “shifting the world onto a sustainable and resilient path” (United Nations, 2015, para. 1). Since then, the terms sustainability and sustainable development have become blurred. Both terms are sometimes used interchangeably without distinguishing their conceptual differences (Ruggerio, 2021; Sheehy & Farneti, 2021). Various researchers explicitly differentiate between the two concepts, describing sustainable development as a kind of process of social, economic and political change, while the term sustainability is seen as the end of such a process and thus describes a status (e.g.,Grunwald & Kopfmüller, 2012; Mebratu, 1998; Sneddon et al., 2006). Different schools of thought can be distinguished, each applying different emphases and perspectives. However, there seems still no consensus on operationalisation in terms of concrete practices or a measurable end status. Nevertheless, the previously described guiding principles of intragenerational and intergenerational equity, as well as the integrative consideration of three dimensions - society, economy, and ecology - are widely recognised (Ruggerio, 2021; Sheehy & Farneti, 2021).

2.3.1.1 Corporate Sustainability

The implementation of sustainable development involves various stakeholder groups in different fields of action. Besides governmental, scientific, and civil society actors, to which this study only briefly refers when necessary, companies play a key role in sustainable development (World Commission on Environment and Development, 1987). However, the question arises of how the concept of sustainable development can be translated into the corporate context. The transfer of the concept of sustainable development to a corporate context is commonly referred to as corporate sustainability (Pazienza et al., 2022). Therefore, this subsection discusses concepts and strategies of corporate sustainability to develop a working, literature-informed understanding for the purposes of this study.

One of the most frequently cited definitions of corporate sustainability comes from Dyllick and Hockerts (2002) who translated the definition of sustainable development from the Brundtland Report to companies. They understand corporate sustainability as "meeting the needs of a firm's direct and indirect stakeholders (such as shareholders, employees, clients, communities, etc.) without compromising its ability to meet the needs of future stakeholders as well" (p. 131), in which the target group shifts from "future generations" to "stakeholders" to account for the corporate dimension.

Similarly, Elkington's (1998) 'triple bottom line' concept emphasises that long-term organisational sustainability cannot be understood solely in economic terms, but requires consideration of the broader social and environmental contexts in which a company operates. In this view, sustainability comprises three interrelated dimensions: economic, environmental, and social, often summarised as profit, planet, and people (Amini & Bienstosck, 2014; Pazienza et al., 2022). The economic dimension relates to the effective and efficient use of both tangible and intangible resources in order to maintain long-term competitiveness and viability. The environmental dimension addresses the use of natural resources and the organisation's impact on the natural environment. The social dimension concerns human well-being, working conditions, and broader questions of equity, fairness, and corporate social responsibility (Amini & Bienstock, 2014; Elkington, 1998; Pazienza et al., 2022). As Pazienza et al. (2022) found, in their analysis of concepts and definitions, the concept of corporate sustainability seems to be clearly defined by the three pillars already mentioned (ecological, economic and social) and their interplay. Accordingly, corporate sustainability is understood as a multidimensional concept that is embedded in business strategy and reflected across organisational activities and decision-making. From this perspective, corporate sustainability is associated with shifts in how companies, their value creation processes, and organisational roles are interpreted, organised, and governed (Pazienza et al., 2022). Building on this understanding, this thesis adopts the view that sustainable corporate governance extends beyond a narrow focus on profit maximisation and is oriented towards systematically reducing negative social and environmental impacts while contributing to social, ecological, and economic welfare. This understanding extends beyond the concepts of corporate citizenship or corporate social responsibility often found in early literature on corporate sustainability (e.g., Carroll, 1991).

In this context, the UN SDGs are referenced as strategic points of orientation for companies in this regard (Wynn & Jones, 2022b). For instance, the European Commission (2017) argued that “the 2030 Agenda integrates in a balanced manner the three dimensions of sustainable development -economic, social and environmental” (para. 6). Similarly, with reference to the industrial sector, PriceWaterhouseCoopers (2015) commented that with the emergence of the SDGs, “sustainability is moving from the corporate side-lines into the mainstream” (p. 6). However, the SDGs do not provide a general or industry-specific blueprint for practical sustainable actions and initiatives. Accordingly, while there is broad alignment regarding the “what” of corporate sustainability, there remains some ambiguity regarding the implementation and integration of sustainability into business practices (Pazienza et al., 2022).

2.3.2 Circular Economy

One frequently encountered concept for transforming the industrial and societal structures towards sustainable development is the concept of the circular economy (CE). For instance, Stahel (2016) argues that promoting CE-principles may contribute to reduce greenhouse gas emissions while simultaneously increasing employment. Thus, in line with the understanding of sustainable development outlined above, the concept of the CE can be interpreted as a means of decoupling economic development from resource use and pollutant emissions. At the policy level, the European Commission (n.d.) has embraced this goal, stating that the “EU’s transition to a circular economy will reduce pressure on natural resources, create sustainable growth and jobs, and is necessary to achieve the EU’s 2050 climate neutrality target and to halt biodiversity loss” (Para 1).

Similarly, at the corporate level, Amini and Bienstock (2014) describe the pursuit of a “zero-waste approach” as the “most sophisticated approaches to sustainability efforts” (p. 15). Beyond waste management, the CE has evolved into a holistic approach encompassing product design, manufacturing processes, and business models in alignment with sustainable development (Geissdoerfer et al., 2017; Kirchherr et al., 2023; Nobre & Tavares, 2021). From this perspective, the CE can be interpreted as an answer to the questions of “how” to implement and realise corporate sustainability.

2.3.2.1 Origins and Related Concepts of the Circular Economy

The concept of the CE is grounded in various schools of thought, making it challenging to attribute to a single author or specific timeframe. One prominent foundation frequently cited (e.g., in Geissdoerfer et al., 2017; Ghisellini et al., 2016; Korhonen et al., 2018) is Boulding´s (1966) analogy of Earth as a spaceship. With images from the 1960s space programs circulating worldwide, Boulding's comparison resonated, suggesting that, like a spaceship, Earth must rely on reproducing its finite resources. He described this "spaceman economy" as follows:

"The closed economy of the future might similarly be called the 'spaceman' economy, in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy" (pp.7-8).

Although Boulding did not explicitly refer to a CE in his work, his idea of Earth as a closed system, with no external inputs or outputs, represents a fundamental principle of the CE concept. Viewing the planet as a closed system, with no possibility of expansion beyond its boundaries, underscores the importance of preserving it as a viable habitat. Building on these ideas, environmental economists Pearce and Turner (1990) developed the concept of the CE as a theoretical economic model. Starting from the notion that "everything is an input for everything else" (p. 33), they highlight the interaction between the economy and the environment.
Furthermore, the origins of the CE can also be traced to a range of practice-oriented approaches and concepts. These include

- eco-efficiency, defined as the "delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity" (DeSimone & Popoff, 1997, p. 47);
- eco-effectiveness, also described as cradle-to-cradle, which focuses on designing products and systems that are inherently waste-free, meaning that used products and materials are viewed as resources for new products and materials (Braungart et al., 2008);

- the performance economy, focusing on “solutions instead of products” (Stahel, 2016, p. 436) and extended product lifespans as a sustainable strategy to create jobs, save energy, reduce greenhouse gas emissions, and prevent waste (Stahel, 2016),
- or Industrial Ecology (IE), seeking to design industrial systems that function similarly to natural ecosystems in which everything is reprocessed into something else (Clift & Druckman, 2016; Frosch & Gallopoulos, 1989).

Informed by the concepts discussed above, the following key principles emerged as central to the CE:

1) The CE aims to harmonise economic systems with Earth’s natural systems and limits, managing scarce resources efficiently within closed loops while avoiding waste and negative environmental impacts, such as emissions and pollution.
2) The CE draws on various concepts and integrates theories from multiple disciplines, offering strategies for diverse actors at different economic levels:
   - global / economy-wide approaches
   - regionally or locally focused industry strategies, such as industrial symbiosis
   - individual product and business-related concepts like eco-efficiency, design principles and business models

While the CE has attracted growing attention worldwide, and is increasingly seen by governments and businesses as a way to align economic growth with sustainable development (Lieder & Rashid, 2016), approaches to its implementation vary widely across organisations (Kirchherr et al., 2017, 2023; Schöggl et al., 2020), covering practices like resource efficiency, circular products, and innovative business models (Bocken et al., 2016; Schöggl et al., 2020).

Thus, the CE continues to evolve as a framework interlinked with sustainability, adapting across scales and sectors (Kirchherr et al., 2017; Rodriguez-Anton et al., 2019; Schroeder et al., 2019).

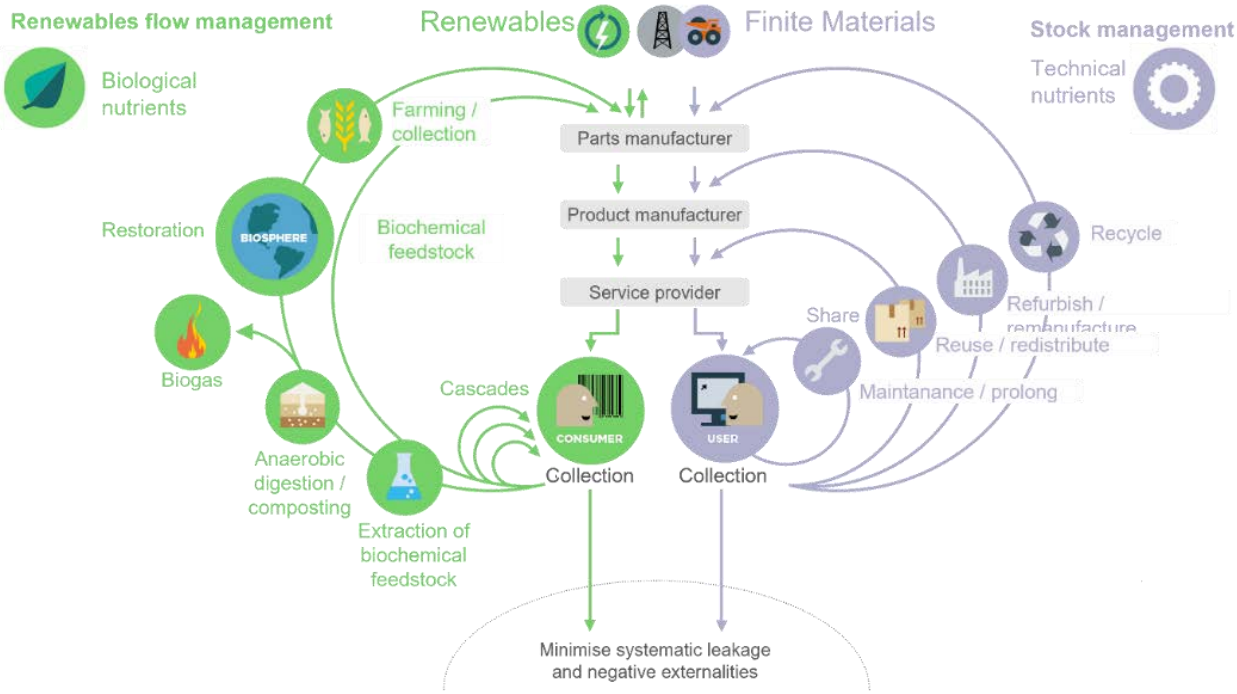
The next subsection reviews existing definitions and conceptualisations of the CE to develop a working, literature-informed understanding for this study.

2.3.2.2 Circular Economy Concepts and Definitions

In 2013, the Ellen MacArthur Foundation and the McKinsey Center for Business and Environment introduced a general definition and conceptualisation of the CE, describing it as “an industrial system that is restorative or regenerative by intention and design” (Ellen McArthur Foundation, 2015b, p. 7). Their “butterfly diagram” (Ellen MacArthur Foundation, 2019) - a model depicting biological and technical resource flows within a lifecycle perspective (Figure 9) - has found great resonance across business, society, and political discourse, cited in scientific literature as a central framework for the CE (e.g., Geissdoerfer et al., 2017; Kirchherr et al., 2023).

Figure 9

Butterfly diagram - illustrating the various restorative and regenerative processes for biological and technical nutrients in a circular economy.



Source: Ellen MacArthur Foundation, 2019

In a similar vein, the European Commission (2015) defined the CE as an “economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized” (p. 2). The definitions and conceptualisations of the CE in the scientific literature show reasonable commonalities and overlaps (see appendix A), highlighting that the CE is a multifaceted construct. The components of which are analysed here and limited to the aspects relevant to the focus of this study.

The CE as a concept to promote sustainable development

The CE is described as an alternative economic system, essentially a way of organising and distributing resources, services, and goods. Interestingly, the reviewed literature rarely addresses how CE relates to existing economic systems (such as market or planned economic systems), whether it builds on their foundational principles, or in what specific ways it differs from them. Rather, it is presented as a response to the criticism of the traditional linear orientation of economic systems, which leads to resource overuse and environmental degradation (Ghisellini et al., 2016; Kirchherr et al., 2017, 2023; Murray et al., 2017). This suggests that the CE does not fundamentally seek new approaches for organising and distributing resources and goods in a macroeconomic sense but rather focuses on mitigating the negative environmental and social impacts associated with linear material flows in current production and consumption patterns (Korhonen et al., 2018). Which is achieved through supportive regulations and policies and implemented through appropriate business strategies and practices (Sardianou et al., 2024; Vogiantzi & Tserpes, 2023).

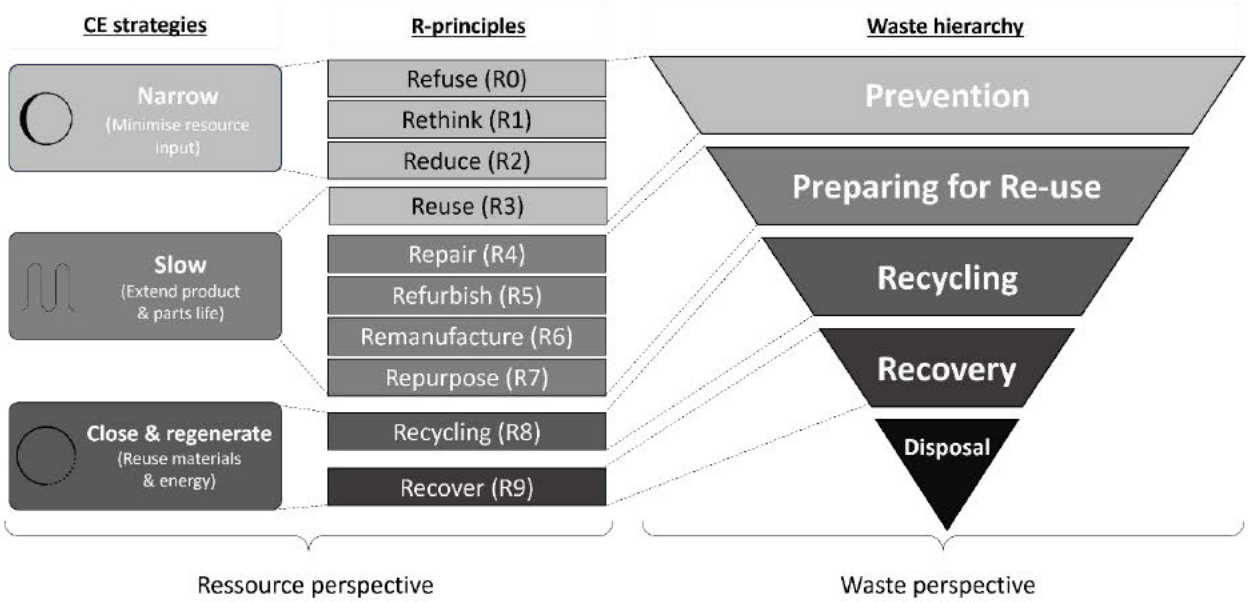
The CE as a set of strategies, principles and practices

Concluding from the previous paragraph, pursuing CE objectives is associated with changes in prevailing production and consumption patterns across different contexts. While regulatory measures can initiate and support these changes, their impact is shaped by the extent to which they are enacted through strategies and practices oriented towards reducing absolute resource use and pollutant emissions to levels within planetary boundaries (Korhonen et al., 2018; Murray et al., 2017).

The literature shows two broad perspectives on how CE can be implemented, which are reflected on the left- and right-hand sides of Figure 10. The first is a resource-oriented perspective, which emphasises three overarching strategies: narrowing, slowing, and closing resource (Bocken et al., 2016; Geissdoerfer et al., 2017), see Table 2. The second is a waste-oriented perspective, which highlights five waste management strategies aimed at preventing waste and ensuring its appropriate treatment Secondly, from a waste-based perspective, five waste management strategies were identified that prioritise the prevention and proper treatment of waste (European Commission, 2023d; Wiegand & Wynn, 2024).

Figure 10

10 R Strategies as the central framework of the CE and their relationship to resource reduction strategies and waste management



Source: Wiegand & Wynn, 2024 based on Bocken et al., 2016, Reike et al., 2018, Kirchherr et al., 2017 and European Commission, 2023d

Table 2

Definition and description of resource-based CE strategies – to narrow, slow, close resource flows

CE – Strategy	Description
Narrowing	The narrowing strategy focuses on achieving more with less, primarily through efficiency gains in product design and manufacturing processes. This involves, for example, producing goods or delivering services with reduced input (e.g., material, energy, or water) and aligns closely with the concept of eco-efficiency.
Slowing	The slowing strategy seeks to extend the lifespan of products, components, and materials. This can be realised through high product quality, durability, and reparability, as well as through services that promote reuse, maintenance, and repair. It builds on elements of eco-effectiveness and the performance economy.
Closing	The closing strategy aims to recover resources from used products and materials for reuse in the production of new goods. This includes both closed loops - where recycled materials are reintroduced into the same product system - and open loops - where recycled materials are applied in other product systems. It also includes ultimate energy recovery from the incineration of products and materials.

Source: The author, based on Bocken et al., 2016; Farooque et al., 2019; Kirchherr et al., 2023

When translated into operational practices, these perspectives are commonly expressed through the so-called R-principles, which provide a structured framework for implementing CE strategies (Figure 10, center) (Ghisellini et al., 2016; Kirchherr et al., 2017, 2023; Reike et al., 2018). Within this framework, the strategies can be grouped according to their primary objectives. The first group (R0–R2) focuses on minimising

overall resource use and preventing negative environmental and social impacts at the product and process level. The second group (R3–R7) is concerned with retaining the value of products and components by extending their useful life. The final group (R8–R9) comprises end-of-life approaches, including material recycling and energy recovery, which are generally positioned at the lower end of CE hierarchies. In addition, the use of renewable energy sources and the reduction of emissions are widely regarded as important supporting elements of CE implementation (Ellen McArthur Foundation, 2015b). As different interpretations of the individual R-principles can be found in literature, Table 3 contains a brief definition of each principle as they are understood in this study.

Table 3

10R-Framework and definitions

R#	Principle	Explanation
R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product or service
R1	Rethink	Make product use more intensive (e.g., sharing or multifunctionality)
R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials and reduce environmental impact
R3	Reuse	Reuse by another user / consumer of discarded product which is still in good condition and fulfils its original function
R4	Repair	Repair and maintenance of defective products so it can be used with its original function
R5	Refurbish	Restore and old product and bring it up to date
R6	Remanufacture	Use parts of discarded product in a new product with the same function
R7	Repurpose	Use discarded product or its parts in a new product with a different function
R8	Recycle	Process materials to obtain the same or lower quality
R9	Recover	Incineration of material with energy recovery

Source: Adapted from Reike et al., 2018 and Kirchherr et al,. 2017

If these strategies and principles are not systematically translated into appropriate practices, they fail to transform existing linear production and consumption patterns. In one of the first comprehensive reviews of 114 CE definitions, Kirchherr et al. (2017) concluded that the “transition to CE needs to occur through activities at three levels” (p.224). Likewise, Nobre and Tavares (2021), based on an empirical study with 44 international scholarly CE experts, categorise the application of CE strategies and principles into three system levels. The micro level pertains to individual products, companies, and consumers; the meso level encompasses organisational clusters and industrial parks and the macro level includes entire cities, regions or nations. This classification appears to be widely accepted within CE literature (Kirchherr et al., 2017; Nobre & Tavares, 2021).

However, as it might be useful for a systemic perspective, it appears insufficient for the practical implementation of CE strategies and principles. It must be assumed, that effective implementation depends on concrete actors who translate strategies into specific activities and practices while collaborating across different levels:

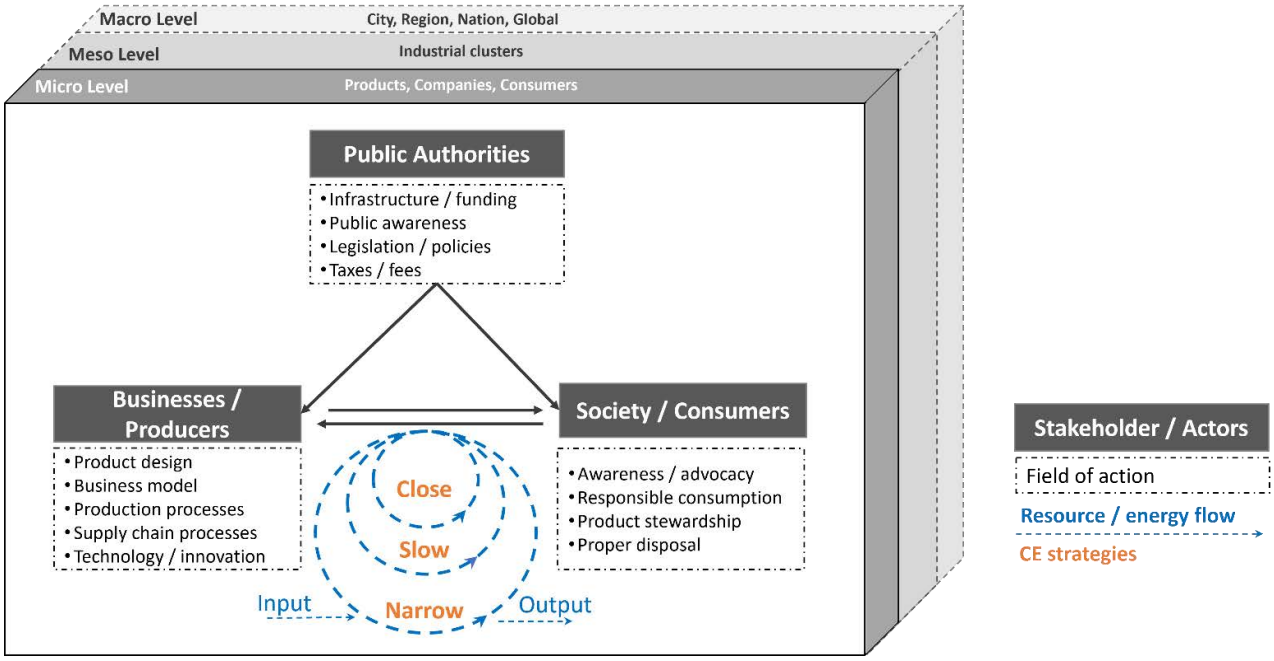
Governmental institutions are responsible for establishing the legal frameworks and infrastructure necessary for a functioning CE and fostering a collective awareness among consumers (Ghisellini et al., 2016; Lieder & Rashid, 2016). Through fair and efficient tax and fee systems (Geissdoerfer et al., 2017; Stahel, 2016) as well as targeted subsidies and incentives (Ghisellini et al., 2016; Maksymiv et al., 2024), governments may create motivation for both businesses and consumers to adopt CE practices.

Society / consumers are integral actors in the CE concept as they can influence the availability and success of circular products and business models through consumption and usage behaviour (Lieder & Rashid, 2016; Stahel, 2016). This requires awareness of the impacts of individual behaviour, a corresponding mindset, and the necessary skills (Ellen McArthur Foundation, 2015b).

Industry / companies are widely regarded as playing a central role in translating the CE concept into practice. This transition is associated with extensive, encompassing product and service design, value creation processes, supply chains and manufacturing systems (Bocken et al., 2016; Geissdoerfer et al., 2017; Kirchherr et al., 2022, 2023; Korhonen et al., 2018; Lieder & Rashid, 2016; Maksymiv et al., 2024).

The conceptual components of the CE discussed in this section - including its levels, key actors, their interactions, and fields of activity - are summarised in Figure 11.

Figure 11
Visual conceptualisation of the CE



In summary, this representation encapsulates the CE understanding that underpins this research. The CE is conceived as a system aimed at minimising resource consumption (input) and waste generation (output) by narrowing, slowing, and closing resource loops. Its implementation is both enabled and influenced by coordinated practices and behaviours across government authorities, private enterprises, and the society. This transition begins at the micro level (individual companies, products, and consumers), scales up to industry clusters (meso level), and extends to regional and global dissemination (macro level). This study focuses on the micro level, exploring how businesses are implementing CE principles and address the key issues of sustainability and circularity in practice.

2.4 Key Issues for the Implementation of Sustainability and the CE

The interdependencies and interactions between actors and levels inherent with sustainable development and the CE, as outlined above, imply two primary pathways - or triggers - for change from a corporate perspective. The first is a reactive approach, in which companies adapt in response to regulatory requirements imposed by governmental institutions, primarily to avoid the costs or disadvantages associated with non-

compliance. The second is a proactive, strategic approach, where companies deliberately implement sustainable and circular practices with the intention of enhancing profitability and gaining competitive advantage, while regulatory compliance is treated as a built-in component of strategy (Lieder & Rashid, 2016; Werning & Spinler, 2020).
As outlined in the introduction chapter, various regulatory requirements and laws are currently under development, which companies will have to comply with in future. If companies pursue a strategy of simply adapting to the relevant regulations, this is unlikely to result in a competitive advantage (Amini & Bienstock, 2014). The focus of this study therefore lies on proactive development, driven by corporate initiative rather than mere fulfilment of external requirements.

This section discusses organisational dimensions and related practices associated with sustainability- and CE-related initiatives. Prior research frequently frames these initiatives as involving systemic organisational change, with products, business models, and supply chains emerging as key change dimensions. These are addressed and described in the following subsections.

2.4.1 Sustainable and Circular Products

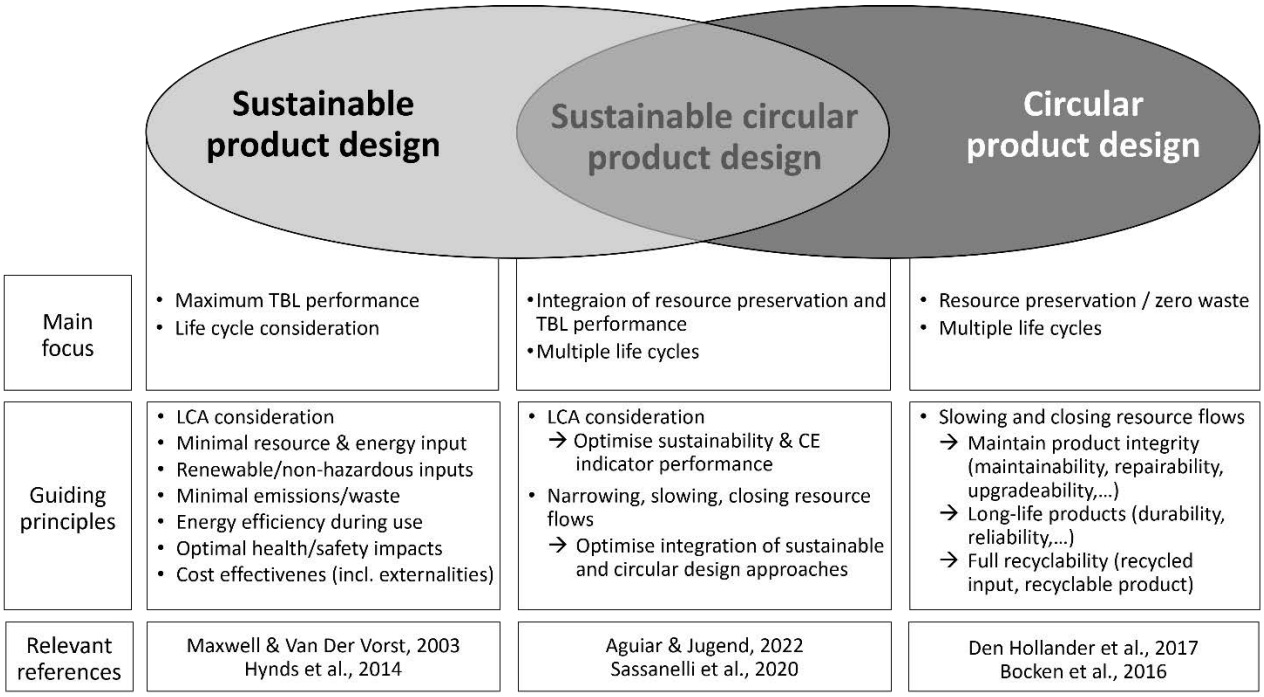
Products are widely regarded as one of the key starting points for the transition to a more sustainable and circular system. For instance, the Ellen MacArthur Foundation (2022), emphasises that design lies at the core of every product and of the wider systems in which it is embedded. Once materials, resources, processes, and activities are aligned with a specific product design, only minor changes can be made (Bocken et al., 2016). Product development can therefore no longer be guided solely by utility and functionality but must also take additional aspects into account. In line with the conceptual relationship between sustainability and the CE outlined in the previous section, the literature highlights several streams that address different aspects and considerations relevant to product design (Figure 12).

The first and chronologically earlier stream addresses sustainable products, with the CE remaining unconsidered. The focus lies on optimising TBL performance, particularly on minimising environmental impacts across the entire product life cycle. While aspects such as repairability and recyclability are acknowledged, they are not defined as specific requirements but rather subsumed under the broader aim of reducing envi-

ronmental impacts. Typical requirements include the use of renewable and non-hazardous materials, energy- and resource-efficient and safe use, waste minimisation, and cost efficiency (Hynds et al., 2014; Maxwell & Van Der Vorst, 2003).

Figure 12

Conceptual relationship between sustainable and circular product design aspects and principles



Source: The author based on Aguiar & Jugend, 2022; Bocken et al., 2016; Den Hollander et al,. 2017; Hynds et al., 2014; Maxwell & Van Der Vorst, 2003; Sassanelli et al., 2020

The second stream explicitly addresses circular products. In this, product design focuses on resource preservation and the assurance of multiple use cycles. Central to this is maintaining product integrity - that is, preserving products in their original form and avoiding obsolescence - through durability, repairability, and upgradability. In line with the zero-waste premise commonly associated with CE concept, products and components that can no longer be used are emphasised as needing to be designed for fully recyclability (Bocken et al., 2016; Den Hollander et al., 2017). Sustainability aspects in the sense of the TBL, such as safety considerations or green house gas emissions, are not included in these contributions. Bocken et al. (2016) even explicitly exclude approaches associated with the narrowing of resource flows from their design strategies for circular products, arguing that these do not contribute to resource preser-

vation. Instead, circular design aims to create products in such a way that the resources embedded within them remain in the economic system and their value is retained.

The third stream, comprising more recent contributions, proposes a more integrated perspective referred to here as sustainable circular product design. This approach combines the strengths of the two aforementioned perspectives by embedding CE principles - narrowing, slowing and closing - within a sustainability framework. In doing so, it places emphasis on both resource preservation and impact minimisation and is increasingly discussed as linking product design considerations to sustainability- and circularity-related indicators (Aguiar & Jugend, 2022; Sassanelli et al., 2020). Such integration is regarded as essential not only for ecological performance but also for economic viability and – albeit addressed to a lesser extant in literature - social aspects. Table 4 provides an overview of relevant contributions and approaches to the development of sustainable and circular products.

In summary, the integrated approach, which seeks to minimise negative impacts throughout the entire life cycle while preserving the value of products, components, and materials for as long as possible and avoiding waste, is interpreted as a key pathway in product design for advancing sustainable development objectives.

Table 4

Overview of relevant sources highlighting differences and overlaps between sustainable and circular product design

Source	Main focus	Conceptual distinction between CE and sustainability	Comments
Hynds et al., 2014	Sustainability	Adresses only sustainability (=TBL); CE not mentioned	• Product design focuses on environmental impact minimisation along the life cycle • Main requirements: Minimal environmental impact throughout the life cycle →Life-cycle assessment (LCA)-based decision making, e.g., material selection, manufacturing decision • CE-related aspects (e.g., dismantlability, reusability, recyclability) are considered under environmental impact minimisation
Maxwell & Van Der Vorst, 2003	Sustainability	Adresses only sustainability (=TBL); CE not mentioned	• Product design focuses on impact minimisation along the life-cycle • Main requirements: Optimised balance between functionality, economic aspects (considering externality costs), environmental and social impacts throughout the life-cycle • CE-related aspects (e.g., recyclability, waste elimination) are considered under environmental impact minimisation
Bocken et al., 2016	CE	Understands CE as an approach to greater sustainability, but sustainability aspects not considered in product design for CE	• Product design focuses on resource preservation →Efficiency (narrowing) is explicitly not part of circular product design, as it does not aim to preserve resources • Main requirements: Long-life products, life-time extension (e.g., repairability), full recyclability
Den Hollander et al., 2017	CE	No clear distinction → Circular = sustainable	• In a CE waste is non-existent → Product design focuses on products to not becoming waste • Main requirements: Maintaining product integrity throughout the entire lifetime (= multiple use cycles), full recyclability at the end of life
Aguiar & Jugend, 2022	Both	Sustainability and CE integrated → CE principles to avoid negative environmental impacts	• Product design focuses on optimising sustainability and CE-indicators along the life cycle →environmental impact minimisation, resource preservation, extended use-phase and multiple life cycles • Main requirements: Narrow/regenerate (e.g., low impact material, energy efficiency, standardisation, renewable & non-toxic inputs), slow (durability, multiple functions, updateability), close (recyclability, recycled input)
Sassanelli et al., 2020	Both	Distinguishes between CE & sustainability → sustainable aspects as part of CE	• Product design focuses on simultaneous consideration of sustainability, circularity and economic viability • Main requirements: multiple life cycles (repairability, recyclability), environmental sustainability, reliability (durability, safety), economic viability.

2.4.2 Sustainable and Circular Business Models

Companies benefit from the development of new products or technologies only if they succeed in designing appropriate business models for their commercialisation (Teece, 2010). Research on business models for sustainability and the CE has expanded significantly in recent years and is regarded as one of the “most vibrant sub-fields of current CE research” (Kirchherr et al., 2023, p. 7). This underlines their role as a key lever in supporting companies’ transition towards the CE. A review of the relevant literature reveals, however, that distinctions are made between sustainable and circular business model approaches. This section therefore clarifies what a business model is, what distinguishes a sustainable (SBM) or circular business model (CBM) from conventional approaches and what possible changes are related to it for companies.

Business model

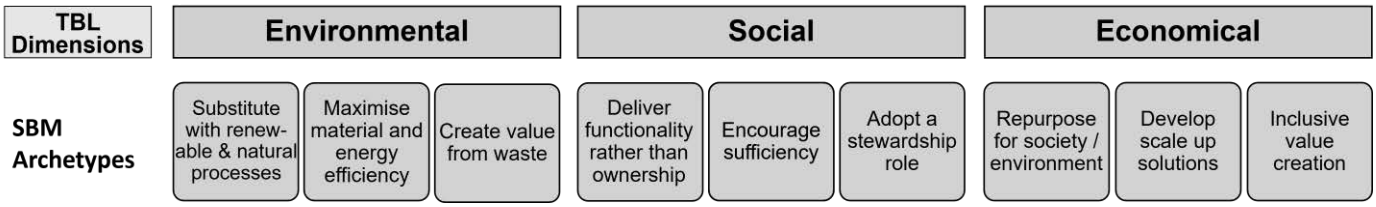
A business model essentially describes how a company operates. It addresses fundamental questions such as what value proposition a company provides, how it is created, who the customer is, and how value is delivered to them and captured for the company (Magretta, 2002). In the literature on sustainable and circular business models, the definition originating from Teece (2010) is most frequently cited, which is very similar to the one outlined here. Accordingly, a business model is defined as “the design or architecture of the value creation, delivery and capture mechanisms employed” (p. 191).

Sustainable business model

A company is embedded within a network of stakeholders, which also includes the natural environment (Bocken et al., 2014). Accordingly, although a business model is generally understood as a market-oriented concept, companies that contribute to sustainable development are characterised by business models that create value not only for customers and shareholders but also for a broader set of stakeholders, including the natural environment. Thus, a sustainable business model is understood as one that generates long-term economic value not as a by-product, but through the integration of social and environmental aspects into its value proposition, creation and delivery, and capture (Bocken et al., 2014; Geissdoerfer, Vladimirova, et al., 2018; Schaltegger et al., 2016). Research on sustainable business models remains relatively young and fragmented. However, a set of archetypes has been established - based on Bocken et

al. (2014) and Ritala et al. (2018) and further refinded by Beard & De Giacomo, (2025) - that represent typological approaches to sustainable business models. These can be mapped to the dimensions of the TBL and understood as clusters of approaches that manifest across all, or only in selected, business model elements and that may also be combined in practice (Figure 13).

Figure 13
Sustainable business model (SBM) archetypes



Source: Adapted from Bocken et al., 2014 and Ritala et al., 2018

The environmentally oriented archetypes include approaches that focus on the use of renewable resources, the reduction and optimisation of resource efficiency - covering both energy and raw materials - and the creation of new value from materials that would otherwise be treated as waste (Bocken et al., 2014; Ritala et al., 2018).

Socially oriented archetypes comprise approaches centred on providing functionality rather than ownership, for example through service-oriented models - so-called Product–Service Systems (PSS) - which focus on access to product use rather than product ownership. Car-sharing models are a typical example. This cluster also includes business models aimed at promoting sufficiency - understood as influencing consumption patterns through, for instance, marketing and sales practices designed to prevent overconsumption, or through consumer education (Bocken et al., 2014; Bocken & Short, 2016). In addition, approaches in which companies assume a leadership role or take responsibility in addressing specific social challenges - such as transparent and traceable supply chain practices, fair trade, or initiatives for animal welfare, biodiversity, and health protection - are included here (Bocken et al., 2014).

Economically oriented archetypes include approaches that prioritise social contributions over the maximisation of economic profit - for example, social enterprises or firms aligned with strict environmental and social standards for the common good (B Lab, 2024; Bocken et al., 2014). The development of sustainable scale-up solutions is directed at providing sustainable alternatives to conventional products and materials on

a large scale, for example through open innovation or by supporting sustainable oriented start-ups (Bocken et al., 2014). Inclusive value creation approaches are oriented towards the shared use of resources, knowledge, or ownership, as well as towards offering solutions for neglected groups (base-of-the-pyramid), such as peer-to-peer platforms enabling users to share and exchange products with one another (Ritala et al., 2018).

It is important to note that the individual clusters are not understood as mutually exclusive. For instance, business models that focus on functionality rather than ownership also contribute to a more efficient overall use of resources. The clustering presented here is therefore based on the main contribution of a given archetype, while individual business models could be categorised differently. Nonetheless, the classification provides a useful starting point for distinguishing sustainable business models from conventional ones, which are oriented solely towards maximising a company´s economic value.

Circular business model

Business models for the CE - referred to in the literature as circular business models - constitute a relatively young field of research. As a result, a wide variety of approaches and definitions can be found. Table 5 provides an overview of relevant contributions on sustainable and circular business models and corresponding typologies. Geissdoerfer et al. (2020) compiled and analysed many of the existing definitions and developed a comprehensive one, which is since widely cited in the field. According to their definition, circular business models are those “that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system. This comprises recycling measures (cycling), use phase extensions (extending), a more intense use phase (intensifying), and the substitution of products by service and software solutions (dematerialising)”. Their definition is thus seen as grounded in the CE strategies of slowing, and closing, but extends these into four business model typologies - cycling, intensifying, extending, and dematerialising. Narrowing does not constitute a distinct CBM typology in their view but is instead relevant in conjunction with the other types. Other definitions remain more closely aligned with the general concept of a business model, as stated above, and extend it based on the CE-principles. For instance, Pieroni et al. (2020) defines a CBM as descrbing “how an organisation or an ecosystem of

organisations create, deliver, and capture value by slowing, closing or narrowing flows of energy and materials" (p.1). Examples of circular business models include services that extend or intensify the use of products and components (e.g., repair or remanufacturing), as well as dematerialisation approaches such as decoupling product functions from physical products through product–service systems (Geissdoerfer et al., 2020; Lüdeke–Freund et al., 2019). With regard to the intersection of SBMs and CBMs, existing studies remain inconclusive. While some contributions explicitly consider CBMs as a subset of SBMs (Bocken et al., 2016; Chen et al., 2020), others highlight examples of CBMs that aim at narrowing, slowing, or closing resource flows without necessarily generating positive TBL outcomes when compared with alternatives (Geissdoerfer et al., 2020; Lüdeke–Freund et al., 2019).

Table 5

Overview of relevant sources highlighting differences and overlaps between business models for sustainability and the CE

Source	Main focus	Definition SBM / CBM	BM Typology	Comment
Bocken et al., 2014	Sustainability	Sustainable business models incorporate a triple bottom line approach and consider a wide range of stakeholder interests, including environment and society.	8 SBM Archetypes	• Developed a typology for SBM based on academic and practice-based examples. • Archetypes could be applied individually, but higher sustainability arises only through combination of approaches
Geissdoerfer, Vladimirova, et al., 2018	Sustainability	Business models that incorporate pro-active multi-stakeholder management, create monetary and non-monetary value for a broad range of stakeholders, and hold a long-term perspective.	–	• Focused on business model innovation and developed strategies for transitioning from a BM to a SBM: start-up, transformation, diversification, acquisition
Ritala et al., 2018	Sustainability	Uses the definition from Bocken (2014).	9 SBM Archetypes	• Applied the SBM archetypes from Bocken to a longitudinal study of global corporations, confirming their practical relevance and extending them with additional insights.
Schaltegger et al., 2016	Sustainability	A business model for sustainability describes, analyses, manages, and communicates (i) a company's sustainable value proposition to its customers and other stakeholders, (ii) how it creates and delivers this value, and (iii) how it captures economic value while maintaining or regenerating natural, social, and economic capital beyond its organisational boundaries.	–	• Provided a comprehensive definition of SBM, highlighting that financial value creation for firms remains central but must integrate broad economic, social, and environmental considerations • No classification or typology of SBMs
Bocken et al., 2016	CE	CBMs are sustainable business models aimed at slowing and/or closing resource flows. Focus lies on achieving economic success through the continuous reuse of products and materials.	6 CBM strategies for slowing/ closing resource flows	• CBMs are not explicitly defined by the authors; rather, the research builds on earlier SBM work and explores which are suitable for slowing and closing resource flows
Chen et al., 2020	CE	CBM is defined as an aggregate of models and innovations that encompass any business model capable of increasing resource circularity in closed loops.	–	• Frames recycling (closing loops) as central CBM strategy, while slowing strategies are considered complementary • Provides a theoretical process framework for transitioning from BM to CBM based on consultancy approaches • no archetypes or typologies are proposed

Source	Main focus	Definition SBM / CBM	BM Typology	Comment
Geissdoerfer et al., 2020	CE	Business models that cycle, extend, intensify, and/or dematerialise material and energy loops to reduce inputs and prevent waste and emission leakage. Includes recycling (cycling), extending use phases, intensifying use, and replacing products with services or software (dematerialising).	4 CBM strategies: Intensify, extend, close, dematerialise	• Notes that not all conceptualisations of CBMs explicitly include sustainability considerations
Lüdeke–Freund et al., 2019	CE	CBMs illustrate how firms create value through implementing CE approaches such as eco-design or cleaner production.	Theoretical generic CBM patterns	• Listed numerous design options for CE implementation based on literature research in a morphological box • Combines generic CBM patterns based on the design options
Pieroni et al., 2020	CE	A circular business model describes how an organisation, or an ecosystem of organisations, creates, delivers, and captures value by slowing, closing, or narrowing energy and material flows.	7 CBM archetypes with 20 subcategories	• Developed CBM archetypes based on scientific and practical literature • Differentiated between upstream and downstream-oriented archetypes → showing dominance of commercial or revenue model perspectives • Conducts validation with various practice partners • Developed a practical concept for CBM implementation
Rosa et al., 2019	CE	CBMs are a new kind of BMs, where the value creation is grounded on keeping the economic value embedded into products after their use and exploit it for new types of market offerings. This action requires a set of return flows (from end users to producers).	14 CBM classes	• Grouped CBMs under the umbrella of sustainable business models • Developed 14 classifications of CBMs based on literature research, with significant overlap between several classes

Based on an action research approach, Pieroni et al. (2020) developed a classification for circular business models that comprises seven categories (Table 6). Five categories are oriented towards downstream activities: dematerialised or efficiency, collaborative consumption, product-service-systems, long life, and next life, while two focusing on the upstream value chain: circular sourcing and circular production and distribution.

Table 6

Circular business model categories

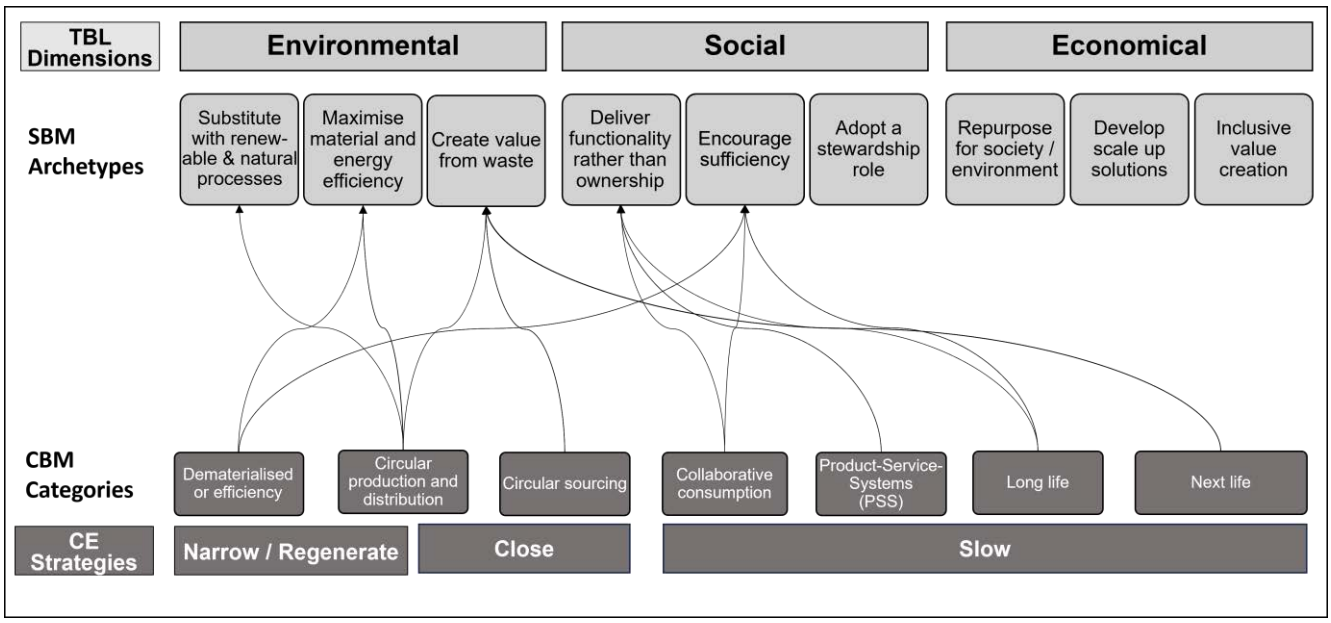
Business model category	Description
Dematerialised or efficiency	Value is delivered by replacing or complementing material-intensive products with digital services and efficiency solutions that reduce resource use and promote sustainable consumption, while value is captured through digital sales, service contracts, subscriptions, or enhanced brand image.
Collaborative consumption	Value is delivered by enabling individuals to share products. This intensifies utilisation and reduces demand for new production, while value is captured through subscriptions, transaction fees, complementary services, and stronger customer engagement.
Product-service systems	Value is delivered by shifting from product ownership to access-based, service-based or function-based services that integrate products with maintenance, repair, or performance guarantees, while value is captured through service contracts, rental fees, or long-term customer relationships.
Long life	Value is delivered through durable and repairable products supported by services such as repair, refurbishment, or modular upgrades, reducing replacement needs and fostering sustainable consumption, while value is captured through premium pricing, recurrent service revenues, and stronger customer loyalty.
Next life	Value is delivered by keeping products in circulation through resale, take-back, refurbishment, recycling, or repurposing, thereby reducing waste and conserving resources. Value is captured through revenues from resale or recycled products, cost savings from recovered materials, and enhanced reputation as a circular and responsible company.
Circular sourcing	Value is created by optimising resource use and minimising environmental impact through asset life extension, by-product reuse, and sustainable input sourcing, while value is captured through cost savings, efficiency gains, and reputational benefits.
Circular production and distribution	Value is created by aligning production with demand, improving process efficiency, and recycling of products and materials for new production while value is captured through cost savings, resource recovery, compliance benefits, and enhanced reputation.

Source: Adapted from Pieroni et al., 2020

A direct comparison and alignment of the SBM categorisations from Bocken et al. (2014) and Ritala et al. (2018) with the CBM categories from Pieroni et al. (2020) reveal that a mapping between CBMs and SBMs is possible, although not all SBMs have a corresponding CBM (Figure 14). Therefore, in this study CBMs are regarded as a subset of SBMs, aimed at narrowing, slowing, and/or closing resource flows. Moreover, it should be noted that the individual business model types do not exist in isolation and are not implemented separately, but rather combined and integrated into an overall strategy tailored to a specific company (Bocken et al., 2014; Pieroni et al., 2020).

Figure 14

Overview and alignment of sustainable (SBM) and circular (CBM) business models



Source: The author, based on Bocken et al., 2014; Pieroni et al., 2020 and Ritala et al., 2018

However, business models appear to be highly industry-specific, yet literature offers few sector-specific studies. To date, there is a scarcity of empirical research that investigates sustainable and circular business models in specific industries. While a group of generalised business model archetypes has been developed based on practical examples (see Figure 14), there is a lack of research providing tailored, actionable and practice oriented guidance for sector-specific business model adaptation. Supporting this view, Stumpf et al. (2021), in a large-scale analysis of over 130 real-world CE projects, found that most initiatives focused on incremental changes within a linear business model, rather than on circular business model redesign. A more recent study by Cagno et al. (2025) on European manufacturing firms reaches a similar conclusion,

showing that incremental adaptations aimed at improving the efficiency of “business-as-usual” practices remain far more common than the implementation of more radical business model innovations, such as product-service systems. This suggests that, despite the strong emphasis in academic literature on business model innovation as a driver of the CE transition, industry actors seem to adopt incremental adaptations rather than to implement radical circular business model innovation (BMI), which “constitutes the development and refinement of business models, regardless of whether entire business models are innovated or only certain elements are replaced and/or recombined” (Bocken & Geradts, 2020, p. 4).

In summary, sustainable and circular BM approaches are understood as those designed to offer, produce, and successfully market products and services in such a way that they generate long-term profits for a company, while at the same time narrowing, slowing, and closing resource flows and avoiding negative impacts on stakeholders, including the natural environment. This suggests the need for companies to review and adapt their existing products and services, manufacturing and distribution processes, as well as their commercial or revenue models. Geissdoerfer, Morioka, et al. (2018) draw a clear distinction between business models (focusing on the individual organisation and its value creation) and supply chains (spanning multiple organisations and their material and immaterial flows). However, since business models and supply chains are interdependent and mutually influential, they are considered to play a decisive role in the transition to sustainability and the CE. The next section therefore examines sustainable and circular supply chains in greater detail.

2.4.3 Sustainable and Circular Supply Chains

Another central theme in the literature on organisational transitions to sustainability and the CE includes the implementation of sustainable and circular supply chains. The transformation of products and business models in line with sustainability and CE principles is widely considered to require changes and innovations within supply chains (Amir et al., 2022; Geissdoerfer, Morioka, et al., 2018; Zhang et al., 2021). Since a single company is typically unable to generate all resources and materials needed for the production and distribution of goods and services, supply chain management (SCM) plays a crucial role in coordinating organisational networks to optimise procurement, manufacturing, and distribution processes in terms of both efficiency and effec-

tiveness (Christopher, 2016). SCM is therefore considered pivotal in enabling sustainability and CE implementation and is referred to as sustainable supply chain management (SSCM) or circular supply chain management (CSCM). As in the areas of products and business models, terminological distinctions are drawn between the two concepts, which will briefly be compared hereafter. Table 7 provides an overview of the relevant research contributions concerning sustainable and circular supply chain management definitions and conceptualisations.

Table 7

Overview of relevant sources highlighting differences and overlaps between sustainable and circular supply chain management

Source	Main focus	Definition SSCM/CSCM	Comment
Seuring & Müller, 2008	Sustainability	SSCM is the management of material, information, and capital flows, as well as collaboration among supply chain partners, while integrating economic, environmental, and social goals derived from customer and stakeholder requirements. In sustainable supply chains, members must meet environmental and social standards to remain part of the network, while competitiveness is maintained through fulfilling customer needs and economic objectives.	• Early conceptual foundation for SSCM • Closed loop supply chain management mentioned as a subset of SSCM with relevance only to the environmental dimension
Seuring et al., 2022	Sustainability	Builds on the 2008 definition and conceptualises SSCM along two dimensions: (1) sustainable supplier management, emphasising risk and performance management, and (2) supply chain management for sustainable products, focusing on supplier collaboration and development.	• Updated and extended former SSCM conceptualisation • Referred to CSCM as a newer strand of research within SSCM, but without detailed discussion.
Batista et al., 2018	Both	CSCM is the coordination of forward and reverse supply chains through purposeful business ecosystem integration for value creation from products, services, by-products, and useful waste flows. Prolonged lifecycles aim to improve the economic, social, and environmental sustainability of organisations.	• Viewed CSCM as an extension to SSCM by adding restorative and regenerative aspects • Interpreted CSCM as a combination of open-loop (cascading) and closed-loop (closed) resource flows
Farooque et al., 2019	Both	CSCM integrates circular thinking into SCM and related industrial and natural ecosystems. It aims to restore technical materials and regenerate biological ones through system-wide innovation in business models and supply chain functions - from design to end-of-life - engaging all stakeholders across product or service life.	• Most cited definition in CSCM literature • Viewed CSCM as an extension of SSCM by adding a zero-waste dimension based on CE principles • Interpreted CSCM as a combination of open- and closed-loop approaches, as pure closed-loop systems allow fewer cascades • Highlights the role of collaboration and digital technologies for CSCM
Geissdoerfer, Morioka, et al., 2018	Both	SCSCM as configuration and coordination of organisational functions within and across organisations to close, slow, intensify, narrow, and dematerialise material and energy loops, thereby reducing resource use, waste, and emissions. It aims to create economic and non-economic value, promote proactive stakeholder engagement, and ensure a long-term perspective.	• Distinguishes between SSCM and CSCM: in SSCM closed loops are not a core element, while in CSCM sustainability issues are not necessarily central • Highlights the integration of both concepts in SCSCM • Extends CSCM by adding TBL perspective, long-term orientation, and stakeholder management.
Montag, 2023	Both	Identified six archetypal elements of the circular supply chain (CSC): (1) R-imperatives, (2) restoration and regeneration cycles, (3) sustainability frameworks, (4) value focus, (5) holistic systems thinking, and (6) paradigm shifts.	• Viewed CSCM as part of SSCM. • Reviewed and analyses 127 contributions on CSCM definitions and provides a conceptualisation.

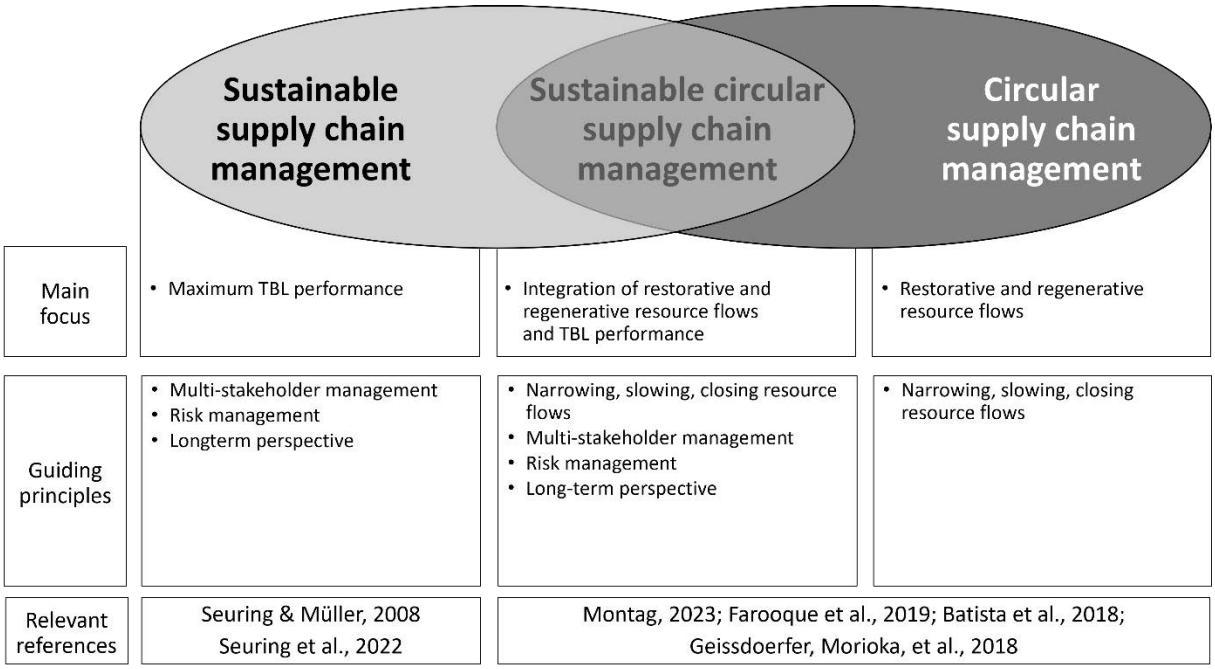
Sustainable SCM extends the conventional SCM objectives - optimisation of time, cost, and quality in material and information flows (Christopher, 2016) - by adding the TBL perspective. SSCM is thus aimed at optimising material and information flows with regard to time, cost, and quality while avoiding negative social and environmental impacts (Seuring et al., 2022; Seuring & Müller, 2008). Circular SCM, by contrast, focuses on restoring and regenerating resource flows with the aim of reducing resource consumption and preventing waste generation (Batista et al., 2018; Geissdoerfer, Morioka, et al., 2018).

Although this could, in principle, be pursued independently of sustainability considerations, the concept of CSCM is largely understood in literature as an extension to the SSCM concept. Accordingly, sustainable circular supply chain management (SCSCM) is understood as the coordination of forward and reverse flows of material and information in such a way that negative social and environmental impacts are minimised, while ensuring the restoration and regeneration of resources and the prevention of waste and emissions, all under conditions of optimised time, cost, and quality (Batista et al., 2018; Geissdoerfer, Morioka, et al., 2018; Montag, 2023).

In contrast to conventional SCM, which prioritises linear process efficiency as a source of economic performance, SCSCM emphasises a long-term perspective of narrowing, slowing and closing resource flows and avoiding negative impacts. This includes multi-stakeholder and risk management as well as collaborative approaches with partners inside and outside the supply chain (Batista et al., 2018; Geissdoerfer, Morioka, et al., 2018; Seuring et al., 2022) (Figure 15).

Figure 15

Conceptual relationship between sustainable and circular supply chain management aspects and principles



Source: The author, based on Batista et al., 2018; Farooque et al., 2019; Geissdoerfer, Morioka, et al., 2018; Montag, 2023; Seuring et al., 2022; Seuring & Müller, 2008

However, the literature on SCSCM remains fragmented, with a strong focus on theoretical and conceptual frameworks, and relatively few empirical studies from which comprehensive (best) practices for the development and implementation of sustainable circular supply chains can be derived. One of the few comprehensive empirical studies in this domain is provided by Zhang et al. (2021), who analysed a full set of case studies curated by the Ellen MacArthur Foundation to identify state-of-the-art SCSCM practices. Their findings indicate the existence of two primary archetypes of circular supply chains. The vast majority - nearly three-quarters of the analysed cases - followed a closed-loop supply chain (CLSC) model. In CLSCs, products, components, or materials remain within the original supply chain and are returned after use with the aim of preserving or recovering value. A smaller portion - slightly over one-quarter - represented open-loop supply chains (OLSCs). In OLSCs, different companies from separate supply chains collaborate to recover products or materials, which are then reused by actors other than the original producer. This is a noteworthy finding, as in closed supply chains the opportunities for cascading are limited, which is why a combination of open- and closed-loop resource flows is regarded as optimal (Batista et al., 2018; Farooque et al., 2019).

The alignment of internal corporate processes and practices, such as procurement and production (De Angelis et al., 2018), and the measurement and monitoring of relevant indicators to support decision-making and avoid negative side effects (e.g., rebound effects), are considered to be critical elements for enabling the CE transition (Vegter et al., 2023). There is also a broad consensus in that digital technologies are essential enablers of SCSCM, as they can enhance traceability, data integration, and information management across the entire life cycle of materials and products (Farooque et al., 2019; Montag, 2023; Seuring et al., 2022; Wu et al., 2025). Nevertheless, the degree of implementation of sustainable and circular practices in companies seems to remain low (Kirchherr & Hartley, 2025; Sarja et al., 2021). This is likely why research on the challenges to implementing sustainable and circular practices – related to supply chains, products and business models - has expanded considerably. The next section therefore explores the key challenges in this context.

2.4.4 Challenges for the Implementation of Sustainability and the CE

In the previous section it was highlighted that the transition to sustainability and the CE entails substantial changes across business operations. This section examines potential challenges that companies face in implementing CE principles.

The challenges and barriers perceived by companies related to sustainability and CE–related change processes are manifold. To provide a structured overview, in the following section the identified challenges are categorised according to the change dimensions discussed in the previous section - namely, product-related, business model-related, and supply chain-related challenges. In addition, challenges were identified that pertain specifically to the organisation’s internal and external environment, which led to a further corresponding category of organisation-related challenges.

Product and design-related challenges

One of the core challenges associated with the implementation of sustainable and circular products identified in previous studies is the availability of alternative materials - such as recycled or biodegradable inputs - with respect to price, quality, and supply stability (Guldmann & Huulgaard, 2020; Sarja et al., 2021; Werning & Spinler, 2020). For instance, when secondary materials are more expensive than virgin materials or compromise the quality of final products, demand tends to remain low. As a result,

interest, investment, and innovation in the further development and improvement of these materials remain limited (Guldmann & Huulgaard, 2020; McMahon et al., 2024).

A key challenge in product development for sustainability and the CE is widely seen as reconciling the design of durable and timeless products, with the fast-paced nature of market trends and innovation cycles (Werning & Spinler, 2020). Developing products aligned with sustainability and CE-principles requires a life cycle perspective (see Section 2.4.1), meaning that products must be thought, designed and developed to be e.g., long-lasting, repairable, and recyclable. At the same time, they must meet customer expectations and contribute to the company's financial performance (Sarja et al., 2021). Meeting these diverse and often conflicting requirements places significant demands on those responsible for product design and development, requiring a broad range of specialised knowledge and skills (Kirchherr et al., 2022).

Organisational and business model-related challenges

Some of the most significant barriers related to the transition to sustainability and the CE seem not be directly related to the core domains of products, business models or supply chain processes, but rather to broader organisational factors and decisions. Thus, it was recognised that focusing on those core domains is too narrow. Rather, particularly the challenges associated with business models are closely intertwined with broader organisational obstacles. Therefore, the change dimension has been expanded to include both organisation and business model.

A lack of awareness regarding the necessity of strategic, long-term changes related to sustainability and circularity is one of the most frequently mentioned challenges in the literature (e.g., Antikainen et al., 2018; McMahon et al., 2024; Sarja et al., 2021 or Werning & Spinler, 2020). This lack of awareness is accompanied by cultural barriers. When the need for and the potential opportunities of change are not recognised (Guldmann & Huulgaard, 2020; Sarja et al., 2021), companies frequently exhibit a lack of interest, commitment, and initiative, both at top management level and among employees (Guldmann & Huulgaard, 2020; McMahon et al., 2024). Additionally, limited knowledge, skills, and competencies related to the understanding and implementation of sustainability and the CE is seen as a central obstacle to organisational change (Guldmann & Huulgaard, 2020). This competence gap can lead to resistance to

change and a lack of innovation capacity within the firm. For instance, fear of cannibalisation is a challenge associated with the transition to circular business models (Werning & Spinler, 2020). If products are used for longer or if new purchases are replaced by services such as repair or refurbishment, companies may anticipate a decline in revenues and growth (Guldmann & Huulgaard, 2020). Furthermore, companies entail market-related risks to this shift (Kirchherr et al., 2018). If new circular offerings fail to meet customer expectations to the same extent as their linear counterparts, or if they are associated with higher costs for consumers and/or the company, businesses may hesitate to implement these approaches (Sarja et al., 2021; Werning & Spinler, 2020).

Moreover, external barriers prevent companies from implementing sustainable and circular business models and practices. These are the lack of supportive infrastructure, such as financial incentives or funding schemes (Guldmann & Huulgaard, 2020; Sarja et al., 2021) as well as the absence of external reference points - such as industry-related lighthouse projects, success stories, best practices, and industry standards (Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; McMahon et al., 2024; Sarja et al., 2021). Lopes de Sousa Jabbour et al. (2018) also highlight a lack of knowledge among practitioners about how DTs can support the transition to sustainability and the CE, and how synergies between digital technology deployment and initiatives related to sustainability and the CE can be meaningfully established and leveraged. Finally, the absence of appropriate indicators to measure and communicate the impact and success of individual actions is seen as another factor that hinders progress in the implementation of circular strategies and practices (Kirchherr et al., 2018).

Supply chain and production-related challenges

A major challenge is seen in the need for cross-organisational collaboration, which is essential for sustainable and circular supply chains. Whether it involves the design and organisation of reverse logistics and processing operations, or ensuring customer-oriented availability of spare parts, repair services, or other product-service combinations, such tasks cannot be managed by a single firm alone. Rather, they require coordinated and networked collaboration among various actors along the value chain (Antikainen et al., 2018; Guldmann & Huulgaard, 2020; Werning & Spinler, 2020). Furthermore, the transition to cleaner and more resource-efficient manufacturing processes, as well as the processing and production of sustainable and circular materials and products,

typically requires changes in technologies and operations, and is therefore associated with significant costs (Kirchherr et al., 2018; Sarja et al., 2021). The relevance and intensity of these challenges, however, appear to differ across organisational and sectoral contexts. The literature review revealed a lack of clarity and consensus regarding the extent to which specific challenges are industry-dependent. For example, Werning & Spinler (2020) identified significant sectoral differences in the challenges faced by companies, while Guldmann & Huulgaard (2020) found no such differences between industries but did identify distinctions between incumbent companies and startups. Similarly, Geissdoerfer et al. (2023) observed context-specific variations in challenges depending on whether companies were engaging in newly founded or transformational business model innovations, and Cagno et al. (2025) found an interrelation between the degree of CE implementation and both the industry sector and company size. These insights highlight the need for further research aimed at understanding challenges from an organisational perspective, particularly with respect to firm size and market environment.

2.5 The Role of Digital Technologies in the Implementation of Sustainability and the CE

This section provides a more in-depth look at the role of DTs and their functionalities in sustainability-related initiatives, with a particular focus on the CE. As briefly outlined in the introduction, DTs encompass electronic tools, automated systems, and technological devices that enable the processing, transmission, and storage of digital data (Wynn & Jones, 2022a). Within the CE literature, DTs are widely interpreted as enablers of corresponding initiatives and practices and as supporting organisations in addressing related challenges (e.g., Bressanelli et al., 2022; Cagno et al., 2021; Kristoffersen et al., 2020; Lopes de Sousa Jabbour et al., 2018; Wynn & Jones, 2022a).

However, it is notable that developments and innovations considered central in this context are interpreted differently. In some cases, relevant functionalities - such as data capture, collection, transmission, and analysis, the virtualisation and interconnection of objects, or communication and interaction with stakeholders - are discussed without being explicitly linked to specific DTs (e.g., Antikainen et al., 2018; Kristoffersen

et al., 2020; Liu et al., 2022). In other cases, seemingly arbitrary combinations of technologies are presented (e.g., Bressanelli et al., 2022; Neri et al., 2023) or umbrella concepts such as Industry 4.0 are used to subsume a range of key technologies (e.g., Cagno et al., 2021; Lopes De Sousa Jabbour et al., 2022; Lopes de Sousa Jabbour et al., 2018; Rusch et al., 2023).

This illustrates that much of the existing literature approaches the topic primarily from a technology- or digitalisation-oriented perspective. At the same time, questions of how different DTs interrelate, depend on one another, and are integrated into corporate infrastructures are often only implicitly addressed. This suggests that the contribution of DTs to CE-related initiatives cannot be fully understood by examining individual technologies or functionalities in isolation. In contrast, this study adopts the perspective of sustainability- and CE-related initiatives and, building on the previously identified change dimensions associated with such initiatives, examines how and which DTs play - or may play - a role in this context. Accordingly, the following sections categorise DTs and their functionalities in relation to the change dimensions discussed above, namely product- and design-related, supply chain and production process–related, and business model- and organisation-related applications of DTs, based on the existing literature. The section concludes with a critical reflection and synthesis of the insights derived from the literature.

Technology deployment related to product and design

The role of DTs in the (re-)design of products for sustainability and the CE is primarily addressed from a theoretical perspective in recent literature (Neligan et al., 2023), while empirical studies on the practical use of DTs in circular product design remain scarce (e.g., Antikainen et al., 2018 or Perotti et al., 2024).

Concerning technologies and functionalities, virtualisation of product development through 3D technologies seems to be one of the most promising digital functions as it allows for optimisation according to various CE design principles, such as reducing material use, extending product lifespan, and facilitating repair, disassembly, and recycling (Han et al., 2023). Virtual product development is also a prerequisite for digital fabrication through additive manufacturing, which contributes to reducing material waste, inventory levels, and transportation needs (Bressanelli et al., 2022; Cagno et al., 2021; Nascimento et al., 2019). The application of Artificial intelligence (AI) and its

ability to detect patterns can support the identification and prediction of market and consumer trends, enabling data-informed product and design decisions (Perotti et al., 2024). Whereas, the integration of sensors and chips into products, referred to as the Internet of Things (IoT), facilitates transparent communication with consumers regarding a product's environmental impact, disposal and return options, or repair services (Chauhan et al., 2022; Lopes de Sousa Jabbour et al., 2018; Perotti et al., 2024). These technologies also serve as enablers for PSS, such as pay-per-use models, and allow for the collection of usage-data, such as the frequency and intensity of use of household appliances (Bressanelli et al., 2018), vehicles, or machines (Ranta et al., 2021). This provides valuable insights into potential design improvements to reduce resource consumption (e.g., fuel, energy or water consumption during the use phase) or for extending the product use phase through enabling predictive maintenance or consumer education (Bressanelli et al., 2022; Lopes de Sousa Jabbour et al., 2018). In addition, Antikainen et al. (2018) highlight the role of social media as a key technology for integrating consumers directly into product and service development through co-creation. This kind of user involvement enhances the customisation and market alignment of circular products and services, contributing to their overall effectiveness and acceptance (Antikainen et al., 2018).

Technology deployment related to supply chain and production

In regards to circular supply chains DTs can potentially play an enabling role in facilitating traceability and transparency of materials, components, products, and packaging, as well as supporting communication between stakeholders across the supply chain (Lopes de Sousa Jabbour et al., 2018; Neri et al., 2024). Additionally, Blockchain technology and cloud-based platforms are particularly seen important in ensuring the secure and trustworthy exchange of data between actors (Neri et al., 2023; Perotti et al., 2024; Upadhyay et al., 2021). These technologies can support the creation of digitally connected networks, which are essential for implementing circular processes across complex and distributed supply chains (Upadhyay et al., 2021). Rusch et al. (2023) highlight the considerable potential of smart contracts for verifying sustainability-related data, as they can provide transparent and verifiable information on certifications, or origin of materials and products. With regard to a company's downstream stages - including customers, consumers, and waste management providers - technologies such as digital product passports (Jensen et al., 2023; Langley et al., 2023),

blockchain, and digital marketing tools can enable efficient communication and potentially promote “green behaviour” among customers und consumers (Chauhan et al., 2022, p. 9) to facilitate use phase extension and reuse, while also supporting higher collection, sorting, and recycling rates (Antikainen et al., 2018; Chauhan et al., 2022; Neri et al., 2023; Perotti et al., 2024; Upadhyay et al., 2021). This shows that DTs could serve as the backbone of circular supply chain management, not only by enabling transparency and trust, but also by activating circular practices among stakeholders.

Furthermore, DTs are seen to play a critical role in business process optimisation - especially in production and logistics - by contributing to the reduction of resource consumption, emissions, and waste generation (Cagno et al., 2021; Chauhan et al., 2022; Lopes de Sousa Jabbour et al., 2018). In this context, IoT technologies and functionalities are considered key enablers for process optimisation (Cagno et al., 2021; Chauhan et al., 2022), while also supporting the integration with other technologies, such as cloud services and big data analytics (Neri et al., 2023). For instance, real-time data collection enabled by interconnected sensors and mobile computing and applications allows for the tracking of products and materials along the supply chain and throughout their life cycle, as well as the monitoring of quality indicators, inventory levels, and resource use (Chauhan et al., 2022; Kristoffersen et al., 2020; Laskurain-Iturbe et al., 2021; Wynn & Jones, 2022a). Other technologies - such as process automation, robotics, and digital fabrication technologies - can contribute to reducing material consumption in manufacturing processes (Bressanelli et al., 2022; Neri et al., 2023) and improving logistics operations (Laskurain-Iturbe et al., 2021; Lopes de Sousa Jabbour et al., 2018).

AI is considered to offer further potential to support circular strategies through predictive analytics, forecasting, and machine learning techniques that can help reduce resource consumption and waste generation (Cagno et al., 2025; Chauhan et al., 2022; Neri et al., 2024; Schöggl et al., 2023). Use cases range from real-time detection of production defects or maintenance needs (Cagno et al., 2025; Chauhan et al., 2022) to decision support for production planning - e.g., through demand forecasting based on market data (Neri et al., 2024; Schöggl et al., 2023) - and the optimisation of energy consumption in heating and cooling systems (Laskurain-Iturbe et al., 2021). In a broader context, mobile applications also offer opportunities to reduce resource con-

sumption, for example by decreasing paper usage, saving fuel, and increasing efficiency through mobile work practices and flexible use of IT devices (Wynn & Jones, 2022a).

However, empirical studies investigating digital technology deployment for the implementation of sustainability and CE remain limited. Prior studies suggest that DTs are currently adopted in production and logistics operations in manufacturing companies primarily for their efficiency and cost-saving potential, rather than being intentionally implemented to advance sustainability goals (Lopes De Sousa Jabbour et al., 2022; Neligan et al., 2023; Schöggl et al., 2023), while at the same time indicating that the associated chances to support sustainability and CE practices are increasingly being recognised (Neri et al., 2023).

Technology deployment related to organisation and business models

DTs can play a pivotal role in business model innovation. Business models based on the virtualisation or dematerialisation of products (Lopes De Sousa Jabbour et al., 2022; Lopes de Sousa Jabbour et al., 2018) - such as sharing schemes or pay-per-use models (Bressanelli et al., 2021), where customers pay for the use or functionality rather than for ownership (e.g., of household appliances or construction machinery; Bressanelli et al., 2018; Neligan et al., 2023; Ranta et al., 2021), - would hardly be feasible without the use of DTs. In this context Ranta et al. (2021) report on a tool manufacturer that offers rental and service options for its products, combining IoT, cloud, and radio-frequency identification (RFID) technologies for data collection and integration, thereby increasing availability, maintenance efficiency, and utilisation while reducing inventory levels and fleet size. In similar vein, examples from the Electronic Equipment and household appliance industries show, that the combined integration of various DTs, such as IoT, blockchain, cloud computing and digital twins, allows for the collection and analysis of product data and to offer corresponding services such as usage-based billing, preventive and predictive maintenance, as well as take back schemes (Bressanelli et al., 2018, 2021). In addition, digital platforms and online marketplaces enable the development of new circular business opportunities - for instance, by facilitating the exchange of industrial by-products, waste materials or scraps between companies and supply chains (Antikainen et al., 2018; Neri et al., 2023).

Critical reflection on the Role of Digital Technologies in the Implementation of Sustainability and the CE

Although DTs are portrayed in the CE literature as central enablers for circular strategies and practices, some studies highlight important limitations and caution against assuming an inherent contribution of digitalisation to CE-related outcomes. Instead, the effects of DTs are highly context-dependent and may give rise to unintended rebound effects, where efficiency gains fail to offset negative impacts such as increased energy or resource consumption (Bressanelli et al., 2022; Zink & Geyer, 2017). In this context, Bressanelli et al. (2021) refer to a digitally supported laundry service system which, while reducing consumption through shared use, may encourage users to wash their clothes more often due to increased convenience, ultimately resulting in higher overall resource consumption.

Furthermore, analysing DTs in isolation provides only limited insight, as their impact is shaped by the socio-technical systems in which they are embedded. Seidel et al. (2013) demonstrate in a case study that the successful sustainability-oriented transformation of a company was not driven by information technology alone, but by changes in organisational practices and actor behaviour enabled by these technologies. Against this background, digitalisation in the context of sustainability and the CE should be understood less as the adoption of individual technologies and more as the development of interconnected socio-technical systems aligned with clearly defined sustainability objectives.

Summary

In this section, several technologies with illustrative use cases potentially facilitating the transition to sustainability and the CE, were identified. Overall, it was realised that the interplay and combination of various DTs can play a crucial role for the implementation of sustainable and circular practices. Moreover, existing studies highlight sector-specific differences and dependencies, as well as variations by company size, with regard to the use and integration of DTs in CE transitions (Neligan et al., 2023; Schöggl et al., 2023). As a result, findings from one company or sector cannot easily be generalised or adapted to others (Chauhan et al., 2022). At the same time, it must be acknowledged that DTs do not automatically lead to sustainability- or CE-related out-

comes, as their effects are highly context-dependent and contingent on their integration within broader socio-technical systems. This underlines the necessity of engaging with sector-specific research to understand specifics and develop tailored transition models.

2.6 Related Research in the Textile and Clothing Industry

The T&C industry received limited attention for long time in the scientific literature on the transition to sustainability and the CE. However, with recognition of the T&C industry as one of the priority sectors in the European Circular Economy Action Plan (European Commission, 2020a), research activity in this area has increased significantly in recent years. Scholars from various disciplines and diverse perspectives have since engaged with studying the transition to sustainability and the CE in the T&C industry. The existing body of literature (Table 8) can be broadly divided into two main categories.

Category one comprises theoretical studies, which are predominantly based on systematic literature reviews, and exploring potential strategies and practices as well as the barriers and drivers associated with their implementation. These studies either adopt a product-centric perspective (focusing on product life cycle stages) without direct reference to individual organisations and related changes, or they are conducted from the perspective of fashion brands and therefore consider only a small part of the T&C industry. The primary focus lies on the realisation of recycling strategies and associated reverse flows between consumers and brands or retail, as well as on the implementation of circular business models such as rental, leasing, or other product-service systems, while the manufacturing stage is largely neglected.

Category two comprises empirical studies, based on case studies, which primarily address the implementation of circular strategies and practices from an organisational perspective. Here too, the focus is largely on fashion brands, while the textile sector is largely neglected. Across both categories, the emphasis on fashion brands is striking. In the following sub-sections, the key findings of the T&C-related studies presented in Table 8 are summarised and analysed with regard to organisational, product-related, and process-related changes in the context of sustainability with a focus on the CE in particular, as well as the role DTs are playing in this context.

Table 8

Relevant research on the transition to sustainability, the CE and digitalisation in the T&C Industry

Source	Theoretical/ empirical	Method	Research subject	Regional focus	Strategies & practices related to sustainability and the CE			Transition to sustainability and the CE		
					Product design	Supply chain & production processes	Business model	Challenges	Influencing factors	Role of DTs
Jia et al., 2020	Theoretical	Literature Review	CE transition in T&C manufacturing companies	none		x		x		
Ki et al., 2020	Theoretical	Literature Review	Strategies, practices and challenges in the CE transition for fashion companies related to internal and external stakeholders	none	x	x	x	x		
De Aguiar Hugo et al., 2021	Theoretical	Literature Review	Strategies for resource reduction, reuse and recycling during the fashion product life cycle and barriers for implementation	none	x	x	x	x		
Abdelmeguid et al., 2022	Theoretical	Literature Review	Challenges for the CE transition in fashion companies	none				x		
Dissanayake & Weerasinghe, 2022	Theoretical	Literature Review	CE strategies and challenges/enablers for circular fashion	none	x	x	x	x		
Alves et al., 2022	Theoretical	Literature Review	Possible adoption of BC and IoT along the T&C supply chain and associated advantages and disadvantages	none		x				x
Abdelmeguid et al., 2024a	Theoretical	Mixed Method	Challenges in the CE transition of fashion companies	none				x		
Hassan et al., 2024	Theoretical	Literature Review	Contribution of digital technologies to CE practices and strategies along the textile product life cycle	none						x
De Felice et al., 2025	Theoretical	Literature Review	CE strategies/practices for companies in T&C industry	none	x	x	x	x	x	x
Glogar et al., 2025	Theoretical	Literature Review	Design approaches and digital technologies supporting design and development of circular T&C products	none	x					x
Orisadare et al., 2025	Theoretical	Literature Review	Strategies, impacts, and challenges of digitalisation and green transition in the T&C industry	none				x		x
Franco, 2017	Empirical	Multiple Case Studies	Challenges of the CE transition in C2C certified fashion brand and textile manufacturing companies	Austria, Germany, Switzerland				x		
Fischer & Pascucci, 2017	Empirical	Multiple Case Studies	Mechanisms and success factors in inter-firm collaborations engaged in the transition to circular textile material flows	Netherlands		x			x	
Brydges, 2021	Empirical	Expert Interviews	CE Strategies and practices implemented in fashion companies	Sweden	x	x	x	x		

Table 8 Continued

Source	Theoretical/ empirical	Method	Research subject	Regional focus	Strategies & practices related to sustainability and the CE			Transition to sustainability and the CE		
					Product design	Supply chain & production processes	Business model	Challenges	Influencing factors	Role of DTs
Colucci & Vecchi, 2021	Empirical	Multiple Case Studies	CE Strategies and practices implemented in fashion companies	Italy			x	x		
Dan & Østergaard, 2021	Empirical	Expert Interviews	Role and requirements for fashion designers in the CE transition in fashion companies	Europe	x					
Rese et al., 2022	Empirical	Mixed Method	Success factors for sustainable product innovations in fashion companies	Germany, Europe, USA	x				x	
Hartley et al., 2022	Empirical	Multiple Case Studies	Barriers related to the CE transition, their interrelation and strategies to overcome them in technical and interior textile manufacturing	Nether-lands				x	x	
Huynh, 2022	Empirical	Multiple Case Studies	Archetypes, technologies, challenges and opportunities of digitalised business models in fashion companies	Norway	x	x	x	x		x
Elf et al., 2022	Empirical	Multiple Case Studies	CE practices and capabilities adopted in small fashion companies	UK			x		x	x
Abbate et al., 2023	Empirical	Multiple Case Studies	Drivers, strategies and practices in CE implementation in slow-fashion companies	Italy	x	x	x			x
Arnold et al., 2023	Empirical	Survey	CE Strategies and practices implemented in textile manufacturing com-panies	Germany	x	x	x	x	x	x
Brydges et al., 2023	Empirical	Expert. Interviews	CE Strategies and practices implemented in fashion companies	Sweden	x					
Saccani et al., 2023	Empirical	Multiple Case Studies	Challenges to CE transition and mechanisms to overcome them in a cir-cular textile supply chain ecosystem	Italy		x		x	x	
Abdelmeguid et al., 2024b	Empirical	Expert Inter-views	Success factors for the CE transition in companies along the textile & clothing value chain	none					x	
Colucci & Vecchi, 2024	Empirical	Multiple Case Studies	CE strategies and practices implemented in born-circular companies (clothing upcycling & remanufacturing)	Italy			x	x	x	
Dziubaniuk et al., 2024	Empirical	Multiple Case Studies	Management heuristics in textile companies' CE-transition	Finland				x	x	
Gazzola et al., 2025	Empirical	Multiple Case Studies	Implementation of MateriaMX software and its impact on CE strategies and sustainability objectives in fashion/ retail companies	none				x	x	x

2.6.1 Key Issues and Challenges

The analysed studies suggest that, while there is a growing awareness of sustainability and the CE within the industry (Arnold et al., 2023), the transition is still in its early stages and remains fraught with significant challenges and uncertainties for companies (e.g., Abdelmeguid et al., 2022; Colucci & Vecchi, 2024; Dziubaniuk et al., 2024; Hartley et al., 2022). At the same time, the literature reveals substantial differences between start-ups, which are founded on circular principles, and incumbent companies, which face fundamental changes in business models, products, supply chains, and processes (Colucci & Vecchi, 2021, 2024; Huynh, 2022). Given these differences, this study specifically focuses on the transition of incumbent firms, as they face the more complex task of reconfiguring established structures and practices.

Organisation and business models

In the context of circular business model innovation in the T&C industry, the focus is primarily on slowing practices aimed at extending the use and life span of fashion products. These include PSS such as rental, sharing, and swapping services, as well as cleaning and repair services (Abdelmeguid et al., 2022; Brydges, 2021; Colucci & Vecchi, 2021; Dissanayake & Weerasinghe, 2022). Also relevant are secondhand and peer-to-peer (P2P) resale platforms for used garments (Abdelmeguid et al., 2024b; Dissanayake & Weerasinghe, 2022; Huynh, 2022). While PSS models are discussed across various studies and analysed through case examples, the number of companies actively and successfully implementing such models seems to remain relatively low (Dissanayake & Weerasinghe, 2022; Elf et al., 2022). The emergence of new market segments enabled by these models has been strongly supported by DTs - such as 3D design and printing, mobile applications, online platforms, social media, and others (Abdelmeguid et al., 2024b; Colucci & Vecchi, 2021; De Felice et al., 2025; Hassan et al., 2024; Huynh, 2022; Orisadare et al., 2025) - making circular offerings more accessible and attractive and thus promising substantial future growth potential (Elf et al., 2022). As Huynh (2022) and Dziubaniuk et al. (2024) highlight, emerging circular market segments are dominated by startups, while incumbent firms tend to be more hesitant in transforming an existing linear business model. This hesitation is largely attributed to the incompatibility of current products and supply chain processes, which would require significant changes, whereas born-circular companies are structured for

circularity from the outset (Colucci & Vecchi, 2021). Consumer awareness - or rather, the lack thereof – is identified as a key barrier to business model implementation. This is rooted in the “widespread fast-fashion attitude” (Colucci & Vecchi, 2021, p. 868) as well as “misconceptions about recycled products are of low quality” (De Felice et al., 2025, p. 18) and general gaps in consumer awareness and interest (De Aguiar Hugo et al., 2021; Dissanayake & Weerasinghe, 2022; Hartley et al., 2022). However, studies examining CE transitions from a consumer perspective (e.g., Vehmas et al., 2018) suggest that there is, in fact, a positive attitude toward circular clothing. In this regard, price is identified as a critical factor influencing consumers' purchasing decisions in favour of sustainable and circular products (Abdelmeguid et al., 2022, 2024b; Brydges, 2021; Colucci & Vecchi, 2021; De Felice et al., 2025; Saccani et al., 2023). The studies by Huynh (2022) and Elf et al. (2022) underscore the importance and potential success of actively involving customers and consumers in the change process, in order to better understand consumer mindsets and raise awareness of sustainable consumption patterns. As noted by Vehmas et al. (2018, p. 296), “consumers also expect more specific and detailed information regarding how their behaviour has affected, for example, the decrease of waste or the use of toxic chemicals and hoped to see the results that have been achieved”. Similarly, Abdelmeguid et al. (2022, p. 515) emphasise that “companies are required to communicate their circular strategies through, for instance, increased marketing, campaigns and platforms that educate and promote awareness among customers, while ensuring the commitment of retailers to these strategies to change consumers' behaviour and mindset and gain their interests”. However, all of this refers to practices of companies that interact directly with customers, primarily fashion brands. The opportunities and challenges for companies operating in the upstream stages, such as textile production and processing, by contrast, receive very little attention. In regard to fully circular business models - those based on the preservation and regeneration of materials and products – previous studies suggest that they are difficult to achieve by individual companies alone. Challenges include the resource-intensive processes associated with collection, sorting, and return logistics (Brydges, 2021; Dissanayake & Weerasinghe, 2022), uncertainties regarding the quantity and quality of post-consumer textiles (Arnold et al., 2023; De Aguiar Hugo et al., 2021; Franco, 2017; Hartley et al., 2022), as well as issues concerning the quality and market demand for recycled materials and products (De Felice et al., 2025; Saccani et al., 2023). Additionally, the technical complexity of textile recycling further contributes to

an unfavourable cost-benefit ratio, making circular textile flows a challenging and uncertain undertaking for companies (Arnold et al., 2023; De Aguiar Hugo et al., 2021; De Felice et al., 2025; Dissanayake & Weerasinghe, 2022). When it comes to organisational changes, the most frequently cited barriers in the T&C realted literature concerning business model adaptation relate to internal organisational aspects: an unsupportive corporate culture, lack of leadership and managerial commitment, uncertainty regarding potential benefits of the CE transition, and deficiencies in knowledge, skills, and resources. These internal deficits are often accompanied by weak communication, and a lack of intra- and inter-organisational cooperation (Abdelmeguid et al., 2022, 2024a, 2024b; Arnold et al., 2023; Dan & Østergaard, 2021; De Felice et al., 2025; Dziubaniuk et al., 2024; Franco, 2017; Ki et al., 2020).

Products and design

The implementation of circular business models is fundamentally dependent on decisions and changes related to products, materials, and manufacturing processes. As Abdelmeguid et al. (2024) note, “the choice of materials and fabrics plays a crucial role in sustainable value creation in the fashion industry”. The use of natural or recycled materials instead of oil-based synthetics, as well as the integration of circular design strategies in product development (Abdelmeguid et al., 2024b; Brydges et al., 2023; Dan & Østergaard, 2021; De Aguiar Hugo et al., 2021; Dissanayake & Weerasinghe, 2022), are well-established and widely researched practices among T&C companies. However, studies also highlight a range of challenges associated with circular product design and manufacturing. One key issue is the quality and availability of recycled and sustainable materials. This has resulted in a niche market where such materials are often more expensive and of lower quality or less available compared to virgin materials (Dissanayake & Weerasinghe, 2022; Fischer & Pascucci, 2017; Franco, 2017). Non-textile components - such as packaging, labels, or chemicals used in printing and dyeing - are also frequently unavailable in versions that offer comparable quality with reduced environmental impact (Franco, 2017). Additionally, textile materials and products are often highly complex. Textiles derive their aesthetic appeal, functionality, quality, and durability from blends of different fibres and the use of advanced chemical treatments. However, these material blends and chemical agents present significant technical challenges for sorting and recycling (Colucci & Vecchi, 2021; Jia et al., 2020; Saccani et al., 2023). This is compounded by a lack of knowledge and skills among

textile designers regarding circular product development (Dan & Østergaard, 2021). The most critical barrier, however, seems to lie in higher cost associated with developing and producing circular products, especially when compared to linear alternatives (Hartley et al., 2022; Saccani et al., 2023). These cost differences represent a major obstacle for companies as the generally low margins in the T&C sector and the high price sensitivity of consumers leave limited room to absorb additional expenses (Brydges et al., 2023; De Aguiar Hugo et al., 2021).

Supply chain and production processes

The T&C industry is characterised by decentralised, fragmented, and highly complex global supply chains (see Section 1.2.1). It is therefore unsurprising that transparency and collaboration are the two main themes emphasised in the literature on sustainable and circular textile supply chains, identified as key aspects of the transition to sustainability and circularity. Studies highlight persistent deficits in transparency - i.e., the exchange of information and data among supply chain actors - as well as a lack of cross-organisational collaboration in developing materials, products, technologies, and processes required for sustainable and circular systems (Abdelmeguid et al., 2022; Alves et al., 2022; Colucci & Vecchi, 2021; De Aguiar Hugo et al., 2021; De Felice et al., 2025; Saccani et al., 2023). Consequently, practices aimed at addressing these barriers are seen as critical tasks for advancing sustainability and circularity in the T&C industry. These include technologies such as blockchain or specialised software systems that enable the traceability of products and materials (Alves et al., 2022; De Felice et al., 2025; Gazzola et al., 2025; Hassan et al., 2024; Huynh, 2022) as well as the active integration of diverse stakeholders to establish closed-loop supply chains (Dissanayake & Weerasinghe, 2022; Fischer & Pascucci, 2017; Saccani et al., 2023). However, the body of literature in this area is broad and fragmented. It ranges from case studies presenting successful examples of closed-loop supply chains in local industrial districts in Italy (Saccani et al., 2023), to findings showing that, for German textile manufacturers, no fully developed approaches to closed-loop systems are yet observable (Arnold et al., 2023).

Other studies document a range of circular practices, such as reductions in water, chemical and energy consumption in production processes (Abbate et al., 2023; Colucci & Vecchi, 2021; De Felice et al., 2025). Nevertheless, these initiatives tend to remain internally focused, targeting individual company processes rather than seeking

to close material loops in collaboration with supply chain partners (Abbate et al., 2023; Colucci & Vecchi, 2021; De Felice et al., 2025). Moreover, empirical work largely concentrates on identifying practices for closed loop supply chains in the fashion sector across several European countries (Italy, Sweden, and Norway), particularly through take-back and recycling systems for used clothing and the associated challenges and opportunities (Abbate et al., 2023; Colucci & Vecchi, 2021; De Aguiar Hugo et al., 2021; Dissanayake & Weerasinghe, 2022; Fischer & Pascucci, 2017), while textile manufacturers in the upstream supply chain have been largely overlooked in this context. Overall, this review demonstrates that supply chain and production processes represent a central change dimension in the transition to sustainability and circularity in the T&C industry — one that requires active, comprehensive and coordinated practices.

Summary

In summary, the challenges associated with the transition to sustainability and the CE in terms of products, supply chains and production processes, as well as organisation and business models in the T&C industry, reveal sector-specific characteristics that require tailored and coordinated practices and approaches (Brydges, 2021; Colucci & Vecchi, 2021). However, there is a lack of practice-oriented research related to the T&C industry, integrating all these fields and aspects. For instance, Ki et al. (2020) and De Felice et al. (2025) call for further research on organisational change management to support better implementation of CE strategies in the sector.With regard to the geographical focus, the German T&C industry has so far been largely neglected. The study by Arnold et al. (2023) is the only focusing on Germany so far; however, it is based on a survey of circular business models among textile manufacturers and allows only limited conclusions to be drawn about operational practices. While the study indicates that the surveyed companies attribute potential to DTs for leveraging the CE transition, it leaves open which specific technologies, functions, or use cases are involved. In contrast, Franco (2017) and Rese et al. (2022) include firms from Germany as well as other regions. Rese’s study is limited to fashion product innovation, while Franco focuses on challenges related to circular products. As a result, the current state of research presents a fragmented and incomplete picture, insufficient for drawing clear conclusions about operational actions for the CE transition among the German T&C industry.

2.6.2 The Role of Digital Technologies

Compared to other sectors, the T&C industry seems to be characterised by a relatively low level of digitalisation (Orisadare et al., 2025; Schöggl et al., 2023). Furthermore, DTs play only a marginal role in most studies addressing the transition to sustainability and the CE within the sector. The majority of these are theoretical works, mostly literature reviews, that focus on individual technologies (e.g., Orisadare et al., 2025) or specific stages of the textile value chain (e.g., Glogar et al., 2025). Hassan et al. (2024) authored the only study to adopt a comprehensive perspective on DTs and circular practices in the T&C industry, based on a literature review. The empirical studies by Huynh (2022) and Gazzola et al. (2025) are both limited to fashion brands - Huynh (2022) explores circular business model case studies, while Gazzola et al. (2025) compare the implementation and benefits of a certain software tool across three cases. Other studies on the CE transition in the T&C sector - whether theoretical or empirical - do not place DTs at the center, although they are often acknowledged as important enablers and facilitators (e.g., Arnold et al., 2023; De Felice et al., 2025 or Elf et al., 2022). This section summarises the few sector-specific findings on the role of DTs and provides an overview of key technologies, functions, and applications. For the sake of clarity, the categorisation again follows the key issues – referred to as change dimensions - identified in Section 2.4.

Technology deployment related to product and design

DTs could enable a range of innovations in T&C-product design and development. A major contribution comes from digital fabrication technologies such as 3D technologies and digital twins, often embedded in CAD/CAM software systems (Glogar et al., 2025). These allow for the creation of virtual prototypes and samples and rapid modification thereby reducing the resources needed for physical samples and testing (Dissanayake & Weerasinghe, 2022; Hassan et al., 2024; Huynh, 2022). Digitally designed products could also be integrated into digitally enabled business models. For instance, consumers could use 3D body scanning technologies to generate avatars and try on digital twins of garments virtually before purchasing (Hassan et al., 2024). Virtual product development combined with apps and online platforms further allows for personalisation and flexible production, enabling customers to design or customise garments according to their preferences (Dissanayake & Weerasinghe, 2022; Hassan et al., 2024). Huynh (2022) refers to this as a pull-demand model, in which only what is needed is

produced, rather than relying on forecasts. Moreover, digital product development and the use of digital twins enable transparent information flows across the value chain, supporting data analytics and decision-making as well as improved end-of-life strategies such as reuse, and the efficiency of sorting and recycling processes (Dissanayake & Weerasinghe, 2022; Hassan et al., 2024).

Technology deployment related to organisation and business models

Within the T&C sector-specific literature on circular business model innovations mostly revolve around rental, resale, and repair services aimed at consumers, enabled and driven by online platforms, social media, and mobile apps (Abbate et al., 2023; Abdelmeguid et al., 2024a; Colucci & Vecchi, 2021; Huynh, 2022). Furthermore, technologies such as IoT, cloud computing, and blockchain, in combination with online platforms, enable applications and marketplaces for secondary raw materials or leftover fabrics (Gazzola et al., 2025) particularly in the B2B sector.

Technology deployment related to supply chain and production processes

Regarding sustainable and circular textile supply chains, studies highlight sector-specific challenges related to transparency and traceability. Given the high levels of globalisation and complexity in textile products and supply chains, transparency and traceability are even more critical than in other sectors - both to address social and environmental risks (see Section 1.2.3) (De Felice et al., 2025; Gazzola et al., 2025; Orisadare et al., 2025) and to enable and optimise reverse logistics (Franco, 2017; Hassan et al., 2024; Jia et al., 2020). The following technologies and their interactions are frequently discussed:

- IoT-based technologies such as sensors, tags, or barcodes to enable product and inventory tracking, take-back systems and the automated collection of product-related data (Abbate et al., 2023; Franco, 2017; Jia et al., 2020; Saccani et al., 2023),
- Blockchain solutions to facilitate secure, cross-supply chain traceability and the exchange of product and material-related data across value chain stages (Abbate et al., 2023; Alves et al., 2022; Huynh, 2022).

These technologies are also considered key enablers for implementing digital product passports (Hassan et al., 2024), as envisioned by the EU Strategy for Sustainable and Circular Textiles (European Commission, 2022b).

Huynh (2022) further highlights the emergence of digitally enabled communication and information flows among supply chain actors. Unlike conventional linear supply chains, where “designers and producers hardly have direct communication with consumers but mostly rely on long-term market forecasts, […] digitalisation fosters multi-actor, multi-dimensional, and integrative communication flows, placing the consumer at the centre and enabling real-time production”. As a result, digital information flows could be created alongside physical flows - connecting all actors with real-time data and contributing to the optimisation of circular systems.

As previously discussed in Section 2.6, DTs can potentially enhance operational efficiency in production processes - reducing waste, energy, and resource consumption. However, in empirical studies specific to the sector, cost reduction seems to be prioritised over CE-driven strategies (Alves et al., 2022; Arnold et al., 2023). Concerning CE-related aspects, technologies such as digital and 3D printing play an increasingly important role in textile production, finishing, and treatment, enabling not only substantial reductions in resource and chemical usage compared to traditional processes but also mass customisation, on-demand production, and the use of recycled materials (Colucci & Vecchi, 2021; Gazzola et al., 2025; Glogar et al., 2025; Hassan et al., 2024)

Summary

In summary, promising indications can be identified for the application of DTs across all change dimensions in the transition to sustainability and the CE in the T&C industry. Table 9 provides a structured overview of the key insights on DTs and their potential role in supporting the transition to sustainability and the CE derived from Sections 2.5 and 2.6.

Despite these insights, it must be noted that empirical studies on specific or standard use cases of DTs in connection with CE practices, their impacts, and the associated challenges remain limited. Moreover, existing studies largely focus on individual technologies, while the interconnectivity between technologies and the implications of their combined use are only marginally addressed. Consequently, sector-specific conclusions regarding actionable pathways for advancing the transition to sustainability and the CE supported by DTs can hardly be drawn. This underscores the need for further sector-specific research into specific technologies and functions in relation to the identified change dimensions.

Table 9

Digital technologies and their potential role for leveraging the transition to sustainability and the CE[2]

DTs	Potential role for advancing sustainability and circularity with use cases from the T&C Industry	Change dimension	References
Internet of Things (IoT)	• Enables physical objects to communicate with each other by using sensors and connecting them with digital applications and systems • Allows for real-time monitoring, tracking, and analysis of product use, condition, or location throughout the lifecycle to optimise process and resource efficiency and supporting new service-oriented business models • Can enhance traceability and identification of products or components, thereby enabling and improving sustainable and circular business models as well as automation and optimisation of collection, sorting, and recycling processes and providing data for a DPP	• Product/ Design • Organisation/ Business model • Supply Chain/ Production	(Bressanelli et al., 2022; Chauhan et al., 2022; De Felice et al., 2025; Dissanayake & Weerasinghe, 2022; Franco, 2017; Hassan et al., 2024; Lopes De Sousa Jabbour et al., 2022; Perotti et al., 2024; Ranta et al., 2021; Saccani et al., 2023)
Social media	• Provides new avenues to reach consumers in order to inform, and educate them about products, services, innovations and developments, to influence consumer behaviour regarding circular activities and involve them into co-creation processes.	• Organisation/ Business model	Abdelmeguid et al., 2024b; Antikainen et al., 2018; Chauhan et al., 2022; Colucci & Vecchi, 2021
Mobile Applications	• Offers diverse organisational opportunities to reduce resource consumption and enhance operational efficiency through monitoring & controlling applications, reducing employee travel activities or replacing paper-based processes by digital ones • Provide the opportunity to extend product lifecycles, for instance, through reselling platforms or to support new business models like rental, leasing or repairing.	• Organisation/ Business model • Supply Chain/ Production	Hassan et al. 2024; Huynh 2022; Wynn & Jones 2022a
Analytics/ Big Data	• Applications to analyse large and complex datasets, revealing patterns and relationships, fostering informed and data-driven decision-making and monitoring and controlling CE and sustainability-related KPIs. • Enables systematic analysis of data, such as inventory levels, customer activities, product returns, and consumer feedback - but also information regarding resource efficiency, waste generation, or emerging trends an integration and dissemination into management systems as well as supporting strategic and operational decision-making.	• Supply Chain/ Production	Alves et al., 2022; Han et al., 2023; Hassan et al., 2024; Kristoffersen et al., 2020; Laskurain-Iturbe et al., 2021; Lopes de Sousa Jabbour et al., 2018
Cloud computing	• Provides the basis for interconnected systems and thereby ensures data and information availability and transparency anytime and anywhere, which enables data-driven decision-making and new business model development. • Enables platforms for secure data storage and exchange between supply chain partners and other stakeholders and can contribute to reduced energy consumption and the reduction of physical goods in various locations	• Supply Chain/ Production	(Bressanelli et al., 2022; Cagno et al., 2021; Gazzola et al., 2025; Neri et al., 2023; Ranta et al., 2021)
Block-chain (BC)	• A distributed ledger database provides tamper-evident recording of transactional data and other information, thus enabling reliable, decentralised data exchange among partners and value chains • Offers various functions such as traceability of product and material data, recording and exchange of data between parties, and, within Smart Contract applications, efficient support for procurement management.	• Supply Chain/ Production	Abbate et al., 2023; Alves et al., 2022; Hassan et al., 2024; Huynh, 2022; Rusch et al., 2023; Upadhyay et al., 2021
Process automation & Robotics	• Are able to operate autonomously, to interact with each other and to cooperate with humans, e.g., in production or logistics processes • Could support circular strategies by leveraging AI systems to undertake autonomous waste sorting or disassembly processes	• Supply Chain/ Production	Cagno et al., 2021; Chauhan et al., 2022; De Felice et al., 2025; Dissanayake & Weerasinghe, 2022; Hassan et al., 2024; Lopes de Sousa Jabbour et al., 2018
Artificial Intelligence (AI)	• Is based on the development of machines and systems applying machine learning techniques and processing unstructured data such as natural language or images • Algorithms are used in a sustainability/CE context by helping with prediction, decision-making, resource optimisation and pattern recognition	• Product/ Desing • Supply Chain/ Production	Chauhan et al., 2022; De Felice et al., 2025; Dissanayake & Weerasinghe, 2022; Hassan et al., 2024; Laskurain-Iturbe et al., 2021; Neri et al., 2024; Perotti et al., 2024; Schöggl et al., 2023
Digital fabrication (DF)	• Refers to processes where computer-controlled modelling, simulation and control tools are used to manufacture physical objects directly from design data • Often supported by computer-aided design (CAD/CAM) tools, which can be directly transferred to manufacturing machines and systems such as automatic assembly systems, or 3D printers (i.e., additive manufacturing) • Additive manufacturing seems to be of particular importance for CE strategies, as it can reduce transportation, inventory, and material usage by producing prototypes, spare parts, or products on-demand and at the point of need, as well as implementing circular design strategies through the use of recycled materials in 3D printing • Digital twins—virtual representations of products or facilities—are also included under digital fabrication and allow for the simulation and optimisation of product properties or functions before physical production and providing stakeholders with information on ingredients, manufacturing, disassembly, or repair requirements throughout the product lifecycle	• Product / Design • Supply Chain/ Production	Bressanelli et al., 2022; Cagno et al., 2021; Colucci & Vecchi, 2021; Dissanayake & Weerasinghe, 2022; Han et al., 2023; Hassan et al., 2024; Huynh, 2022; Lopes De Sousa Jabbour et al., 2022; Neri et al., 2023; Schöggl et al., 2023

[2] This table was developed by the author and was also used in Wiegand & Wynn, 2024

2.7 Conceptual Models and Frameworks

While a strategic and structured approach has been identified as a key factor for the transition to sustainability and the CE (see Section 2.4.4), the absence of best practices and industry-related lighthouse projects, combined with uncertainty regarding potential benefits, seem to represent a barrier for companies to implement respective strategies (Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; McMahon et al., 2024; Sarja et al., 2021). As previously outlined, this transition extends beyond individual functions or departments. It represents a holistic change process that involves all corporate functions and demands extensive coordination with external stakeholders. Existing models and frameworks operationalising the transition of sustainability, the CE and digitalisation in companies are either focusing on isolated aspects - such as business model innovation (e.g., Chen et al., 2020) or circular product design (e.g., Aguiar & Jugend, 2022), or are too general to provide practical guidance for companies.

For instance Lopes de Sousa Jabbour et al. (2018), propose a five-step process, integrating the identification and implementation of Industry 4.0 technologies within the CE transition. In the first step, companies must make strategic decisions about changes to their business models, referring to the ReSOLVE framework (Ellen McArthur Foundation, 2015a), which outlines six areas of action for narrowing, slowing, and closing resource flows. The second step involves identifying relevant Industry 4.0 technologies that support these actions. The third step requires decisions on changes in product design, production, and logistics/reverse logistics. The fourth step emphasises integration with partners and stakeholders along the supply chain. Finally, the model calls for the definition of specific goals, metrics, and implementation measures.

While this roadmap provides an initial orientation and entry point for companies seeking to navigate the transition to sustainability, the CE and digitalisation, it does not offer actionable implementation measures nor address the organisational antecedents necessary for such a transition. Moreover, it considers only four technologies – IoT, cloud manufacturing, additive manufacturing and cyber-physical systems – and illustrates only broad use cases, whereas the previous section of this study identified a far broader range of technologies and related potentials. Thus, although this roadmap offers a rough initial guide, it lacks sufficient depth to support the change process itself - especially with regard to the organisational challenges discussed in Section 2.4.4.

By contrast, the model proposed by Graessler et al. (2024), which explicitly addresses organisational change within the CE transition, completely omits the aspect of digitalisation. Nevertheless, it offers a more holistic approach, structured into six iterative phases.

The first phase – initiate – is emphasised as particularly critical. According to the authors, this phase distinguishes the CE transition from other types of change, as it involves creating the necessary organisational conditions, such as awareness, knowledge, skills, and commitment to CE in a company. Following the initial stage, the process continues in phases that resemble the “PDCA” or “Deming cycle” (Deming, 1998) for continuous improvement. These phases emphasise evaluating the current state as well as developing and planning changes to business models, products, and processes. The implementation, evaluation, and adjustment phases emphasise agile and iterative approaches, quick solution development, stakeholder involvement, and performance evaluation based on triple bottom line criteria. Although this framework provides a more comprehensive structure for managing the transition process, it overlooks specific content-related recommendations as well as critical challenges and influencing factors related to the transition process.

Santa-Maria et al. (2021) present a Circular Business Model Innovation (CBMI) framework that does not follow a phase model. Instead, it highlights topics differentiating CBMI from conventional BMI initiatives thereby extending existing knowledge on business model innovation. However, it also stresses that the transition process is shaped by company-specific characteristics such as firm size, industry, and experience, making clear that a ‘one-size-fits-all’ approach is not feasible. Consequently, the authors call for sector-specific recommendations and practical solutions tailored to distinct challenges.

Sector-specific models for the T&C industry are scarce. Those available in academic literature can be grouped into two main categories:

The first group comprises models that address sustainability and the CE from a product perspective, focusing on product life cycles and related changes required to close textile flows (e.g., Brydges et al., 2023; Colucci & Vecchi, 2021; De Aguiar Hugo et al., 2021; Dissanayake & Weerasinghe, 2022). Moreover, Hassan et al. (2024) developed a literature-based framework linking DTs to circular practices along the textile product lifecycle.

While these perspectives are useful from a macro-level policy standpoint, they largely ignore the structure of the textile value chain, in which each stage is operated by independent companies producing diverse materials and products. As a result, such models offer limited guidance on the transition to sustainability, the CE and digitalisation for T&C companies.

The second group includes frameworks that address specific elements or aspects of the transition specifically related to T&C companies. Dan and Østergaard (2021) developed a framework outlining the skills, competencies, and tasks required by textile and fashion designers. Huynh (2022) proposed a classification of sector-specific digitised business models from the perspective of fashion and outdoor brands and retailers, and Elf et al. (2022) introduced a framework of sector specific dynamic capabilities required for the transition to sustainability and the CE. Franco (2017) focused on challenges faced by incumbent T&C companies related to the implementation of CE principles. Abdelmeguid et al. (2024b) were the only ones to develop a holistic framework for the transition to sustainability and the CE from an organisational perspective. By interviewing managers from fashion brands and recycling companies, they derived recommendations for actors along different value chain stages, without, however, directly including these actors into their study. Furthermore, while the integration of technologies is mentioned, it remains underdeveloped in their framework. the authors emphasised that future research should expand the sample size and diversity of participants and place greater emphasis on the role of technologies.

Overall, existing models remain fragmented and thematic rather than holistic and therefore do not provide a sufficient foundation for comprehensive practical guidance on the transition to sustainability, the CE and digitalisation for T&C companies.

2.8 Chapter Summary

In addressing RO1, the literature review critically examined how sustainability, the CE and digitalisation are interrelated and implemented in companies. It further assessed the current state of knowledge on the transition from a corporate perspective and explored potential sector-specific characteristics of the T&C industry. To ensure a structured and transparent approach, three research questions were formulated to guide the review:

a) What are the key issues and challenges in the implementation of sustainability and the CE in an organisational context,
b) What role do digital technologies play in this implementation?
c) What models and frameworks exist for the transition of organisations to sustainable and circular practices?

The literature review followed a semi-structured approach, combining a database search with subsequent snowballing. The findings reveal three key change dimensions as well as their interrelations and the related challenges associated with transitioning to sustainability, the CE and digitalisation:

- Product
- Supply chain and production processes
- Organisation and business model

Regarding the role of DTs in this transition, the nine technologies commonly subsumed under the SMAC and BRAID acronyms were found to be of particular relevance for the transition towards sustainability and the CE, as they support or enable related initiatives, with potential use cases illustrated in relation to the identified change dimensions (see Table 9).

Furthermore, the analysis revealed that existing conceptual and practical models aiming to operationalise the transition to sustainability, the circular economy, and digitalisation remain limited in scope. Many focus on isolated aspects such as product design, life-cycle thinking, business models, or organisational capabilities, while lacking an integrative organisational perspective and offering only descriptive insights rather than concrete guidance for companies. In addition, the role of DTs is often neglected or addressed only narrowly, despite their growing importance as enablers of circular practices.

Taken together, the findings indicate that existing frameworks do not adequately address the multi-level and systemic changes required for the transition to sustainability, the CE and digitalisation. They provide useful conceptual entry points but lack the depth, specificity, and integrative perspective required to serve as practical guidelines for T&C companies. The results therefore provide the basis for developing a provisional conceptual framework in the next chapter which builds the basis for further empirical research in the German T&C industry.

3 PROVISIONAL CONCEPTUAL FRAMEWORK

3.1 Introduction

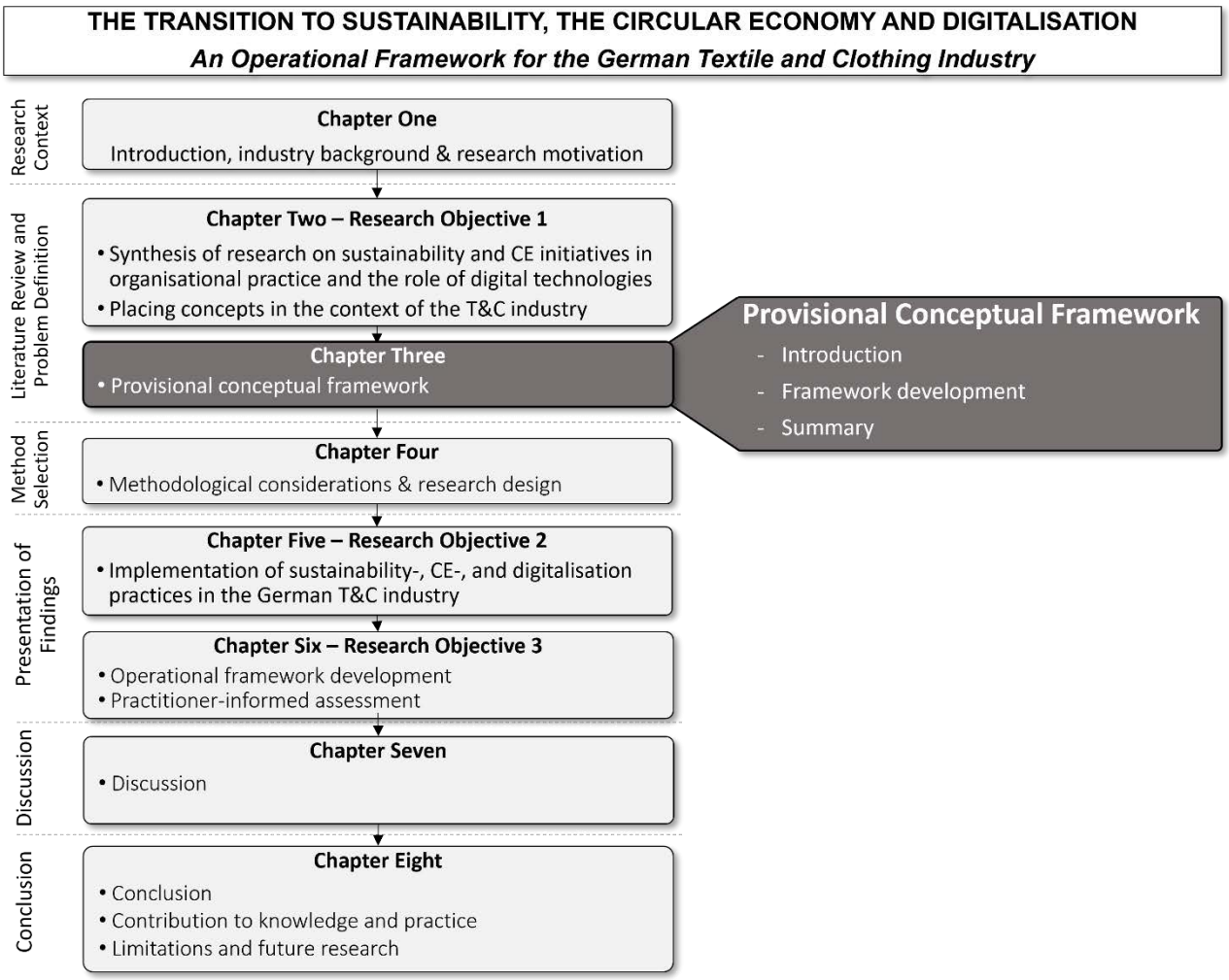
The literature review in the previous chapter aimed to understand the state of knowledge, the key issues and the role of DTs in the transition to sustainability and the CE from an organisational perspective. It has shown that this transition entails a range of changes across different organisational dimensions. Although several conceptual models and frameworks exist that address aspects of the transition, they remain fragmented and largely descriptive and are of limited practical use for companies. What is lacking is an integrative approach that captures the complexity of the transition and translates it into actionable guidance. To address this gap, the present chapter develops a provisional conceptual framework (PCF) that provides the basis for designing a coherent empirical study.

Concept development represents a central task within any research endeavour, as it addresses, in Gerring's (2001) words, "the most basic question of social science research: What are we talking about?" (p. 35). A conceptual framework can be understood as a network of interconnected concepts that collectively offer a structured overview of the phenomenon under investigation (Jabareen, 2009). It is often presented as a visual mapping of the research domain that serves as the foundation for subsequent analysis and model development (Leshem & Trafford, 2007). This study aims to examine the transition to sustainability, the CE and digitalisation in the German T&C industry from an organisational perspective. For this purpose, a clear understanding and classification of the core subjects of investigation are indispensable. A conceptual framework "explains, either graphically or in narrative form, the main things to be studied" (Miles et al., 2020, p. 15) – in other words, it provides a structure to articulate the key ideas, concepts, assumptions, or theories, as well as the relationships between them. The purpose of such conceptual clarity, however, is not only to shed light on the nature of the phenomenon under study, but more importantly, to assess and refine the initially defined research objectives or research questions, and select appropriate methods for investigation (Podsakoff et al., 2016).

This study is based on the broad theoretical field of organisational change, which comprises three dimensions: context, referring to the internal and external factors that trigger and shape change; content, denoting the specific areas and issues subject to change; and process, describing how change is implemented over time (Pettigrew,

1987). The PCF adapts this model to the transition to sustainability, the CE and digitalisation, illustrating its key elements and their dynamic interactions. Following this introduction, the rest of the chapter is structured as follows. In Section 3.2 the PCF is developed and described based on the findings from the literature review. In Section 3.3. a short summary is provided and the ROs 2 and 3 are evaluated and guiding questions for the empirical study are derived (Figure 16).

Figure 16
Structure of Chapter Three in context of the thesis



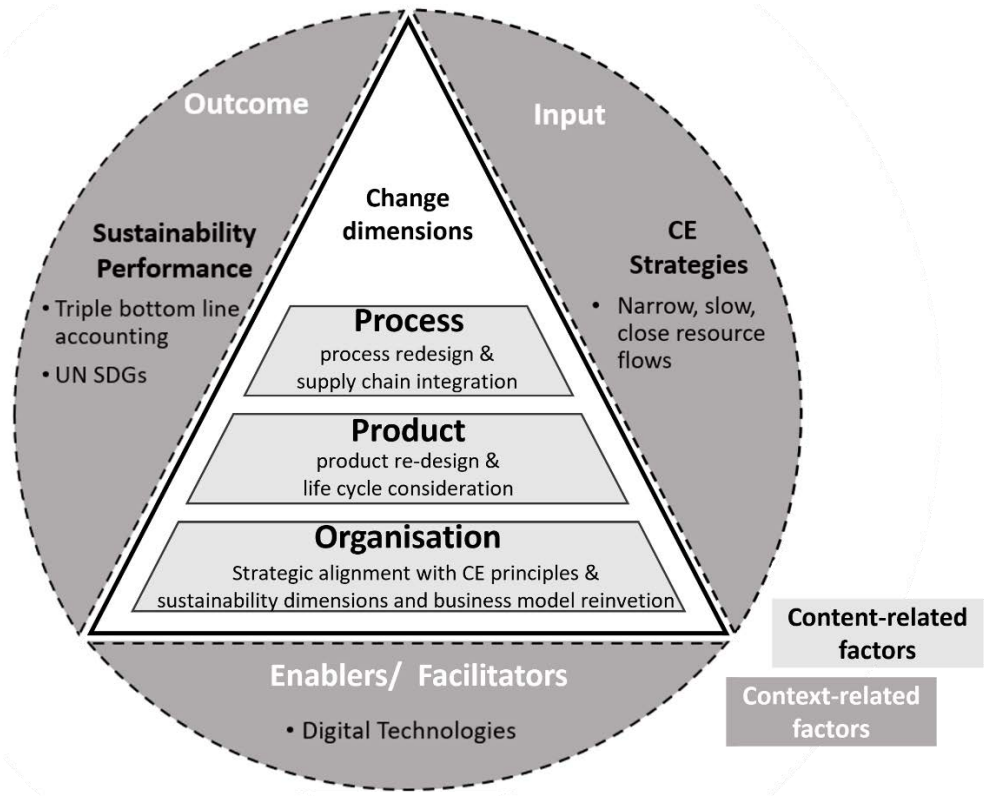
3.2 Framework Development

The literature review revealed three core context-related factors that shape an organisation's transition to sustainability, the CE and digitalisation. Firstly, the UN SDGs (United Nations, 2015) and the principle of triple bottom line accounting (Elkington, 1998) as the overarching goals and concepts of corporate sustainability.

Secondly, the guiding strategies of the CE, narrowing, slowing and closing resource flows (Bocken et al., 2016) and thirdly, the potential of nine SMAC and BRAID technologies that enable and drive organisational change. Building on these contextual factors, three organisational dimensions have been identified as requiring active change activities: the organisation incl. the business model, the products, and the associated supply chain and production processes. However, research on the integration of sustainability, the CE and digitalisation at the organisational level remains at an early stage. Although a number of frameworks and models address specific aspects of change, such as business model innovation, a comprehensive framework that integrates all relevant dimensions and provides clear guidelines for the T&C industry is still lacking.

The PCF therefore provides the foundation for investigating the status of the transition to sustainability, the CE and digitalisation in the German T&C industry. The goal is to derive practical recommendations on how context factors and change dimensions can be further developed into viable operations and practices (Figure 17). The individual components of the PCF and their assumed dynamic interactions are explained in the following subsections.

Figure 17
Provisional conceptual framework



3.2.1 Context-Related Factors

Outcome

Sustainability is commonly defined as development that “meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987, p. 24). This understanding forms the foundation for the UN SDGs (United Nations, 2015), which set clear objectives and indicators for sustainable global development. In recent years, sustainability has gained prominence in international policy and, consequently, also in corporate context. Building on Elkington’s (1998) triple bottom line it is increasingly recognised that enduring corporate success necessitates not only economic viability but also the systematic consideration and measurement of environmental and social impacts. The economic dimension relates to ensuring a company’s competitiveness and the associated value creation. The environmental dimension focuses on how a company impacts and interacts with natural resources and ecosystems, with the overarching goal of preserving them over the long term. The social dimension aims to enhance human well-being, foster social relations, and promote social justice, all of which should be supported and improved through business activities (Elkington, 1998). Accordingly, the simultaneous economic, ecological, and social viability along with the UN SDGs, are considered a key outcome of corporate activity - one that must be pursued through appropriate strategies and practices.

Input

Within the broader concept of sustainability, the CE is recognised as a central lever for the transition to a more sustainable industrial system. It is gaining growing relevance in both academic research and corporate practice, as it offers principles and approaches for operationalising sustainability goals within organisations. At its core, the CE describes an economic system that balances economic development with environmental and resource protection. According to the Ellen MacArthur Foundation, the CE is defined as a system that is inherently restorative and regenerative, aiming to keep products, components, and materials circulating at their highest utility and value for as long as possible (Ellen McArthur Foundation, 2015a). This calls for stronger emphasis on reduction, reuse, recycling, and recovery of materials. The literature review identified three primary strategies for CE implementation.

These are: narrowing (reducing resource consumption and increasing efficiency), slowing (extending product and component lifespans through reusing, repairing or remanufacturing), and closing (creating closed material loops through recycling and energy recovery) resource flows (Bocken et al., 2016). These strategies aim to preserve the value of resources, materials, and products for as long as possible. In this PCF, CE strategies are therefore understood as input-oriented contextual factors that provide direction for corporate action, with the aim of achieving the overarching objectives of sustainable development.

Enablers/ Facilitators

Digital technologies have been identified as essential enablers and facilitators for companies in the implementation of sustainable and circular practices, as well as in achieving sustainable business performance. As such, they represent the third domain of contextual factors in the PCF. DTs can be defined as electronic tools, automated systems, and technological devices that allow for the processing, transmission, and storage of large volumes of data (Wynn & Jones, 2022a). The literature review revealed a wide range of technologies and potential use cases that can be leveraged to improve the resource efficiency of products and processes or to enable circular business models. However, research in this area remains highly fragmented. Existing studies tend to focus either on individual technologies or on specific CE practices, while a comprehensive and practice-oriented overview is largely missing. Moreover, there are notable sector-specific differences in how DTs are approached, with the T&C industry having received relatively little attention so far. This points to the need for more sector-specific research that examines how DTs can be applied effectively in practice and which implementation approaches are most conducive to supporting the sustainable and circular transition.

3.2.2 Content-Related Factors

The transition to sustainability and the CE affects multiple system levels and actors, all of which interact and must be addressed holistically (see Section 2.3). The starting point for this transition lies at the micro-level - that is, the level of individual actors such as businesses, consumers, and governmental institutions - whose actions shape and drive the transition process. Among these actors, companies hold central position, as they typically use resources to create value. In doing so, they make key decisions

about the type, quantity, and handling of materials, must comply with legal regulations, and align their value propositions with market needs. For this reason, businesses form the core of the PCF developed in this study and represent the primary unit of analysis. Achieving alignment with sustainability goals and implementing CE strategies and practices requires a multidimensional approach encompassing three core change dimensions. Firstly, at the organisational level, the strategic, cultural, and structural conditions that support alignment with sustainability dimensions and CE principles must be established. A core element in this process is the evaluation and, where necessary, the reconfiguration of the business model. A business model is commonly defined as “the design or architecture of the value creation, delivery and capture mechanisms employed” (Teece, 2010, p. 191). Sustainable and circular business models are those designed to create, deliver and capture value in such a way that they generate long-term profits for a company, while at the same time narrowing, slowing, and closing resource flows and avoiding negative impacts on stakeholders, including the natural environment (Bocken et al., 2014; Pieroni et al., 2020; Ritala et al., 2018). This is directly linked to the second dimension, which is a company's products and services. The CE principles must be embedded from the very beginning of product and service development - in particular, product design should aim to avoid waste and resource depletion as well as any negative impact on people and the natural environment throughout the entire product life cycle (Aguiar & Jugend, 2022; Bocken et al., 2016; Den Hollander et al., 2017). Thirdly, business model innovation and product re-design are closely linked to process re-design. This includes not only internal operations - ranging from procurement to production and distribution - but also the integration of forward and reverse flows through supply networks, in order to retain products and materials within the economic system (Farooque et al., 2019; Geissdoerfer, Morioka, et al., 2018; Montag, 2023).

3.3 Summary

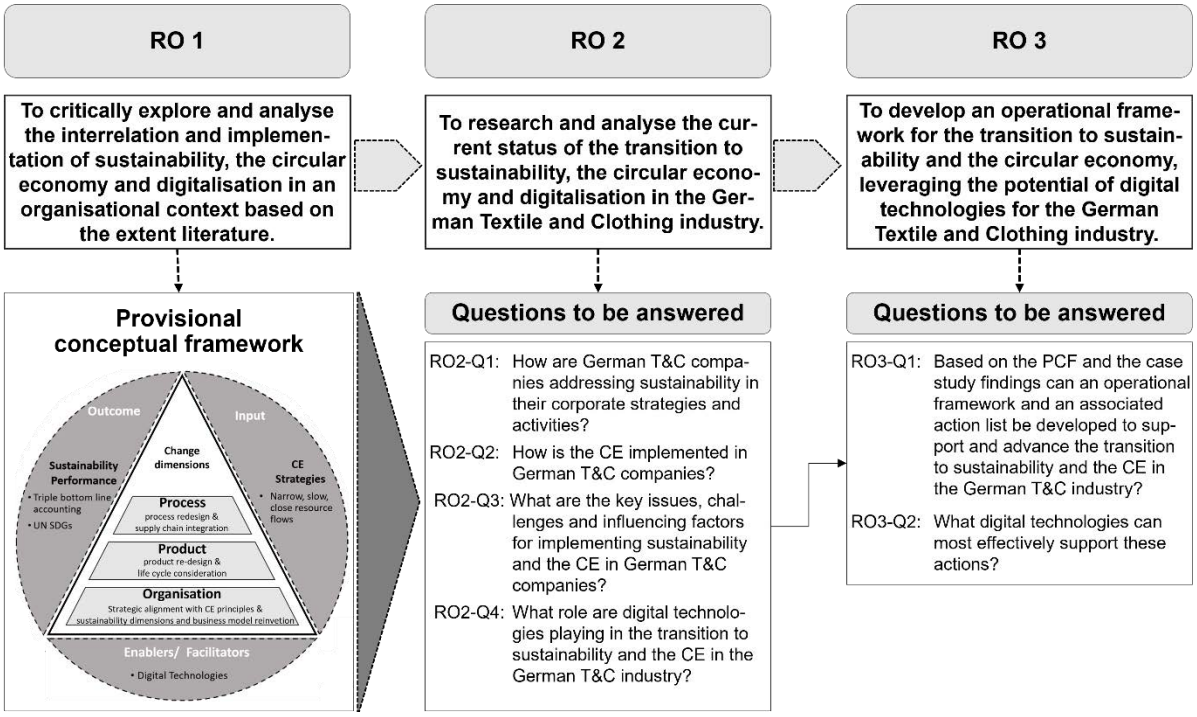
In this chapter, a PCF was developed to explore the CE transition within companies operating in the T&C industry. In line with the understanding previously outlined - that companies are central actors in the CE transition - and drawing on Pettigrew’s dimen-

sions of strategic change, the PCF incorporates two core dimensions: contextual factors, which drive, guide, and shape corporate activities and actions, and content-related factors, which represent the corporate change dimensions.

DTs appear to be important enablers of this transition. At the same time, there is still limited understanding of how sustainability, CE strategies, and DTs are integrated in practice in the German T&C industry, and of the challenges and benefits associated with this process. Although recent research has increasingly examined the implementation of specific CE strategies across different sectors, the T&C industry remains comparatively underexplored, particularly with regard to digitalisation. This points to a clear need for empirical research. The developed PCF addresses RO1 and provides the researcher with a structure for addressing ROs 2 and 3. Thus, the PCF builds the basis for empirically analysing the individual change dimensions and the state of adaptation to the contextual factors of sustainability, the CE and digitalisation (see Figure 18). To ensure a structured approach in addressing RO2 and RO3 and to define an appropriate research design, the author considered it useful to derive specific questions from the research objectives to be addressed based on empirical data. The research methodology and design applied for the collection and analysis of the respective data are explained in detail the next chapter.

Figure 18

Mapping of research objectives, provisional conceptual framework and guiding questions for the empirical study

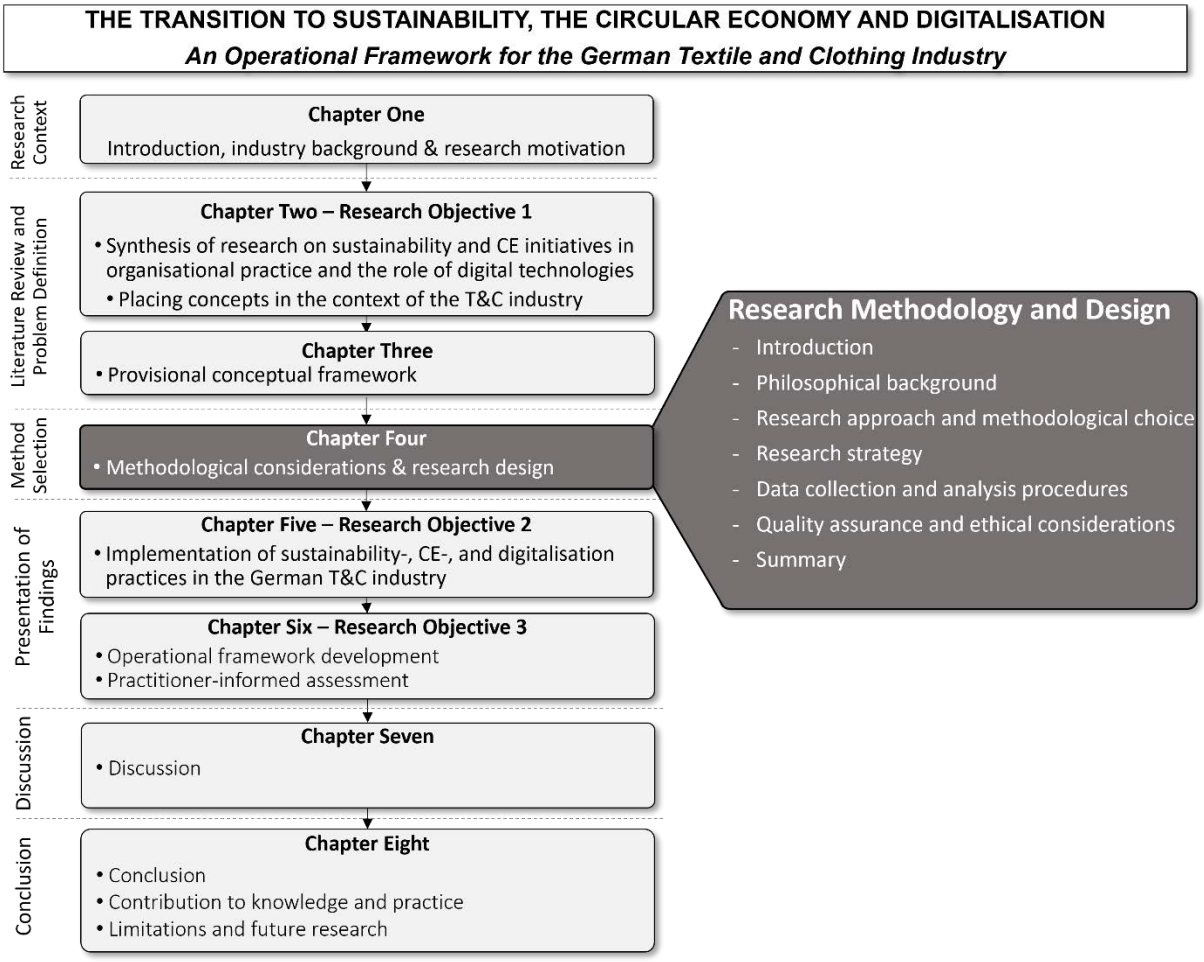


4 RESEARCH METHODOLOGY AND DESIGN

4.1 Introduction

Research is generally understood as a multi-stage process comprising several phases that must be navigated. In the previous chapters, the research topic was introduced, the existing literature reviewed and based on the findings, a PCF was developed. This also led to the formulation of detailed questions for further empirical investigation. This chapter now discusses the research methodology selected to gather data and to answer the questions. As de Vaus (2009) notes, the purpose of a research design is “to ensure that the evidence obtained enables us to answer the initial questions as unambiguously as possible” (p. 9). Designing a research study requires several key decisions about how evidence - that is, relevant data - will be collected, analysed, and interpreted. These decisions, in turn, are made by researchers based on their underlying “basic set of beliefs that guides action” (Guba, 1990, p. 17). Therefore, this chapter is structured as follows (see Figure 19).

Figure 19
Structure of Chapter Four in context of the thesis



In Section 4.2, the philosophical assumptions underpinning this study are outlined and situated within a broader philosophical context. Section 4.3 justifies the chosen research approach, while Section 4.4 details and justifies the selected research strategy as well as the methods deployed for data collection. In Section 4.5 the methods and techniques for data collection and analysis are introduced. Section 4.6 presents the measures taken to ensure the quality and ethical integrity of this research. Finally, Section 4.7 provides a summary of the overall research methodology applied in this study.

4.2 Philosophical Background of the Study

Research aims to create knowledge. However, neither within business and management studies nor within the broader social sciences is there consensus on how knowledge is generated or which forms of knowledge can be considered ‘legitimate’. Instead, multiple approaches to knowledge generation coexist, each grounded in distinct research philosophical assumptions – that is, philosophical positions concerning how research problems are defined, what kind of knowledge is sought, and which epistemic approaches are considered appropriate (Evald et al., 2018; Holzer et al., 2012).

A comprehensive review of all research philosophical perspectives would exceed the scope of this study and is not required for its research interest. Accordingly, the aim of this section is not to provide an exhaustive overview of research philosophy, but to make the assumptions underlying this research explicit and to situate them within the relevant paradigmatic discourse. In the subsequent sections, the decisions made for the research approach, research design, and methods will be justified.

The concept of a research paradigm is not used consistently in the literature on research philosophy in business and management studies. Alongside the notion of paradigms, related concepts such as schools of thought (Easterby-Smith, 2021) or research traditions (Neuman, 2014) are employed to address overlapping issues. What these concepts share is their focus on fundamental assumptions about the nature of reality, the generation of knowledge, and the role of values in the research process, thereby framing scientific inquiry (Saunders et al., 2023).

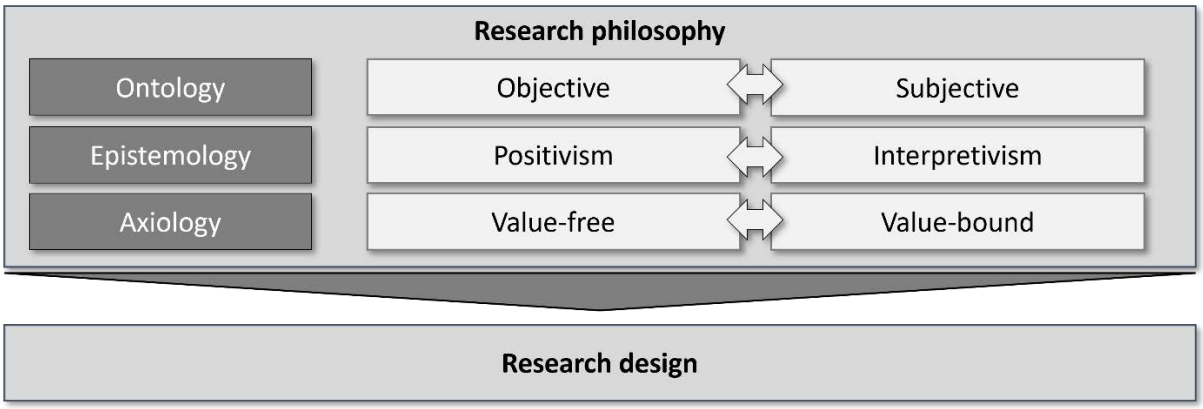
In this study, the term paradigm is used in line with Guba and Lincoln (1994) and further developed by Saunders et al. (2023). Accordingly, a paradigm refers to a set of ontological, epistemological, and axiological assumptions that guide a research project.

Together, these assumptions influence how the research object is conceptualised, what types of knowledge are considered valid, and how the role of the researcher is understood within the research process.

Ontological assumptions concern fundamental views about the nature of reality and what is regarded as existing (Neuman, 2014; Saunders et al., 2023). Epistemological assumptions address how knowledge about this reality can be generated and what is considered valid knowledge (Neuman, 2014; Saunders et al., 2023). Axiological assumptions, in turn, relate to the role of values in the research process, including how researchers position themselves in relation to the object of inquiry and the extent to which personal beliefs and experiences shape knowledge production (Saunders et al., 2023).

Figure 20 summarises these dimensions and illustrates the continua along which different positions may be located. The following sections briefly outline each dimension and explicitly articulate the philosophical assumptions on which this study is based. This structured reflection clarifies the study's underlying knowledge interest and provides a transparent foundation for the subsequent methodological decisions.

Figure 20
Core elements of research philosophy and their continua



Source: The author based on Döring, 2023 and Saunders et al., 2023

Ontological Assumptions

Ontological positions are commonly situated along a continuum between objectivist and subjectivist perspectives (Easterby-Smith, 2021; Saunders et al., 2023). Objectivist approaches assume the existence of a reality independent of human actors, whereas subjectivist positions emphasise that reality - particularly social reality - is fundamentally shaped by human perception, interpretation, and interaction (Neuman, 2014; Saunders et al., 2023).

This study is grounded in a two-level ontological assumption. On the one hand, the existence of an objective, naturalistic reality independent of human perception, such as climate change or resource scarcity, is acknowledged. Natural resources and ecological systems exist regardless of how individuals or organisations perceive or evaluate them. This level of reality constitutes the structural framework within which human life and action take place. At the same time, humans are understood as thinking beings who are aware of their own thinking. Knowledge concerning reality is therefore acquired through perception, from which anticipatory assumptions about actions and their consequences are developed, which subsequently shape the world through human action (von Glasersfeld, 2018). In the context of organisational research, Hejl (2006) raises the question of whether organisations adapt to the world as it objectively exists or to their perception of that world, concluding that active adaptation can only occur in relation to what is perceived - that is, to an environment that organisations construct as their own and realise through action. Based on these assumptions, social, organisational, and economic phenomena are not understood as given, but as constructed through human and organisational perception, interpretation, and action. Concepts such as sustainability, the CE and digitalisation do not have fixed or objectively determined meanings; instead, their relevance and specific forms emerge through the interpretations, decisions, and practices of organisational actors. Organisations therefore do not respond directly to an objective reality, but to their perceived and interpreted environments, which in turn guide organisational action.

In this study, the socially constructed level of reality is of primary relevance. Accordingly, the analysis does not focus on the ontic properties of natural reality, but on organisations' interpretations and actions. Accordingly, the ontological assumptions of the study are deliberately differentiated: while the existence of a reality independent of human actors is acknowledged, the research focus is placed on constructed realities

that are decisive for organisational decision-making, strategic action and change processes.

This forms the basis for the epistemological reflection: If organisational reality is not directly accessible, the question arises as to how knowledge about these realities can be generated and which epistemological approaches are appropriate.

Epistemological Assumptions

Epistemological positions are closely linked to ontological assumptions, as different conceptions of reality imply different approaches to knowledge generation (Easterby-Smith, 2021). An objectivist ontology typically aligns with a positivist epistemology, which assumes that the social world exists externally and that knowledge about its reality can be obtained through objective methods of observation and measurement (Easterby-Smith, 2021; Saunders et al., 2023). Neuman (2014) characterises positivist social research as the transfer of natural sciences approaches to the social sciences. Such an approach is particularly suitable where stable, causal relationships are to be identified, and generalisable statements are sought (Easterby-Smith, 2021).

A subjectivist ontological position, by contrast, implies an interpretive approach to social research (Burrell & Morgan, 2016). Neuman (2014) explicitly employs the German concept of “Verstehen”, referring to the understanding of lived experiences (p.103). From this perspective, knowledge is not discovered but constructed through perception, interpretation, and interaction. Knowledge is therefore not independent of the knowing subject, but context-dependent, situational, and processual (Neuman, 2014; Saunders et al., 2023). This perspective requires understanding rather than explanation and does not seek to produce objective or universally valid knowledge (Bell et al., 2019).

Against the background of the ontological assumptions outlined above - acknowledging a naturalistic reality independent of human actors while focusing on socially constructed organisational realities - different epistemological approaches are conceivable. A strictly positivist research interest could be applied to questions concerning causal relationships between organisational actions and, for example, ecological impacts. However, such an approach would provide limited insight into how organisational actors perceive sustainability, the CE and digitalisation and translate these perceptions into action.

Therefore, for the purposes of this study, an interpretive epistemological position is more appropriate. From this perspective, individuals and organisations make sense of their environment by interpreting experiences, attributing meanings, and acting upon these interpretations. Knowledge is understood as provisional and subject to ongoing revision (Neuman, 2014); interpretations and perceptions are enacted through organisational action and adjusted in light of new experiences arising from that action (Hejl, 2006). Knowledge thus emerges in a continuous process of interpretation, action, and re-interpretation.

Accordingly, this study does not seek a single “correct” description of organisational reality, but rather aims to reconstruct and understand how companies make sense of and shape the transition to sustainability - particularly to CE practices - and digitalisation. This perspective highlights the need to examine how companies adapt their organisations, business models, products, and operations. It also considers how and why DTs are integrated into these practices and what barriers or challenges are perceived. A meaningful understanding of these developments requires a contextualised analysis that takes into account the complex interplay of factors influencing corporate action.

Axiological Assumptions

Axiological assumptions address the role of values in the research process and the researcher’s position in relation to the object of inquiry. Different axiological positions correspond to different epistemological orientations. Positivist research approaches typically aspire to value neutrality, with researchers positioning themselves as detached observers who seek to minimise the influence of personal beliefs, normative orientations, and subjective biases in order to produce objective and generalisable knowledge (Saunders et al., 2023). From this perspective, researchers’ values should neither affect data collection nor the interpretation of findings (Döring, 2023).

Interpretive research approaches, by contrast, are associated with a value-bound position, recognising that research is inevitably shaped by normative orientations, experiences, and assumptions (Döring, 2023; Saunders et al., 2023). Given that knowledge is understood as constructed and context-dependent, a strict separation between researcher and research object is considered neither possible nor desirable (Neuman, 2014). Values and experiences are therefore not denied but reflected upon and made

transparent as integral components of the knowledge production process (Saunders et al., 2023).

In line with the ontological and epistemological assumptions of this study, a value-bounded axiological position is adopted. The research is guided by a normative interest in sustainability and the CE, and responsible organisational adaptation. These value orientations motivate the analysis of how organisations perceive the opportunities and challenges related to sustainability, the CE, and digitalisation, interpret them, and translate them into organisational practices. At the same time, the study follows a reflexive approach to value involvement. The author's professional experience in the German T&C industry provides in-depth contextual understanding of the research field, while also requiring continuous self-reflection to critically examine implicit assumptions. Rather than claiming value neutrality, the study therefore seeks transparency regarding the role of values and prior experience in the research process, without predetermining interpretations or outcomes.

In summary, this study adopted a research philosophical position that conceptualises organisational realities as socially constructed, generates knowledge through interpretive inquiry, and evaluates its epistemic value through organisational practice. The study does not seek to identify universally valid laws, but to develop a context-sensitive understanding of organisational practices in relation to sustainability, the CE and digitalisation. Knowledge is understood as provisional, and its relevance derives from its practical applicability. This research philosophical position provides the foundation for the research approach, methodological choices and strategy outlined in the next section.

The ontological, epistemological, and axiological assumptions underlying this study are briefly summarised and justified in Table 10.

Table 10
Philosophical assumptions underlying the study

Element	Assumptions for this research	Justification for this research
Ontology *What is the nature of reality?*	**Differentiated ontology** • A naturalistic objective reality exists independently of human perception • Organisational and social realities are socially constructed	• The study acknowledges the existence of a material, naturalistic reality (e.g. climate change, resource scarcity) that forms the structural context for organisational action • At the same time, organisational realities are understood as constructed through perception and action • The transition to sustainability, the CE and digitalisation does not have a fixed or objective meaning, but is shaped by how organisations interpret related concepts, chances and challenges and translate them into practice
Epistemology *How can knowledge be obtained?*	**Interpretivist epistemology** • Knowledge is generated through interpretation and understanding of organisational practices	• Given the focus on socially constructed organisational realities, knowledge cannot be obtained through observation and measurement, but requires interpretive engagement with organisations • Knowledge is generated by reconstructing how organisations perceive, interpret, and respond to their perception of sustainability, the CE and digitalisation • This approach enables an in-depth understanding of organisational practices • Different interpretations and solutions for implementing sustainability and CE practices supported by digital technologies may coexist, provided they prove viable in practice • Therefore, knowledge is understood as provisional and subject to revision as interpretations and practices evolve over time
Axiology *What is the relationship between the researcher and the subject?*	**Value-bounded** • The relationship between researcher and research subject is recognised and reflexively addressed	• The study is guided by a normative interest in sustainability and the CE, and responsible organisational adaptation • The researcher's professional experience in the German T&C industry provides contextual understanding and practical insights into the research field • This experience enhances the relevance and depth of the analysis, particularly with regard to organisational practices and constraints • At the same time, the researcher acknowledges the risk of bias associated with a value-bound position and addresses this through reflexivity, transparency, and critical self-reflection throughout the research process.

4.3 Research Approach and Methodological Choice

Building on the research philosophical foundations outlined in the previous section, this section presents the research approach and methodological decisions adopted to examine the transition to sustainability, the CE and digitalisation in the German T&C industry. The main aim of this research is to develop a deep understanding of how companies in the German T&C industry shape the transition to sustainability and the CE, the role DTs play in this process, and the practice-related insights that can be derived

from it. The focus is not on explaining causal relationships, but on understanding organisational perceptions, and practices within a complex and dynamic environment.

Against the study's interpretivist epistemological position, knowledge is understood as socially constructed, context-dependent, and evolving. Accordingly, the research approach sought to reconstruct the meanings and practices enacted by organisations. The study, therefore, follows an interpretive logic oriented towards understanding (Verstehen in the sense of Neuman, 2014), rather than hypothesis testing or statistical generalisation.

Methodologically, empirical research approaches can be broadly distinguished by different logics of reasoning, most notably deductive, inductive, and abductive (Reichertz, 2014). Deduction involves testing pre-existing theories to confirm or reject specific hypotheses. This approach applies general assumptions to specific observations to assess the validity of the overarching theory (Brühl, 2021; Saunders et al., 2023). In contrast, induction moves from the observation of individual cases to form general theoretical statements (Brühl, 2021; Saunders et al., 2023). Abduction combines both approaches. It begins with incomplete observations and generates plausible hypotheses that explain limited information, which are then subject to further investigation (Van Maanen et al., 2007).

The choice of a primarily inductive research approach followed directly from the interpretivist epistemological position outlined above. As organisational change processes are understood as socially constructed and knowledge about these realities is accessible through interpretation and interaction, the research interest requires an open and exploratory approach. As discussed in Chapter Two, the fragmented state of existing research on the transition to sustainability and on CE and digitalisation in T&C companies further reinforces the appropriateness of an inductive approach.

An inductive research design enabled the researcher to capture organisational practices from the companies' perspectives. The study did not seek to identify universally valid laws, but to generate insights that can be evidenced and transferred to organisational practice.

Alternative methodological approaches were deliberately not adopted. Although a deductive design could enable the identification of causal relationships between individual variables - such as the pursuit of certain practices and a company's sustainability

performance - it is not suitable for understanding organisational action. The focus was instead on gaining insights into individual practices and perceived challenges and influencing factors related to sustainability, the CE and digitalisation in the German T&C industry. To achieve this, an appropriate research strategy was selected for the study, as outlined in the next section.

4.4 Research Strategy

Building on the interpretive and inductive research approach outlined in the previous section, this section describes the research strategy and methodological choices adopted in this study. The objective was to develop an understanding of how German T&C companies perceive and shape the transition to sustainability and the CE and how DTs are integrated into this process. Given the focus on organisational practices in a complex and still underexplored field, a qualitative research design was considered appropriate. The following sections outline the case study strategy, data collection procedures, and analytical approach applied to this study.

4.4.1 Case Study Design

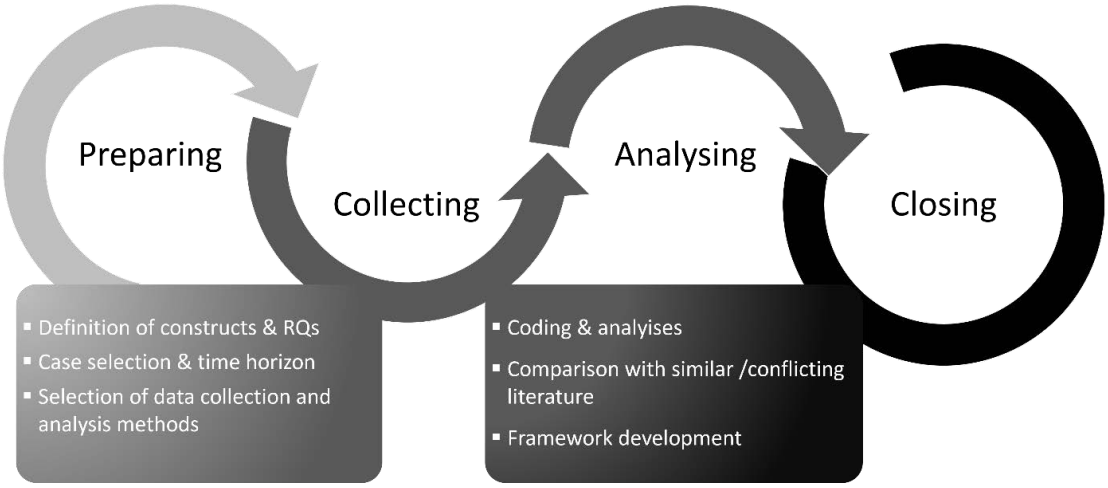
This study adopted a qualitative case study design. The case study approach represents a well-established scientific research strategy and must be distinguished from its use as illustrative practice examples or teaching cases (Borchardt & Göthlich, 2009; Gummesson, 2017). As a research strategy, case studies enable in-depth investigation of complex phenomena in their real-life context and are particularly well-suited to examining dynamic processes, interdependencies, and actor perspectives through multiple data sources (Eisenhardt, 1989; Eisenhardt & Graebner, 2007; Gummesson, 2017; Yin, 2018).

In line with this study's interpretive and inductive orientation, the case study approach is particularly appropriate, as it allows for the exploration of 'how' and 'what' questions - both of which are central to this study (see Figure 18) (Yin, 2018). Rather than isolating variables or testing predefined hypotheses, the case study approach allows for the reconstruction of meanings, practices, and decision-making processes as they unfold within a specific contextual setting (Eisenhardt, 1989; Eisenhardt & Graebner, 2007).

The methodological literature offers different procedural models for conducting case study research, which vary primarily in their underlying philosophical orientations. Yin

(2018) proposes a deductive approach in which prior theory plays a central role in guiding data collection and analysis, reflecting a more deductive and positivist orientation. In contrast, Eisenhardt (1989) and Gummesson (2017) advocate an inductive, qualitative approach to case study research in which theoretical insights emerge through systematic engagement with empirical material. Hence, a qualitative case study design was adopted for developing an in-depth understanding of organisational practices, challenges and influencing factors in the transition to sustainability and the CE and the role of DTs in shaping these practices in the German T&C industry. The methodology for this study therefore followed the case study approach outlined by Eisenhardt (1989), which is illustrated in Figure 21 and subsequently discussed in detail with reference to the specific research topic and objectives guiding this study. Having already established the link between the PCF and the resulting research questions in this section; the next section outlines the approach for case selection.

Figure 21
Overview of the case study research process



Source: The author based on Eisenhardt, 1989

4.4.2 Case Selection

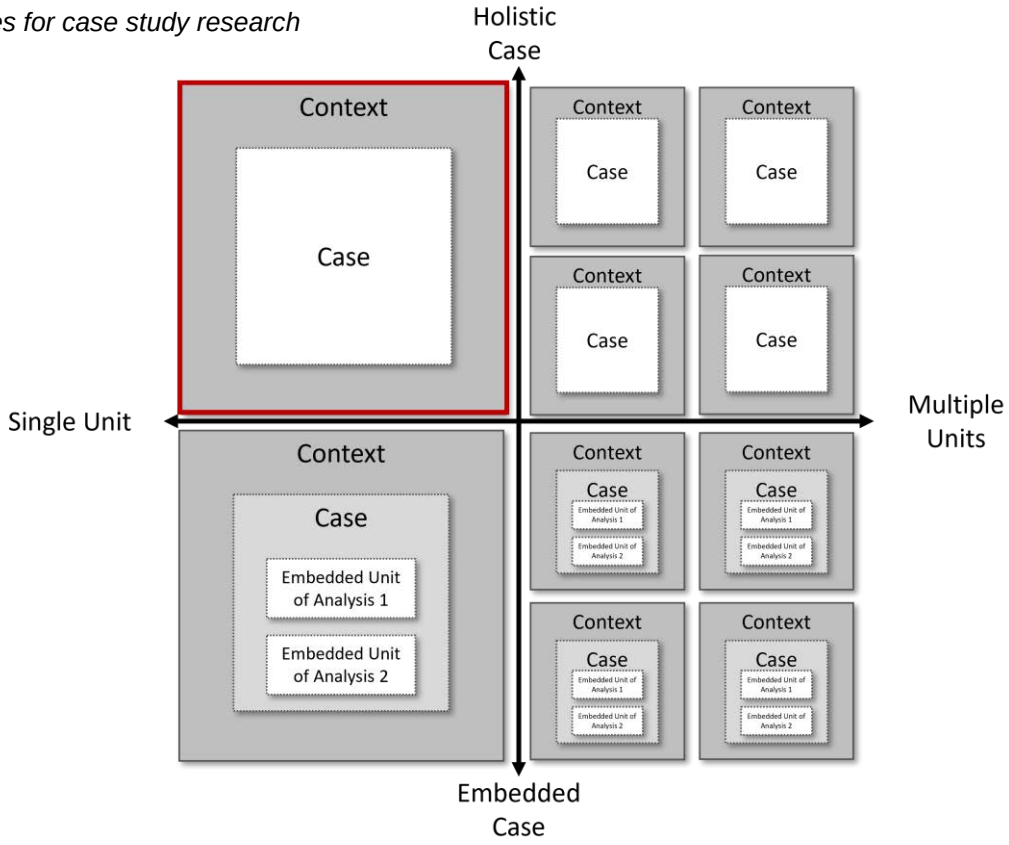
Case study research requires the strategic selection and clear conceptualisation of the case and its unit of analysis (Saunders et al., 2023; Yin, 2018).

Case studies may be designed as single or multiple cases and may follow holistic or embedded designs, depending on whether one or multiple units of analysis are examined within a case (Yin, 2018). These dimensions give rise to four basic design strategies (Figure 22). A single case study is typically selected when the case is considered

critical, unique, or representative of a broader phenomenon. In contrast, a multiple case study design is chosen to allow for replication logic and to provide a stronger empirical foundation by comparing findings across different cases.

This study adopted a single, holistic case study design, in which the German T&C industry constitutes the case and the primary unit of analysis. Sustainability, the CE and digitalisation form the thematic context within which this case is examined. This design choice reflects the overarching research aim of understanding how the German T&C industry as a whole responds to the changing regulatory, technological, and societal environment through organisational practices, rather than providing detailed firm-level analyses.

Figure 22
Basic strategies for case study research



Source: Adapted from Yin 2018, p. 46

The German T&C industry was selected as a single case due to its significant social, environmental, and economic relevance, as outlined in the introduction to this study. The sector is associated with substantial environmental impacts resulting from linear production and consumption patterns and has been identified as a priority sector under

both the European Circular Economy Action Plan and the German National Circular Economy Strategy (BMUV, 2024; European Commission, 2020a).

Moreover, Germany holds a central position in the European T&C sector, being the second-largest producer in the EU (Eurostat, 2023). Owing to this position, Germany is frequently described as a “key player and changemaker” in the pursuit of sustainability and circularity in the sector (Gözet & Wilts, 2022, p. 9).

Investigating the German T&C industry as a holistic case study requires including multiple organisations, as the industry itself does not exist as an immediately observable or unified actor. Rather, it is constituted through the practices and interactions of the companies and actors operating within it. Access to the industry and its dynamics is therefore only possible through empirical engagement with individual organisations. For this reason, empirical data are collected from multiple companies. These companies, however, are not conceptualised as individual cases, but serve as empirical points of access to the broader, industry-level perceptions and practices that constitute the focus of the analysis. This distinction is central to the research design. The objective is not to compare firms or to derive firm-specific success factors, but to identify dominant patterns, shared interpretations and practices, as well as overarching challenges and influencing factors that shape the industry’s transition to sustainability and the CE, including the role attributed to DTs in this process. Consequently, the study does not aim to produce causal explanations or best-practice rankings at the firm level. Rather, the study seeks to provide a contextualised snapshot of prevailing strategies, practices, and perceptions at a particular point in time.

The next step involved determining an appropriate time horizon for conducting the case study research. A brief overview of possible approaches and the rationale for the time horizon chosen in this study will be presented in the following section.

4.4.3 Time Horizon

According to Saunders et al. (2019), two general approaches can be applied when selecting a research time horizon:

- Longitudinal studies involve repeated data collection over an extended period of time and are particularly suited to analysing processes of change and development.
- Cross-sectional studies investigate a particular phenomenon at a specific point in time.

For this study, a cross-sectional design was selected in order to capture a broad variety of strategic approaches and practices related to sustainability, the CE and digitalisation within the German T&C industry under current regulatory, technological, and market conditions.

In line with the study's constructivist research philosophy, this snapshot does not aim to produce definitive or timeless knowledge, but rather to generate a provisional and context-specific understanding that can serve as an orientation for practical solutions. These insights are understood as temporarily valid and are expected to be proven in organisational practice over time, as well as to be reviewed, further developed, and adapted through future research.

The next step involved identifying appropriate methods and instruments for data collection and analysis. These are described and justified in detail in the next sections.

4.5 Data Collection and Analysis Procedures

Building on the research philosophical foundations, the interpretive–inductive research approach and the selected case study design, this section outlines the data collection and analysis procedures employed to this study. It explains how the epistemological assumptions are translated into concrete procedures for data collection (Section 4.5.1) and data analysis (Section 4.5.2).

4.5.1 Data Collection Procedures

From a constructivist perspective, data are not understood as neutral representations of an external reality, but as the outcome of constructive and interpretive processes (Gillespie et al., 2024). Data collection and data analysis were therefore not treated as strictly separable stages, but as interrelated processes through which organisational

meanings, practices, and interpretations were progressively reconstructed and refined. This study aimed at understanding how companies make sense of the transition to sustainability, the CE, and digitalisation through a case study of the German T&C industry.

Data collection in case study research is not tied to a single method. Instead, various methods are typically combined to gain meaningful and in-depth insights (Eisenhardt, 1989). The decision for certain data collection techniques should primarily be determined by the specific objectives of the study and be appropriate to the nature of the research subject (Borchardt & Göthlich, 2009). In this study, document analysis and semi-structured expert interviews are employed as complementary data collection methods. Documents represent existing materials, including textual materials such as company reports, websites, articles, and publications in print or online media, as well as non-textual materials, such as audio or video recordings, images or physical goods (Gummesson, 2017; Saunders et al., 2023). Document analysis provides insights into publicly communicated strategies, self-descriptions, and practices of organisations, while interviews offer access to internal perspectives and experiential knowledge that are not visible in formal documents. Interviews constitute a central data source in case study research, as they enable direct access to the interpretations, experiences, and decision-making logics of organisational actors (Yin, 2018). In this study, semi-structured expert interviews were chosen because they provide a flexible yet focused framework that ensures coverage of key themes (Saunders et al., 2023) while allowing respondents to elaborate on context-specific practices and meanings relevant to sustainability, the CE and digitalisation.

Beyond the methods employed in this study, further qualitative research approaches exist that would, in principle, have been suitable for investigating the organisational change processes in the German T&C industry in greater depth. In particular, participatory and interventionist approaches such as action research can provide rich insights into organisational practices, decision-making processes, and learning dynamics, as they closely link research and practical change (Döring, 2023; Easterby-Smith, 2021). Through the active involvement of researchers in organisational change processes, such approaches can generate detailed knowledge about the implementation, challenges, and effects of specific measures (Neuman, 2014). These approaches were deliberately not adopted in the present study. An action research approach would have

required intensive and long-term access to individual organisations, as well as the possibility of actively engaging in organisational processes (Döring, 2023, p. 989; Saunders et al., 2023). Such access was not available within the scope of this research project. Moreover, an interventionist approach would have narrowed the analytical focus to a small number of organisations and would therefore have been less suitable for identifying industry-level patterns, practices and challenges characterising the German T&C industry´s transition to sustainability, the CE and digitalisation.

This decision also constitutes a limitation of the study. An interventionist research approach may offer substantial additional value for future research, particularly in tracing the practical implementation and effectiveness of specific strategies and practices over time. In light of these considerations, the present study adopted a qualitative case study design that enabled a comparatively broad capture of organisational perspectives while still allowing for interpretive depth, without requiring active intervention in organisational processes.

As organisational realities are understood as socially constructed and context-dependent, companies were not selected for statistical representativeness of the German T&C industry but for their potential to provide rich insights into how sustainability, especially CE-practices, and digitalisation are perceived and enacted in practice. Accordingly, purposive and theoretical sampling (Eisenhardt & Graebner, 2007) was employed to select organisations actively engaged in these change processes, thereby enabling the reconstruction of dominant meanings and practices at the industry level. The aim was to examine a broad range of approaches and practices while also ensuring a high degree of insight and analytical depth. Based on this combined approach, a set of selection criteria was defined (see Figure 23).

Figure 23
Sampling strategy and criteria for company selection

Sampling strategy	Criteria
Theory focused sampling	Commitment to sustainable development
Heterogenous sampling	Companies of NACE Codes 13 and 14
	“Mittelstand” Companies

First, organisations selected as empirical access points to the industry were required to demonstrate active engagement and commitment to sustainable development. Possible indicators of such engagement included participation in relevant sustainability-related initiatives or the presence of a dedicated sustainability section on the company's website that provides comprehensive information on ecological and social aspects of business activities. Second, the selected organisations were required to reflect the structure of Germany's *Mittelstand* - that is, the country's distinctive group of mostly family-owned, small and medium-sized companies - representing more than 90% of the T&C sector in Germany (BMWK, 2025).

Relevant indicators for this purpose included the company's classification under the NACE industrial sector taxonomy (see Section 1.2.1) and the 'Mittelstand' definition from the German Institut für Mittelstandsforschung (Institute for Mittelstand research – IfM Bonn). According to the IfM Bonn (2023), the term *Mittelstand* represents a distinctive feature in the German economic context, one that is not commonly used in the same way in other regions. What makes it unique is that, in addition to the quantitative criteria of employee numbers and annual turnover - as defined by the EU for SMEs - the *Mittelstand* includes a qualitative dimension: the unity of ownership and management. A company meets this criterion when

- the entrepreneur exercises significant personal influence,
- bears the entrepreneurial risk, and
- the company serves as the primary source of the entrepreneur's personal income and livelihood.

Based on this definition, a company is classified as *Mittelstand* if

- up to two natural persons or their family members hold (directly or indirectly) at least 50% of the company's shares, and
- these natural persons are also part of the company's management.

This definition therefore goes beyond the purely quantitative SME classification and includes companies that may formally qualify as large enterprises by size but are nonetheless shaped by *Mittelstand* characteristics in their ownership and governance structures. To ensure that only organisations with a clear commitment to sustainability were included, the first step was to extract a list of German member companies of the German Partnership for Sustainable Textiles (PST). The PST is a multi-stakeholder initiative consisting of companies and associations, NGOs, trade unions, standard organi-

sations, and the German government. It aligns with the EU Green Deal and the European Commission's textile strategy and "is committed to a social, ecological, and corruption-free textile and garment industry […] that respects the rights of all workers, protects the climate as well as the environment and acts with integrity" (PST, 2025, para 1).

At the time of compilation (May 2022), the PST listed 64 member companies based in Germany. A cross-check with the Dun & Bradstreet company database using NACE codes revealed that only 21 of these companies are classified as textile or clothing manufacturers, as defined by NACE codes 13 and 14. The remaining 41 companies operated in a wide range of other sectors, primarily focused on T&C trading and retail, and were therefore not included in the empirical inquiry, as they fell outside the defined scope of this study. The distribution of the potential case study companies by economic classification and size is shown in Table 11. These companies were considered to serve as empirical access points to the industry, based on the assumption that firms which voluntarily join an initiative aimed at promoting a more sustainable and circular T&C industry are genuinely committed to sustainable development.

Table 11
Overview of the potential number of companies for data collection based on the membership list of the PST

Criteria		Number of companies
NACE Code	13	3
	14	18
Company classification	SME (according to EU definition)	19
	Large (but Mittelstand according to IfM Bonn definition)	2
	Total	**21**

Furthermore, due to the relatively small number of textile manufacturing companies (classified under NACE code 13) in the initial sample, an additional search for companies was conducted using the Dun & Bradstreet company database. These organisations were selected based on an informed assessment that they demonstrated a clear commitment to sustainable development and responsible business practices, supported by publicly available information. In eight companies, existing professional contacts facilitated access to these organisations. In total, 29 companies were included as empirical access points for the study (Table 12).

Taken together, these organisations provide a solid empirical basis for understanding how companies in the German T&C industry address sustainability and the CE through practices, which challenges they perceive in this process, and how DTs are understood and used in this context.

Table 12

Companies included in the case study as empirical access points to the German T&C industry

Company Code	Company Description	PST member	NACE CODE
C01	Development and manufacturing of work wear, private label, textile merchandising and promotion goods	yes	13
C02	Manufacturing of bed linen	yes	13
C03	Manufacturing of woven fabrics	yes	13
C04	Manufacturing & processing of natural & synthetic fibres	no	13
C05	Manufacturing & dying of yarns	no	13
C06	Manufacturing & dying of yarns	no	13
C07	Manufacturing & dying of yarns	no	13
C08	Manufacturing of nonwovens & technical fabrics	no	13
C09	Manufacturing of fabrics	no	13
C10	Textile finishing	no	13
C11	Textile finishing	no	13
C12	Development & manufacturing of socks, underwear, fitness and loungewear for kids and adults	yes	14
C13	Development and manufacturing of work wear	yes	14
C14	Development and manufacturing of work wear	yes	14
C15	Development & manufacturing of underwear & bed linen	yes	14
C16	Development & manufacturing of business wear	yes	14
C17	Development and manufacturing of slow fashion clothing for women	yes	14
C18	Development and manufacturing of work wear	yes	14
C19	Development & manufacturing of corporate fashion for men and women	yes	14
C20	Development and manufacturing of work wear	yes	14
C21	Development and manufacturing of work wear	yes	14
C22	Development and manufacturing of sports and functional clothing and accessories for men, women and children	yes	14
C23	Development and manufacturing of fashion clothing for men and women	yes	14
C24	Development and manufacturing of sports and functional clothing for men, women and children	yes	14
C25	Manufacturing of textile membranes and outdoor textiles	yes	14
C26	Development and manufacturing of fashion clothing for men and women	yes	14
C27	Development and manufacturing of fashion clothing for men and women	yes	14
C28	Development and manufacturing of sports and functional clothing & accessories for men, women and children	yes	14
C29	Development and manufacturing of work wear	yes	14

4.5.1.1 Document Analysis

The use of secondary data sources has become indispensable in case study research, particularly in light of the increasing shift of corporate communication and interaction through digital channels and the vast amount of information available on the internet nowadays (Gummesson, 2017; Saunders et al., 2023). In line with the philosophical assumptions underlying this study, publicly available documents were used to gain insights into how organisations in the German T&C industry address sustainability and

the CE through practices, which challenges they perceive in this process, and how DTs are understood and used in this context. Empirical material was collected from the official websites of the organisations included in the study (see Table 12) as well as from relevant industry-specific trade media published between June 2022 and January 2025. Based on the Genios business database, the most relevant trade publications for the German T&C sector include *Textilwirtschaft* and its associated online platform *TWnetwork.de*, as well as *Melliand Textilberichte* and its online presence. As all analysed documents were publicly accessible, no prior consent from the organisations was required.

Documents were collected in English where available. The collected materials were extracted, catalogued (including source and access date), and saved as PDF files in individual folders for each company on an external secured storage device. Where materials were only available in German, they were translated into English by the author, with translations subsequently checked using AI-supported translation tools. To ensure transparency and consistency across data sources, all documents were referenced in English. In line with the interpretive orientation of the study, translation is understood not as a purely technical procedure but as an interpretive step through which the researcher shapes meaning (Easterby-Smith, 2021). To mitigate potential distortions, translated texts were carefully reviewed against the original-language versions by the researcher, a native German speaker, and interpreted in relation to her organisational and industry context. The original-language documents were retained for reference.

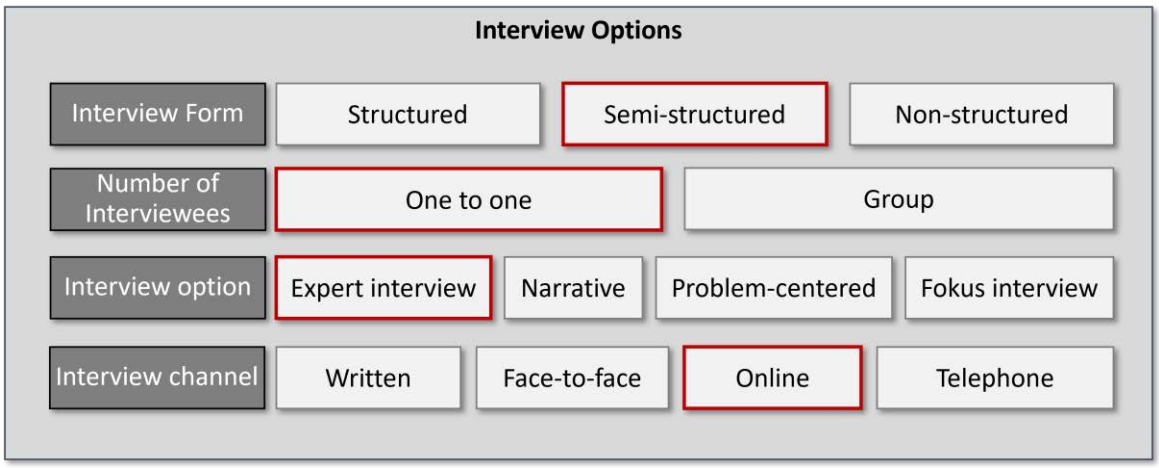
A more resource-intensive translation strategy, such as independent professional translation, was not employed. This decision reflects the study's analytical focus on reconstructing organisational meanings, practices, and strategic orientations rather than conducting fine-grained linguistic or discourse analysis. Within the constructivist framework guiding this research, documentary materials are treated as one form of organisational sense-making that contributes to a broader understanding of industry-level change processes.

4.5.1.2 Interviews

Interviews constitute a central data source in qualitative case study research, as they provide direct access to the interpretations, experiences, and decision-making logics of organisational actors (Yin, 2018), and were therefore used in this study alongside the analysis of publicly available documents. Interviews can be positioned along a continuum between two extremes: fully structured and entirely unstructured. Between these poles lie various degrees of semi-structured formats. Interviews can also be classified by the number of participants - such as individual or group interviews - and by their objective, for example, as focus, expert, problem-centred, or narrative interviews. Depending on how they are conducted, interviews may take written, oral, telephone, or online form (Döring, 2023; Patton, 2014; Saunders et al., 2023).

In this study, semi-structured expert interviews were employed to explore how key organisational actors understand and enact the transition towards sustainability, the CE and digitalisation in their everyday organisational contexts. Experts were defined as individuals holding relevant positions (e.g., managing directors or sustainability managers) within the case-study companies, possessing subject-matter expertise and experience at the strategic and operational levels (based on Döring, 2023). All interviews were conducted as one-to-one expert interviews rather than group interviews. This format was chosen to allow participants to speak openly about strategic considerations, organisational challenges, and internal decision-making processes without the influence of group dynamics, hierarchical constraints, or confidentiality concerns (Easterby-Smith, 2021). Group interviews were therefore not considered appropriate for capturing individual perspectives and organisation-specific experiences in sufficient depth. Finally, interviews were conducted online via video conferencing. This mode of interaction was chosen for pragmatic and logistical reasons, as it enabled access to geographically dispersed participants while ensuring efficient use of time and resources, without compromising the depth or quality of the data collected. Figure 24 provides an overview of the different interview formats and the specific decisions made for this study.

Figure 24
Overview of possible interview options and options selected for this study



Source: The author based on Döring, 2023; Patton, 2014 and Saunders et al., 2019

To collect data that adequately reflect the diversity of organisational perspectives within the German T&C industry, the group of interview participants was deliberately composed to ensure broad coverage of relevant organisational contexts, based on the following criteria:

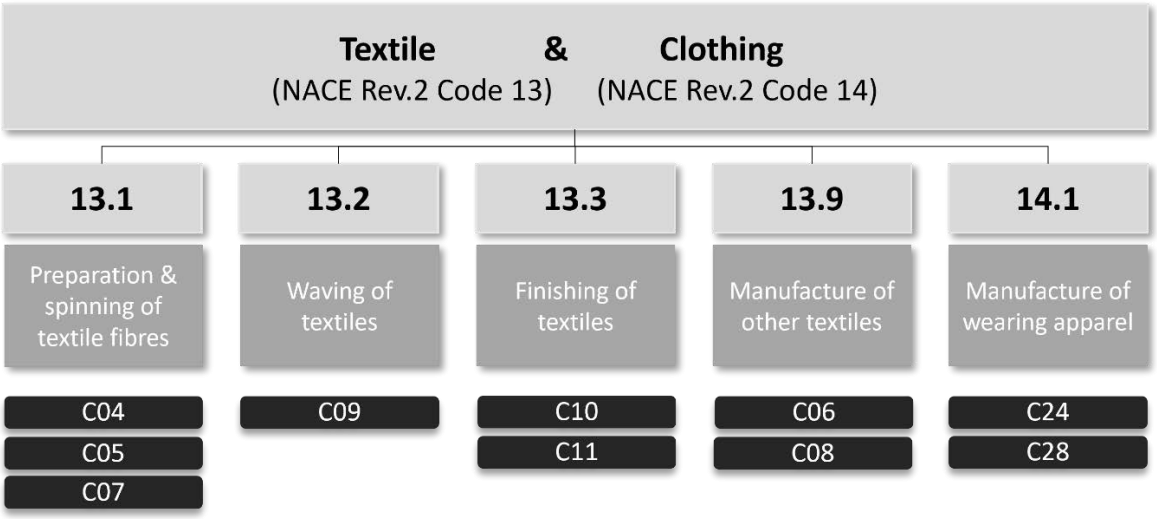
First, at least one expert from companies operating in one of the T&C value chain processes, as defined by NACE codes 13 and 14, was included. Second, the organisations represented by the interviewees were required to have explicitly integrated sustainability and CE principles into their corporate vision or strategic orientation. These criteria ensured that interviewees were directly involved in and able to reflect upon organisational change processes related to sustainability, the CE, and digitalisation. Several experts from the organisations listed in Table 12 were contacted and invited to participate in an interview. Ten managers from ten different organisations agreed to take part in the study (Table 13).

Table 13
Overview of interview respondents' profiles

Company code	Interviewee role
C04	Project Lead New Business Development & Sustainability
C05	Management Quality, Energy, Environmental Protection, Occupational Health and Safety
C06	Certification and Sustainability Manager
C07	Head of Quality Assurance & Sustainability
C08	Sustainability Manager
C09	Head of Sustainability and Marketing
C10	CEO
C11	Head of Research and Development
C24	Director of Quality & Corporate Responsibility
C28	Senior Innovation Manager Sustainable Materials and Manufacturing

The researcher deemed that ten in-depth interviews with industry professionals experienced in the transition to sustainability- and CE-practices and representing diverse backgrounds (Figure 25) would be sufficient to gather meaningful data for addressing the research questions, which is supported by Guest et al. (2006), who observed that "basic elements for meta-themes were present as early as six interviews" (p. 59).

Figure 25
Overview of NACE classification of the interview respondents' companies



The managers were contacted to confirm availability, and interview appointments were arranged at a time convenient for each participant. At least one week before the scheduled interviews, participants received a preparation package consisting of an interview consent form (see Appendix B.1) and research brief (see Appendix B.2). All documents were prepared and sent in German, as it is the native language of both the researcher and all interview respondents. This decision was made to ensure clarity, minimise misunderstandings, and facilitate open and nuanced communication. For transparency, English translations of these documents were included in the appendices (B.1–B.2). In line with the interpretive orientation of the study, language choice and translation are understood as integral components of the research process rather than purely technical steps. The use of participants' native language was therefore intended to support the accurate expression of meanings, experiences, and interpretations relevant to the research focus. Due to the geographical dispersion of participants, as well as time and budget constraints associated with the research project, all interviews were conducted

online using the video-conferencing tool MS Teams. Prior to each interview, participants provided informed consent for audio recording and transcription. No objections were raised to this procedure.

The interview guide consisted primarily of open-ended questions, supplemented by selected multiple-choice items (Figure 26 and Figure 27). This structure supported s focused discussion of key themes while allowing participants sufficient flexibility to elaborate on organisation-specific experiences, challenges, and interpretations.

Figure 26

Example of a multiple-choice question

In welchem Umfang verfolgt Ihr Unternehmen die folgenden Strategien und Praktiken?

(To what extent does your organisation pursue the following circular practices?)

	nicht angedacht (not considered)	wird in Betracht gezogen (considering it)	Umsetzung begonnen (implementation started)	Umgesetzt (implemented)
Geschäftsmodellinnovationen (z.B. Miet-/Leihmodelle, "Produktion auf Abruf", Second-Hand, ...) (Business model innovations (e.g. rental/loan models, "production on demand", second-hand, ...))				
Reduzierung von Emissionen und Abfall in den Geschäftsprozessen (Reduction in emissions and waste in operations)				
Reduzierung des Verbrauchs natürlicher Ressourcen (z.B. Verwendung von recycelten Materialien, Wasserrückgewinnung) Reduction of natural resource consumption (e.g. use of recycled materials or water reprocessing)				
Aktivitäten zur Verlängerung der Produktnutzungsphase (z.B. Reparaturservices) Activities to extend the product use phase (e.g. repair services)				
Wiederverwendung von Materialien, Produkten oder Verpackungen (Reuse of materials, products, packaging)				
Produktion/Einkauf von (Vor-) Produkten mit hohem Rezyklatanteil (Production/purchase of (pre-)products with a high proportion of recycled material)				
Wiederverwertung (Recycling) von Waren, Materialien oder Verpackungen (Recycling of goods, materials or packaging)				
Zusammenarbeit mit Partnern in eigenen oder anderen Wertschöpfungsketten (z.B. gemeinsame Ressourcennutzung, Nutzung gemeinsamer Plattformen, Zusammenarbeit im Bereich der Abfallverwertung,...) Cooperation with partners in own or other value chains (e.g. use of comm[illegible] platforms, cooperation in waste recycling ...)				

Figure 27
Example of a multiple-choice question

Bitte markieren Sie die Technologien, die Ihr Unternehmen bereits verwendet oder einzuführen plant.
(Please tick the technologies your company already uses or is planning to implement.)

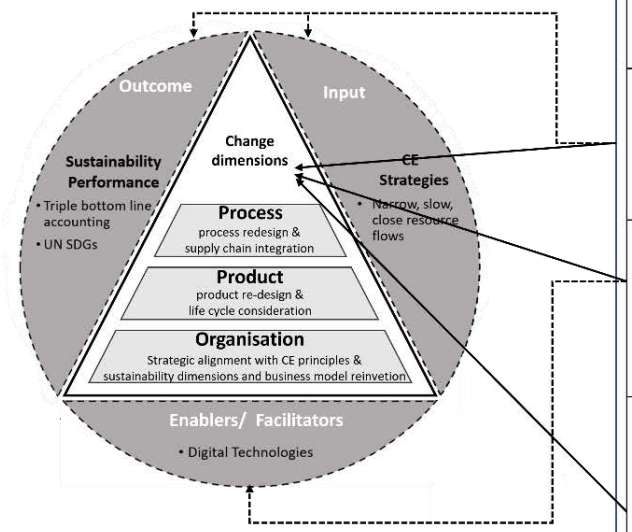
	Im Einsatz (implemented)	Einführung geplant (implementation planned)
Blockchain		
Robotik (Robotics)		
Künstliche Intelligenz (Artificial Intelligence)		
Internet der Dinge (IoT) (z.B. RFID) (Internet of Things, e.g., RFID)		
Digitale Entwicklung & Fertigung (z.B. 3D-Design, Digitaler Zwilling, 3D- Druck) Digital development & manufacturing (e.g., 3D design, digital twin, 3D printing)		
Soziale Medien (Social Media)		
Mobile Computing (z.B. Apps, Tablets)		
Big Data & Analytics		
Virtual or Augmented Reality (VR / AR)		
Computing (e.g. software as a service, Cl		

Participants were asked to complete the multiple-choice questions prior to the interview and return the form to the researcher in advance. This procedure served as a preparatory step to support shared understanding of key concepts, identify potential ambiguities, and focus the subsequent interview discussion on relevant organisational practices, technologies, and experiences. The multiple-choice items were not used as measurement instruments, but as a means to support and structure the qualitative interview conversation and to facilitate more focused and in-depth discussion during the interview situation.

The interview guide was structured around five thematic blocks aligned with the elements of the PCF (Figure 28). The first two blocks captured descriptive information regarding the company's position within the textile value chain and organisational size, providing contextual background for interpretation. The third block focused on the implementation of sustainability and CE related strategies and practices, including their perceived impacts on organisational structures, products, and processes, as well as stakeholder engagement. The fourth block addressed the perceived role of DTs, their integration into sustainability and CE practices, and their perceived relevance for future developments in this context. The fifth block explored challenges, needs and wishes for support as well as perceived factors influencing the organisational transition to sustainability, the CE and digitalisation.

Figure 28

Links between PCF and the interview guide



Interview guide addressing RO2

Thematic blocks	Phenomenon / questions addressed
1 & 2 Statistical data	- Classification of the company within the T&C value chain - Company size category
3 Assessing the applied or planned sustainability / CE strategies and practices	- Strategies, activities, measures - Impact on products, processes, business model, organisation - Stakeholders that are involved - Challenges that are faced
4 Assessing the role of digital technologies in the CE-transition	- General assessment of digitalisation and CE in the T&C Industry - Assessment and examples for digital technology deployment in the respondent´s organisation - Assessment of the future development of the CE transition and digitalisation in the respondent´s organisation
5 Assessing challenges and needs for the transition in the T&C industry	- General assessment of challenges related to the transition to sustainability, CE and digitalisation in the T&C industry - General assessment of chances or influential factors related to the transition to sustainability, CE and digitalisation in the T&C industry - Assessment of what kind of support the respondent's organisation would need during the transition

The interviews were conducted between May and September 2024, with each session lasting approximately 50 to 70 minutes. At the beginning of each interview, participants were informed when the recording would start and end. MS Teams generated an initial automated transcript, which was subsequently reviewed, corrected, and supplemented by the author based on the original audio recordings. As interviews were conducted in German to facilitate natural, open and nuanced discussion, transcripts were translated into English by the author and checked using AI-supported translation tools. In line with the interpretive orientation of the study, transcription and translation are understood as interpretive steps that may shape meaning (Easterby-Smith, 2021). To mitigate potential distortions, translated transcripts were reviewed carefully in relation to the original German versions and their organisational context. The thesis supervisor, a native English speaker, additionally reviewed translations presented in this thesis to enhance transparency and consistency.

All transcripts were anonymised, catalogued, and securely stored on an encrypted external data drive. In this thesis, all direct quotations from the interview data are presented in English, regardless of the original language of the interview. More resource-intensive procedures, such as independent professional transcription or back-translation, were not employed, as the analytical focus of the study lies on reconstructing organisational meanings and practices rather than conducting fine-grained linguistic or

discourse analysis. The analytical tools and procedures applied to both interview and documentary data are described in Section 4.5.2.

4.5.1.3 Practitioner Feedback

The practical relevance and an initial assessment of the practical applicability of the operational framework presented in Chapter Six, were examined through an online questionnaire (see Appendix D). The assessment was designed as a complementary method to the qualitative case study findings and aimed to provide an additional perspective on the framework's plausibility, clarity, and perceived usefulness from the viewpoint of practitioners. For the design and administration of the assessment, the Jisc Online Surveys platform provided by the University of Gloucestershire was used. Managing directors and sustainability managers from the 29 organisations included in the empirical investigation - either listed as contact persons within the German Partnership for Sustainable Textiles (PST) network or previously involved as interview participants - were personally invited to participate.

As German is the participants' native language, both the questionnaire and the operational framework were provided in German to ensure clarity and facilitate accurate interpretation. The translation of the questionnaire and the framework from English to German was done by the author, a native German speaker.

Following data collection, the questionnaire and responses were translated into English by the author for documentation purposes. Translation accuracy was verified through a back-translation procedure, whereby the English versions were translated back into German using translation software and compared with the original responses.

The questionnaire started with a brief introduction explaining the purpose of the study, followed by a structured presentation of the operational framework. Participants were first asked to indicate their sector affiliation (textile or clothing industry). The questionnaire then presented eleven statements related to the framework, which were assessed using a five-point Likert scale ranging from 'strongly agree' to 'strongly disagree'. In addition, participants were asked to identify those change dimensions in which they perceived the greatest challenges or gaps, as well as those in which, from their perspective, the greatest progress had been achieved. Finally, three open-ended

questions invited respondents to reflect on the strengths and weaknesses of the framework and to identify any aspects they felt were missing. The assessment was conducted in September 2025 and remained open for a period of ten days. In total, eight complete responses were received, four from textile companies and four from clothing companies.

The assessment was not intended to provide validation or generalisable results. Rather, it served as a practical plausibility check exploring whether the framework aligns with practitioners' experiences and whether it is perceived as useful for addressing real organisational challenges. At the same time, it is acknowledged that such feedback can only provide a preliminary indication of practical relevance.

While personal interviews with the practitioners might have allowed for follow-up questions and more in-depth insights into their interpretation and assessment of the framework, the online questionnaire format was chosen for pragmatic reasons. Given the limited availability of senior practitioners and the time constraints of the study, arranging additional in-depth conversations was not feasible. Consequently, the questionnaire approach prioritised structured and comparable feedback over deeper qualitative exploration.

Meaningful experiential learning and substantive further development of the framework can only emerge through its application in organisational practice over time. Therefore, alternative research designs – such as longitudinal studies, experimental approaches, or action research involving the implementation and testing of the framework within organisations – could potentially provide stronger forms of empirical validation. However, such approaches would require sustained organisational access and active intervention over extended periods and were therefore beyond the scope of the present study. The chosen approach thus represents a pragmatic and appropriate method for obtaining initial, structured feedback on the framework's relevance and usability, while explicitly recognising the need for further empirical testing and iterative refinement.

4.5.2 Data Analysis Procedures

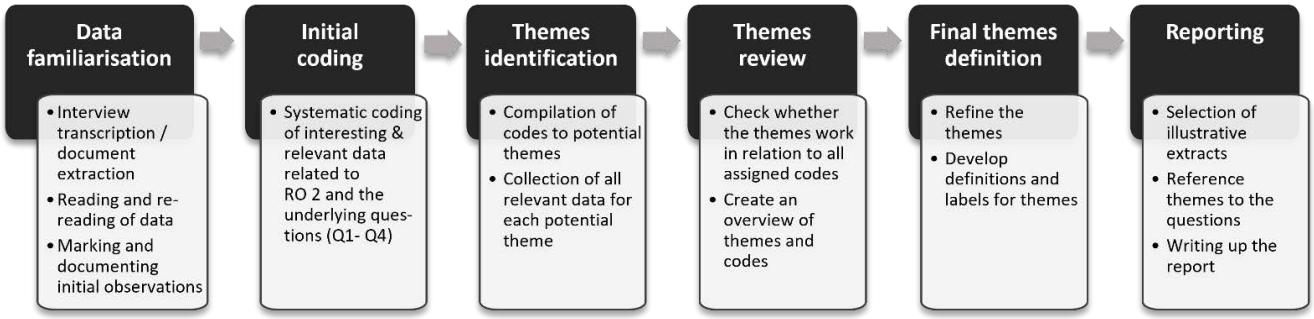
Qualitative data typically appears in the form of words and texts, or occasionally images, and therefore require different analytical methods and tools than quantitative, numerical data, which can be analysed using mathematical and statistical procedures

(Miles et al., 2020). The qualitative research approach adopted in this study generated large volumes of data. Although often complex and difficult to analyse, such data yield rich and valuable insights (Gummesson, 2017; Saunders et al., 2023). The key challenge was how to most effectively “sort the data and find patterns” (Gummesson, 2017, p. 256). The literature offers a range of interpretive approaches to text and document analysis, many of which follow similar procedures - such as Mayring`s (2015) qualitative content analysis or the thematic analysis proposed by Braun and Clarke (2006). These approaches are grounded in a systematic and predominantly inductive process of coding, in which the material is broken down into small units of analysis (e.g., documents, passages, or sentences), and specific text segments are assigned codes or categories that attribute meaning to the data (Döring, 2023; Miles et al., 2020). For this study, a systematic approach to data analysis and interpretation based on the thematic analysis method proposed by Braun & Clarke (2006) was applied. The analysis was guided by RO2 and its four research questions (RO2-Q1–RO2-Q4) as well as by the elements of the PCF, with the aim of developing well-grounded interpretive insights from the empirical material. Consistent with the interpretive orientation of the study, the analysis acknowledged that interpretation is shaped by the researcher’s perspective, prior experience, and value position. To ensure analytical rigour and transparency, a structured and systematic procedure was applied consistently to both interview transcripts and documentary data.
The analytical process comprised six steps (Figure 29), which are briefly outlined below. These steps were applied iteratively rather than in a strictly linear sequence, allowing for repeated refinement of codes and themes as understanding developed.

To support the qualitative data analysis, the software NVivo was used. It served as a supportive tool rather than as an executing or automated instrument. The use of qualitative data analysis software is discussed critically in the literature, particularly where it is employed to automate analytical tasks such as efficiently scanning large volumes of text for frequently occurring words, phrases, or topics. Such applications risk overlooking meanings that emerge only through close engagement with context (Saunders et al., 2023). In this study NVivo was used to support the organisation, structuring, and documentation of the analysis process. All analytical decisions - including coding, interpretation, and theme development - were conducted manually by the author. The software only facilitated a transparent and traceable linking of codes, text segments, and emerging themes.

Figure 29

Overview of the data analysis procedure applied to this study



Source: The author based on Braun and Clarke, 2006

Step 1: Familiarisation with the data

A core principle of qualitative research is that the researcher must become thoroughly familiar with the data used to address the research objectives. This means repeatedly reading and immersing oneself in the material to fully understand its content (Saunders et al., 2023). In this study, familiarisation began during the reading and collection of documents related to the companies and continued through the review and correction of the transcripts against the original interview recordings. Although time-consuming, this step was essential for effective and meaningful data analysis. As Braun and Clarke (2006) note, familiarisation "provides the bedrock for the rest of the analysis" (p.87). In this study, transcripts and textual documents for each company were imported into NVivo, read closely, and were manually coded for relevant insights, with initial ideas and observations noted.

Step 2: Initial coding

In the second step, relevant text segments were coded iteratively based on the four research questions (RO2-Q1 – Q4). This step was carried out in multiple rounds, with each round focusing exclusively on one specific question. During coding, labels were assigned to individual text segments (Saunders et al., 2023), in order to give meaning to the data within the context of the research project and its guiding questions. In addition to the questions elements of the PCF were also taken into account. Text passages were analysed to determine whether they supported, expanded, or even challenged the components of the PCF. As a result, a dual coding strategy was employed, incorporating both data-driven and concept-driven codes (Braun and Clarke, 2006; Saunders et al., 2023). This combination allowed the analysis to remain interpretive

rather than deductive. The PCF was not used to test predefined assumptions but served as an analytical lens to support the interpretation of the data while remaining open to insights emerging from the empirical material. Throughout the analysis, the codes were continuously refined to avoid overlap and to ensure the use of more precise or meaningful terminology where appropriate.

Thanks to the use of Nvivo, this process remained manageable and ensured full transparency at all times regarding both the applied codes and the corresponding text segments (Figure 30).

Figure 30
Extract of the coding protocol applied for thematic analysis

Name	Files	References
RO2-Q1 - Implementation of Sustainability in products, processes and	357	2637
CE as part of sust.	4	4
Corporate governance, strategy, structure, culture	292	1350
Business model	181	499
Communication & Education	80	171
cooperation & collaboration	87	157
Corporate Citizenship	37	68
Strategy & Structure	118	455
Environmental and social Impact	240	1283
Processes	204	1015
Product & materials	112	267
RO2-Q2 - CE Strategies & Practices erl.	233	979
Close	104	260
Recyclable products	44	91
Recycling of products	89	167
Narrow erl.	137	473
Reduce negative environmental impact	90	234
Reduce resource consumption	80	185
Reduce waste & scrap	34	52
objectives	13	19
Slow erl.	99	227
RO2-Q3 - Role of Digital Technologies	88	237
Drivers & Goals of Digitalisation	20	32
DT fields of application	72	145
Role of DTs	9	
Supply chain transparency		
RO2-Q4 - Key issues, challenges & influencing factors		
Challenges		
...nces, benefits		

Step 3 - 5: Iterative identification, review and final definition of themes

In the next steps, the coded segments were grouped into emerging themes. A two-stage approach was adopted. In the first stage, each text was analysed and coded at least four times. Each round focused on one of the research questions (RO2-Q1 to Q4). In the second stage, all codes and their associated content were re-examined. This process allowed for the identification of initial clusters and recurring patterns, which served as the basis for grouping the codes into preliminary themes. Where classifications were ambiguous, adjustments to codes and content were made accordingly. As the analysis progressed, these themes were regularly reviewed refined and related to the PCF. Increasingly, relationships between the themes became evident and were structured into overarching and sub-themes. Following this iterative process, the themes were consolidated based on the assigned codes. Each theme was clearly defined and illustrated with examples.

Step 6: Reporting on the findings

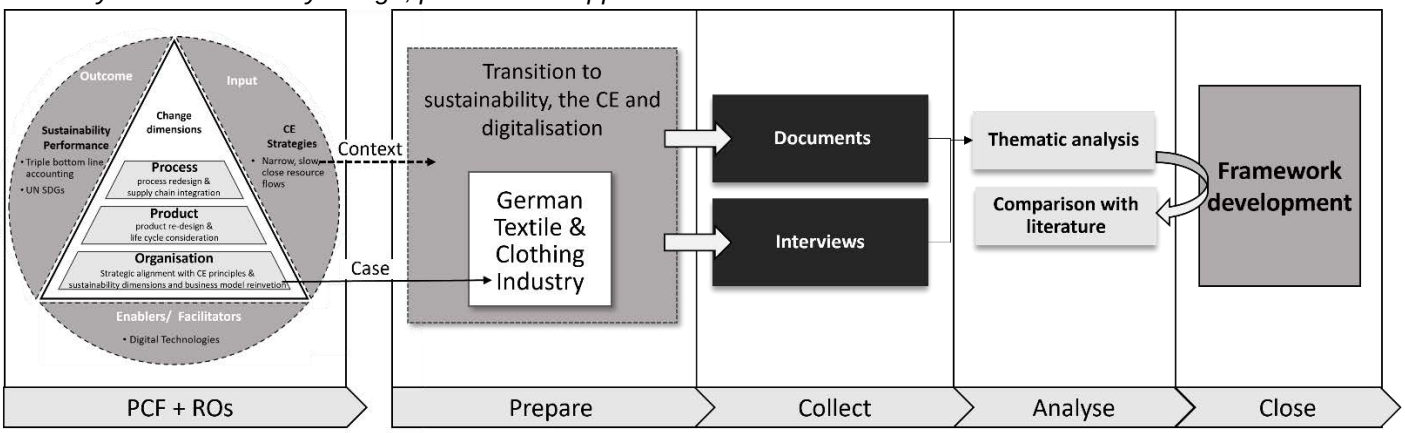
Once the coding and theme development were completed, the final step involved presenting and documenting the results of the thematic analysis in relation to the questions. The findings derived from this process are presented in detail in Chapter five.

4.5.3 Summary

This study employed a qualitative, inductive case study design to investigate how the German T&C industry is shaping its transition to sustainable and circular practices, and what role DTs play in this context. It addresses a complex and previously underexplored field - particularly with regard to the deployment of DTs. To generate context-specific and practice-oriented insights, a case study design was selected, structured around the PCF and guided by four research questions (see Chapter three). The German T&C industry is conceptualised as a holistic single case, with data collection based on a combination of document analysis and semi-structured expert interviews. These methods were applied, analysed, and iteratively compared with the academic literature to further refine and develop the PCF into a practice-oriented, operational framework. This systematic, transparent, and iterative approach (Figure 31) ensured the analytical depth and traceability of the study. The next section outlines the measures taken to ensure trustworthiness of the study and compliance with relevant ethical standards.

Figure 31

Summary of the case study design, process and applied methods



4.6 Quality Assurance and Ethical Considerations

Ensuring research quality and adhering to ethical standards are fundamental components of any rigorous research - particularly within interpretive, qualitative research, where questions of objectivity and generalisability are frequently raised (Eisenhardt, 1989). Sub-section 4.5.1 therefore outlines the measures taken to ensure the trustworthiness of this research, based on established quality criteria for qualitative inquiry. Sub-section 4.5.2 presents the ethical considerations that were integrated throughout the research process to safeguard participants' rights and uphold the integrity of the study.

4.6.1 Quality Assurance

Qualitative research is often criticised for lacking scientific rigour, mainly because findings are based on small sample sizes and may not be easily generalisable (Eisenhardt, 1989). This raises concerns about whether conventional scientific quality criteria (validity and reliability) are adequately met (Flick, 2022). To counter these critiques, it is essential to demonstrate a rigorous research process by applying quality criteria tailored specifically to qualitative research (Döring, 2023; Rheinhardt et al., 2018). Several frameworks for assessing the quality of qualitative research exist. One widely adopted approach is the construct of trustworthiness, proposed by Lincoln & Guba (1985), which comprises the dimensions of credibility, transferability, dependability, and confirmability.

These dimensions are briefly explained below based on definitions and explanations given by Döring, 2023; Miles et al., 2020; Rheinhardt et al., 2018; Saunders et al., 2023 followed by a discussion of the strategies and techniques applied to this study to meet these criteria:

Credibility

Credibility is considered the cornerstone of trustworthiness in qualitative research. It refers to the extent to which findings are plausible and convincing. Research results are deemed credible when they are well-founded, clearly explained, and logically derived from the data.

Transferability

Transferability refers to the extent to which research findings can be applied to other contexts, cases, or settings. Unlike statistical generalisation in quantitative research, qualitative transferability relies on providing sufficient contextual information for readers to determine relevance.

Dependability

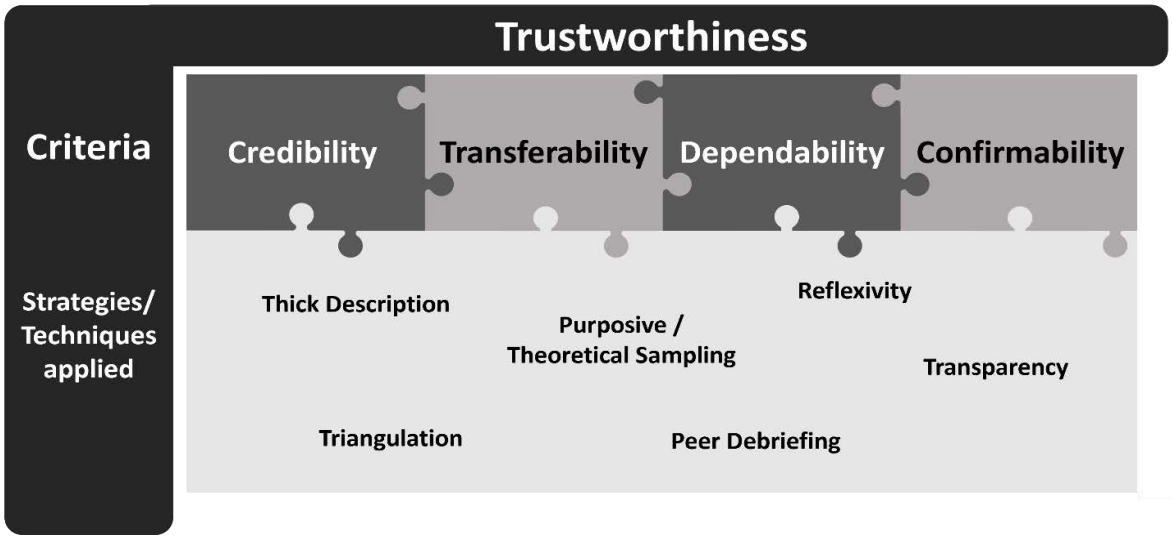
Dependability focuses on the transparency, consistency, and logical coherence of the research process. It requires thorough documentation of all methodological decisions and any changes that occurred during the research, including data collection, analysis, and interpretation to enable readers to understand how interpretations were generated.

Confirmability

Confirmability refers to the degree to which a study´s findings are not predetermined by the prejudices or interests of individual researchers but arise from the research subject.

To ensure a high level of research quality, this study applied multiple techniques to meet trustworthiness, which are summarised in Figure 32 and described below.

Figure 32
Quality assurance framework applied to this study



Thick description

All decisions made during the research process - including those related to research design, methods, and analysis tools - as well as the rationale for those decisions, potential rival explanations, and uncertainties were carefully documented. The study provides a rich and detailed description, enabling readers to fully understand and assess the research. Previous sections of this chapter outlined the research design, context, data collection, case selection, and analysis process in detail. Supplementary materials, such as illustrative references are presented throughout the findings in Chapter five to further support the study's credibility, dependability and confirmability. Transferability is supported by the detailed description of the industry context and organisational characteristics, allowing readers to judge whether and how the identified patterns may resonate with or inform similar change processes in other sectors or regional contexts.

Purposive / theoretical sampling

The purposive selection of companies, as described in detail in Section 4.4.2, ensured that all participating companies are part of the German T&C industry and committed to sustainability. The sample also reflects heterogeneity in size and economic activity, thereby enhancing both the credibility, transferability and confirmability of the findings.

Triangulation

This study used different data sources for broadening and contextualising interpretation. The analysis draws on data source triangulation by combining semi-structured interviews with organisational actors and publicly available documents. These data sources provide different, and at times contrasting, perspectives. Such differences are treated as analytically informative rather than problematic, as they reflect the socially constructed and context-dependent nature of organisational realities, thereby supporting the study's dependability. Other forms of triangulation were not applied. For instance, the study did not employ methodological triangulation (e.g. observation or action research), researcher triangulation, or theory triangulation (Easterby-Smith, 2021). This decision is consistent with the interpretive orientation of the study, which prioritises coherent, in-depth understanding over comparison or measurement. Future research could build on these findings by applying longitudinal, participatory, or multi-researcher designs to further explore the implementation and development of practical actions related to sustainability, the CE and digitalisation.

Researcher reflexivity and peer debriefing

The researcher explicitly addressed potential subjectivities and personal assumptions in Section 4.2. Throughout the study, ongoing self-reflection ensured awareness of own assumptions and experiences and how they were influencing the research process and findings. Discussing the research process, findings, and interpretations with fellow researchers helped identify potential biases and alternative explanations. This study benefited from regular exchanges with researchers from various disciplines working on sustainability, the CE and digitalisation in the T&C industry. Feedback was gained through peer-reviewed publication processes, collaborative book projects (e.g., Wynn & Wiegand, 2025), doctoral colloquia, and supervisory meetings, which supports the dependability and confirmability of the study.

Transparency in Reporting

The presentation of findings in this thesis integrates quotations and excerpts from raw data to substantiate the study's claims and provide insight into the interpretive process. This approach not only enhances the clarity and persuasiveness of the findings but also allows readers to judge the quality and relevance of the data, thereby reinforcing the credibility and dependability of the study.

4.6.2 Ethical Considerations

Research ethics concerns both the conduct of researchers during the research and the potential impact of the research and its findings on participants and third parties (Saunders et al., 2023). Researchers are expected to act ethically throughout the entire research process. This includes considering both immediate and long-term consequences for individuals, groups, or institutions under investigation, their stakeholders, and even the researchers themselves. Ethical decisions must always prioritise the well-being of those involved (Saunders et al., 2023).

This study was conducted in full accordance with the Handbook of Principles and Procedures (as of March 2024) of the University of Gloucestershire. The following key principles were adhered to:

Voluntary participation and informed consent

All participants were approached be e-mail or phone and asked whether they were willing to take part in this study. Participation in the interviews was entirely voluntary; no participant was under any obligation and could withdraw from the interview process at any time. Written informed consent was obtained from all participants, confirming that the data collected through the interviews could be used for research purposes and potential publications. Participants were also assured that all findings would be presented in anonymised form.

Consent for recording

Prior to the start of each interview, participants were explicitly asked for their consent to record the conversation, and all interviewees agreed to that. It was clearly communicated when the recording began and ended.

Confidentiality and data protection

To ensure confidentiality and protection of all interview data, the raw data were stored on external password-protected devices inaccessible to third parties. Recordings were transcribed immediately after each interview and anonymised, ensuring that only anonymised data were used during the subsequent analysis. All collected data were used exclusively for research purposes. All documents used in the document analysis were publicly available and consisted of information either published or explicitly released by the respective companies. In the reporting of findings, companies are also presented in anonymised form to prevent the identification of individual interviewees.

Researcher independence

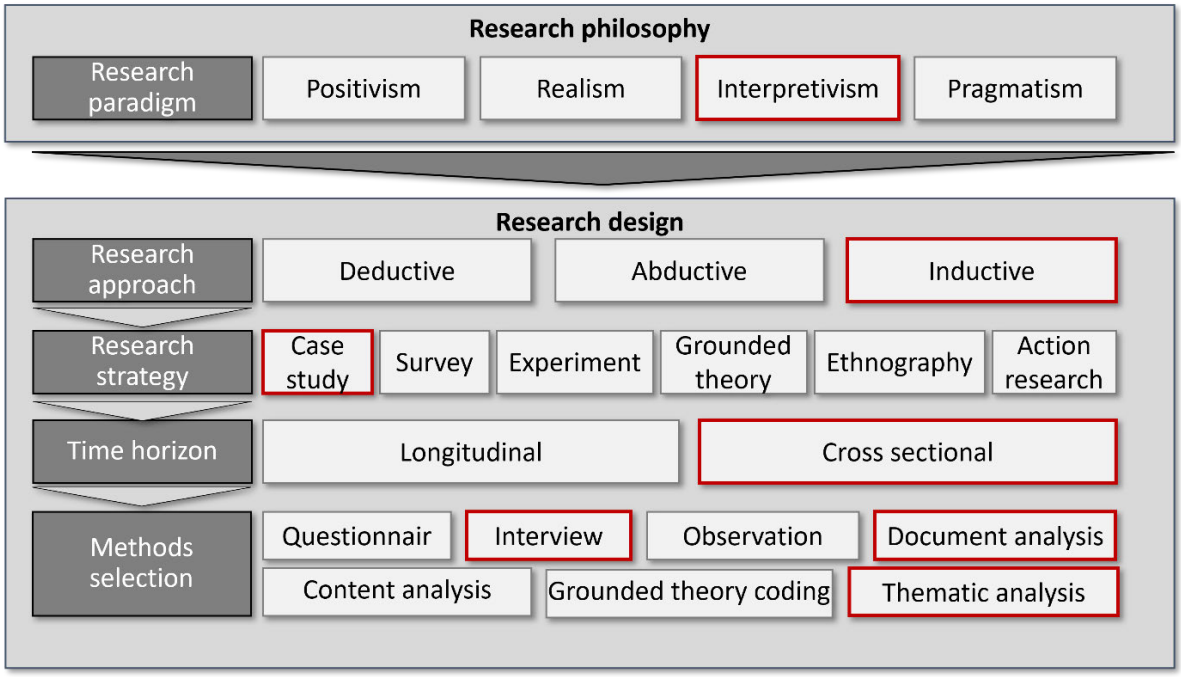
At the time of the study, the researcher was not employed by any company in the T&C industry and was therefore not subject to any organisational obligations or conflicts of interest. Additionally, power dynamics during the interviews were not a concern. All interviewees held senior decision-making positions within German T&C companies and were not influenced by the researcher during the study.

4.7 Summary

In this chapter the methodological approach used to investigate the research questions presented at the end of Chapter three, was outlined. Grounded in an interpretivist philosophical stance, the study employed an inductive, qualitative research design to explore the complex and under-researched phenomenon of the transition to sustainability and the CE and the role of DTs in this context. The research design followed a case study strategy using a cross-sectional approach. This means that data collection was conducted at a single point in time, allowing for interpretation of the status quo rather than capturing developments or processes. This design aligns with the overarching research objective of understanding the current state of the transition to sustainability, the CE and digitalisation in the German T&C industry. In line with this objective, company selection followed theoretical and purposive sampling strategies. The focus was on T&C companies actively committed to sustainable practices, with attention to diversity in company size and economic activity. Data collection was based on a combination of document analysis and semi-structured expert interviews with decision-makers from the industry. The data analysis followed Braun and Clarke's (2006) six-phase thematic analysis approach, incorporating both data-driven and concept-driven coding strategies and supported through the use of NVivo software. Finally, the chapter presented and explained the measures taken to ensure the trustworthiness of the study and its findings, as well as the adherence to ethical research standards in accordance with the University of Gloucestershire's Handbook of Principles and Procedures. Figure 33 summarises the philosophical assumptions and the corresponding methodological decisions made by the researcher for this study. The chosen research approach, in combination with the selected methods, provided a robust and transparent basis for generating practical insights into the transition to sustainability, the CE and digitalisiation the German T&C industry. In the Chapter five, the findings that emerged from the methodological procedures described above are presented and detailed.

Figure 33

The author´s philosophical position and research design decisions



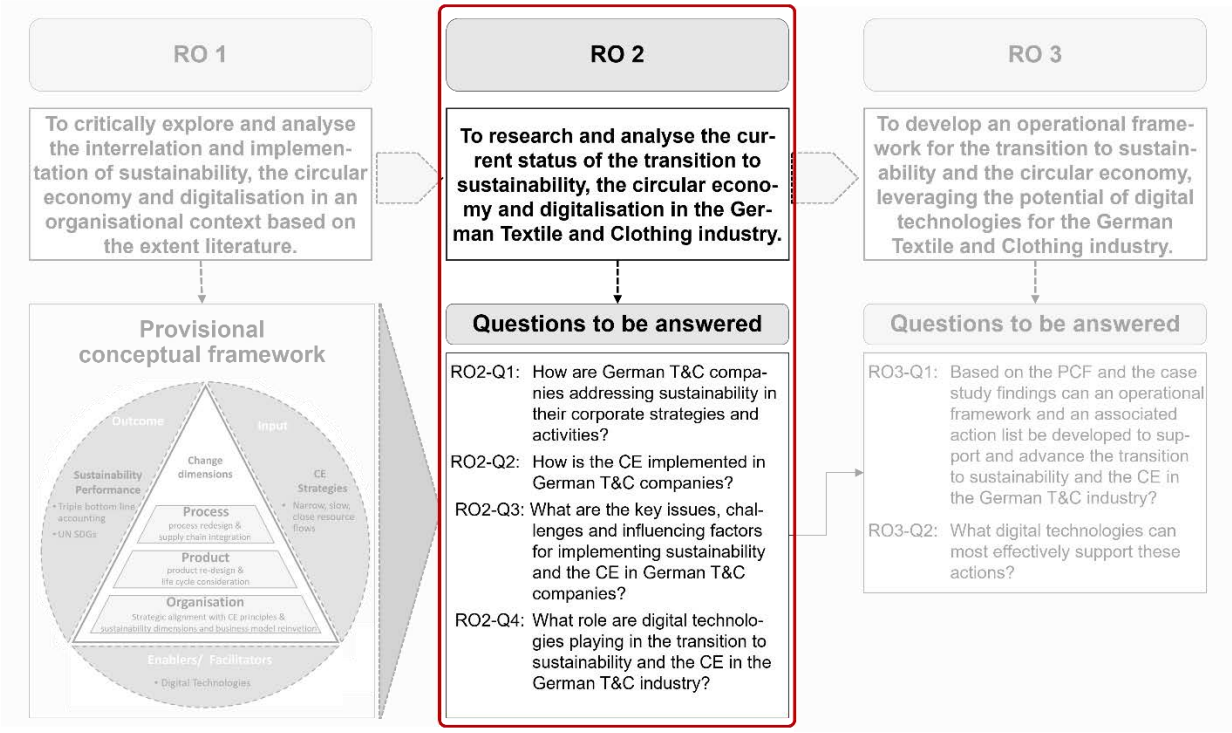
Source: The author, based on Saunders et al., 2023 and de Vaus 2009, p. 9

5 FINDINGS AND ANALYSIS

5.1 Introduction

The previous chapter outlined the research design and described the various methods of data collection employed in this study. This chapter presents the aggregated findings derived from the document and interview analysis. It also builds the basis for the development of an operational framework for the transition to sustainability, the CE and digitalisation in the German T&C industry. These findings address RO2 and respond to the associated questions Q1 – Q4 (Figure 34).

Figure 34
Research objective 2 and associated research questions addressed in this chapter



This chapter presents the key findings, organised thematically in alignment with the study's aims. The analysis draws on data from company websites, internal documents, and expert interviews. Direct quotations are included where appropriate, and pseudonyms are used to ensure the anonymity of participants. A total of 430 documents were collected from 29 companies, and expert interviews were conducted with representatives from 10 of these companies. A transcript was created for each interview, which was included in the total number of documents. So, in total, 440 documents were analysed (Table 14). While sustainability websites were available for all 29 companies,

only 20 companies published sustainability reports. Moreover, 19 companies disclosed sustainability strategies or guidelines, and 22 companies provided other sustainability-related publications such as codes of conduct or supplier guidelines. Trade journals proved to be an important supplementary source, with 16 companies being covered in relevant articles.

Table 14

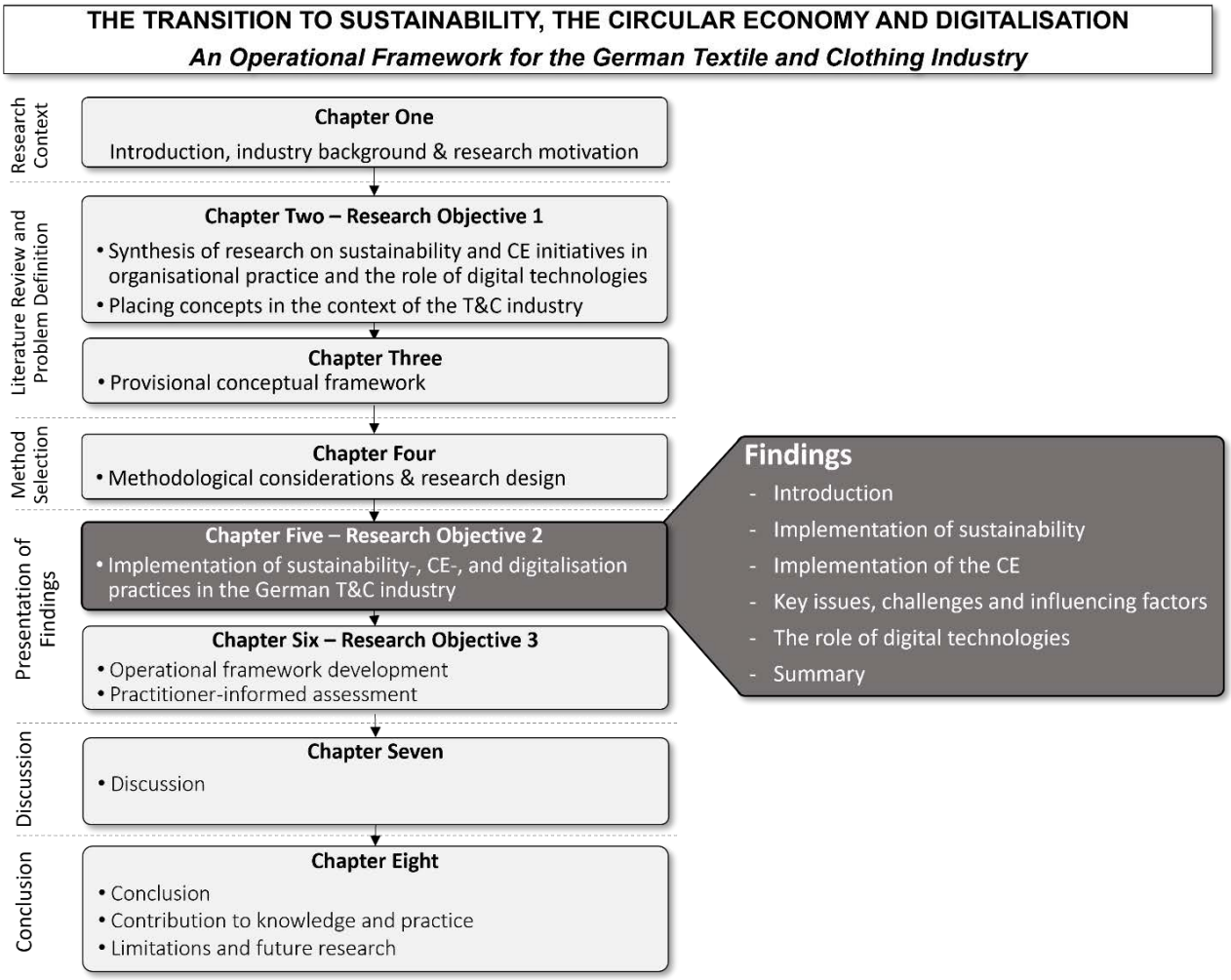
Overview of case study companies with size class, management structure, and publicly available sustainability information

Company Code	NACE CODE	Company Size according to EU SME definition	Family/ owner managed	Relevant documents included in analysis						Number of documents analysed
				Sustainability website	Sustainability report	Company-related articles In industry trade journals	Published sustainability strategy/ policy	Other published sutainability-related documents	Interview transcript	
C01	13	SME	no	X	X	X	X	X	-	**25**
C02	13	SME	yes	X	-	X	-	X	-	**7**
C03	13	SME	yes	X	X	X	X	X	-	**26**
C04	13	large	yes	X	X	X	X	X	-	**12**
C05	13	SME	yes	X	-	X	-	X	X	**11**
C06	13	SME	no	X	-	X	-	X	X	**17**
C07	13	SME	no	X	-	X	X	-	X	**6**
C08	13	large	yes	X	-	X	-	X	X	**16**
C09	13	SME	yes	X	X	-	-	-	X	**3**
C10	13	SME	yes	X	-	-	-	-	X	**3**
C11	13	SME	yes	X	-	-	-	-	X	**5**
C12	14	SME	yes	X	-	-	X	X	X	**4**
C13	14	SME	yes	X	X	-	X	X	-	**8**
C14	14	SME	yes	X	X	-	X	X	-	**4**
C15	14	SME	yes	X	X	X	X	X	-	**9**
C16	14	SME	yes	X	X	X	X	X	-	**16**
C17	14	SME	yes	X	-	-	-	-	-	**9**
C18	14	SME	yes	X	X	X	X	X	-	**10**
C19	14	SME	yes	X	X	-	X	X	-	**4**
C20	14	SME	yes	X	X	-	X	-	-	**7**
C21	14	SME	yes	X	X	-	-	X	-	**5**
C22	14	SME	no	X	X	X	X	X	-	**15**
C23	14	large	yes	X	X	X	X	X	-	**23**
C24	14	SME	yes	X	X	-	X	X	-	**12**
C25	14	SME	no	X	X	X	X	X	X	**50**
C26	14	SME	no	X	X	-	X	-	-	**3**
C27	14	SME	yes	X	X	X	-	X	-	**17**
C28	14	large	yes	X	X	X	X	X	X	**101**
C29	14	SME	yes	X	X	-	X	X	-	**12**
			Total	**29**	**20**	**16**	**19**	**22**	**10**	**440**

Following this introduction, Chapter five is structured into six sections (Figure 35) and provides the foundation for the framework development in Chapter Six. Section 5.2 examines how the case study companies address sustainability in their strategies and activities (RO2–Q1). Section 5.3 explores how they implement CE practices (RO2–Q2). Section 5.4 investigates the key challenges, issues, and influencing factors in implementing sustainability and the CE (RO2–Q3). Section 5.5 focuses on the role of DTs in the transition (RO2–Q4). Finally, Section 5.6 summarises the key findings of the chapter.

Figure 35

Structure of Chapter Five in context of the thesis



5.2 Implementation of Sustainability (RO2 – Q1)

The analysis of documents and interviews indicated that the understanding of sustainability and the measures reported extend across all three core areas of corporate sustainability - corporate governance, environmental impact, and social responsibility. At the same time, the way these are prioritised and interpreted differs markedly across the case study companies. The findings also indicate differences between companies in the textile industry (NACE Code 13) and those in the clothing industry (NACE Code 14), as well as between companies of different sizes. For instance, among the companies in the clothing industry, 16 of 18 (76%) are publishing dedicated sustainability reports, even though they are not legally required to do so. In contrast, only 4 of 11 (36%) companies in the textile industry are publishing targeted sustainability reports (Table 14). From the data analysis, thirteen key themes emerged that were assigned to the three change dimensions, offering insights into how the case study companies are addressing and implementing sustainability across the organisational, product, and process dimensions (Table 15). The individual themes for each change dimension are presented and described in detail hereafter.

Table 15

Strategies and activities related to sustainability at the organisational, product, and process levels in the case study companies

Change dimension	Themes
Organisation	Sustainability strategy and objectives
	Integration of sustainability management into corporate structure and culture
	Sustainability-related communication, cooperation and collaboration
	Adoption of sustainable and/or circular business models
	Corporate citizenship
Product	Product design & development
	Material selection
	Product certification
	Packaging
Processes	Risk management
	Cross-supply chain transparency
	Responsible production and procurement
	Greenhouse gas emissions reduction

5.2.1 Organisation

At the organisational level, the analysis indicated that sustainability is strategically and structurally embedded within the case study companies. 23 of 29 companies (79%) are family- or owner-managed, in some companies for several generations (Table 14), reflecting a strong long-term orientation and regional rootedness. Senior management actively assumes environmental and social responsibility, integrating these aspects into the company's overall strategy and operations. This indicates a strong commitment to sustainability, rooted in long-term thinking and a sense of responsibility across generations, as C01 states: "As an independent family business in its fourth generation, we are very familiar with long-term planning and responsible action". The other six companies are owned by investors, but also in these companies, sustainability appeared to be firmly established as a strategic responsibility of senior management. This was apparent in the organisational embedding of sustainability management, both structurally and culturally, and in the company's broad engagement with stakeholders.

Sustainability Strategy and Objectives

International goals and agreements - such as the SDGs and the Paris Climate Agreement - along with national and international legal frameworks, emerged as key drivers and guidelines shaping the development of corporate sustainability strategies. The case study companies explicitly commit to supporting these objectives and aim to contribute through their core business strategies and activities. This commitment is reflected in the efforts to align both strategic goals and operational measures with regulatory requirements and broader policy agendas, with the overarching aim of minimising the companies` ecological and social impacts while maintaining and expanding economic viability. This demonstrates that companies align their performance with the three dimensions of the triple bottom line. For instance, C14 refers to "linking the 17 United Nations SDGs with the company's values and processes" as a core element of its corporate strategy, while C25 explicitly focuses on selected SDGs as strategic priorities. However, others, like C07 and C16, do not explicitly reference these goals and frameworks, but their strategic objectives - such as the avoidance of environmental impacts and the reduction of CO_2 emissions - indicate that their actions are aligned with these overarching agendas. Additional illustrative references from the companies regarding their sustainability commitment are provided in Table 16.

Table 16

Illustrative references on the alignment of corporate strategies and objectives with international sustainability goals and frameworks from the case study companies

Theme	Illustrative references
International goals & agreements	C01: "We are also committed to contributing to the United Nations Sustainable Development Goals (SDGs) – primarily through our sustainable core business but also by supporting social and environmental projects beyond our business activities."
	C04: "The adoption of the Sustainable Development Goals mark the next step for our sustainability reporting. [...] This enables us to identify areas where our actions can contribute to achieving the shared targets by minimizing any negative impact."
	C07: "Our aim is to constantly reduce and avoid the environmental impact of products, raw materials and production processes."
	C14: "An integral part of the corporate strategy is linking the 17 United Nations SDGs with the company's values and processes."
	C15: "Although we don't work with the SDGs in our daily operations, we have used benchmarking to evaluate how our sustainability strategy (including goals and measures) contributes to these SDGs."
	C16: "[C16] is committed to minimizing environmental impacts by using resource-saving materials, reducing waste and promoting environmentally friendly production methods. We strive to reduce our CO^2 emissions and implement sustainable sourcing practices."
	C25: "[C25] is particularly committed to the following development goals: SDG 5 'Gender equality', 6 'Clean water and sanitation', 8 'Decent work and economic growth', SDG 9 'Industry, innovation and infrastructure', SDG 12 'Sustainable consumption and production patterns', SDG 13 'Climate protection measures', SDG 14 'Life under water', 15 'Life on land' and SDG 17 'Partnerships to achieve the goals'."
	C28: "The development of our strategy is primarily guided by international political goals and frameworks such as the SDGs – the United Nations' Sustainable Development Goals; the Paris Climate Agreement; and the concept of planetary boundaries. These provide us with guidance on which issues are relevant in order to find the best possible solutions for people and our environment."
Laws & regulations	C22: "We will ensure that sustainability is truly diffused and practised in all areas. However, we must increasingly focus on what is required by law. This is becoming more and more, which means that there is no longer so much room for additional commitment, even though we expressly support these legal requirements as an important step towards greater sustainability in the economy."
	C23: "The basis for this is the implementation of the increasing legal requirements in Germany and the EU, which already set the demanding path."
	C28: "Although [C28] is not subject to the Supply Chain Due Diligence Act due to the company size we have nevertheless been complying with its requirements for a long time – voluntarily and out of conviction."

Integration of sustainability management into corporate structure and culture

The anchoring of sustainability within the case study companies was further reflected in the fact that sustainability goals and measures are actively managed. This is particularly apparent in two key aspects:

Firstly, sustainability-related corporate objectives are formulated to guide various operational business areas and to align sustainability initiatives with the company's economic goals and interests. For instance, C06 states on its sustainability webpage: "We are currently in the final steps of defining our strategic goals for 2030, which include initiatives in water reduction, carbon footprint reduction, sustainable product development, and innovative recycling concepts. These goals reflect our commitment to environmental responsibility and our role in the sustainable transformation of the textile industry". C18 describes its strategic process in its sustainability report as follows: "We have given concrete form to our vision by specifying 117 objectives and made sure that our decisions are guided by integrity. We started the implementation with a set of more than 400 actions to be applied across all areas of the company".

Secondly, it is apparent in the structural and cultural embedding of sustainability within the organisation, reflected in a clear assignment of responsibilities for sustainability-related topics and tasks to dedicated positions, teams, or departments. While C01 states that it has promoted sustainability since its founding and anchored it within the management team, most other companies have only recently established dedicated

positions and responsibilities for sustainability. For example, C03 emphasises: “The establishment of an independent staff position for sustainability management in 2016 was an important step for us. This both professionalised and strategically aligned the company’s commitment. […] Our Sustainability Manager is the go-to person for everyone and everything related to sustainability”. C04, in turn, consolidated its sustainability responsibilities into a newly established department: “In 2022, we consolidated our efforts in corporate social responsibility with the establishment of our own department, gaining even more impact”. In the cases of C09, C26, and C29, responsibility for sustainability lies directly with the executive management. C09 states that the daughter of the owner “represents the third generation of the family to continue the tradition. She joined the company in 2021 and is primarily responsible for Change Management and Sustainability”. In contrast, C26 has deliberately chosen not to assign sustainability to a central role, but instead to share the responsibility across its departments: “The durability of our products is both a product feature and an environmental measure. Isolated decisions would not be beneficial here. Personal responsibilities exist in areas such as product development, responsible corporate management, environmental management, and social matters, but continuous coordination within the team is essential. The final decision on the specific form of initiatives and measures rests with management”. Regardless of the specific structural anchoring, four key areas of responsibility emerged from the analysis as central tasks of sustainability management in the case study companies:

Firstly, sustainability managers are frequently positioned as central contact points and support resources for all sustainability-related issues. One of their key responsibilities is the development of sustainability strategies, objectives, and measures, along with reporting and providing strategic advice to senior management (e.g., C03, C15, C18, C28).

Secondly, sustainability management is tasked with ensuring transparent communication and fostering awareness and competencies related to sustainability among internal and external stakeholders, while actively contributing to the development of a sustainability-oriented corporate culture (e.g., C01, C03, C18, C20).

Thirdly, coordinating and steering the achievement of sustainability objectives through interdisciplinary collaboration with various departments and management levels. In this function, sustainability management seems to act as an interface to both internal and

external partners to support the operational implementation of sustainability practices (e.g., C03, C18, C22, C23, C28).

Fourthly, sustainability management is responsible for developing performance indicators to monitor and evaluate progress toward sustainability objectives, as well as ensuring compliance with relevant sustainability-related standards, laws and regulations (e.g., C14, C18, C23).

Figure 36 summarises the findings by illustrating corporate sustainability management as a central institution that integrates sustainability into both the corporate strategy and objectives and its organisational structure and culture. External legal and policy initiatives, such as the SDGs, act as the main drivers. Internally, the core responsibilities lie in translating these drivers into strategic objectives and operational measures, building awareness and knowledge among all relevant stakeholders, and initiating, coordinating, monitoring, and reporting on the implementation and achievement of the strategic objectives. Table 17 presents illustrative references for the four identified key tasks of corporate sustainability management from the case study companies.

Figure 36

Key drivers and tasks of sustainability management in the case study companies

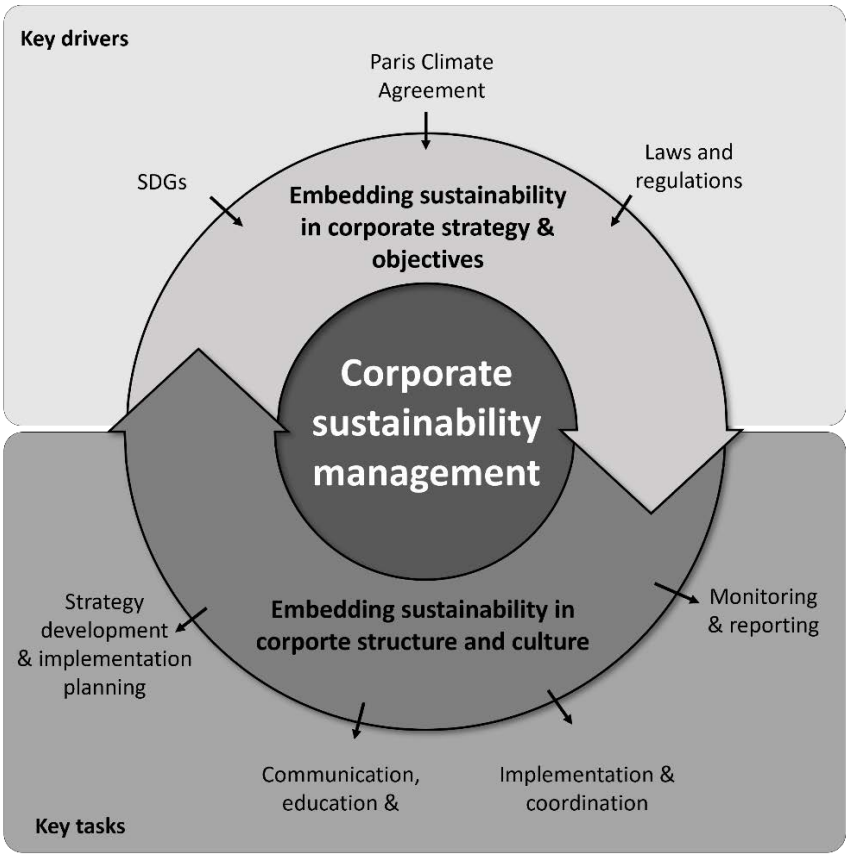


Table 17

Illustrative references on key tasks of sustainability management from the case study companies

Responsibilities & tasks	Illustrative references
Strategy development & implementation planning	C03: "The establishment of an independent staff position for sustainability management in 2016 was an important step for us. This both professionalised and strategically aligned the company's commitment."
	C15: "At [C15], the CSR team is considered to be so important. This team is anchored in the company as an interface and offers independent advice and support in all sustainability matters."
	C18: "Our team „Quality, Values & Sustainability" advises management in respect of all aspects of sustainability; it coordinates the implementation of measures and communications. Our sustainability officer is the point of contact, both internally and externally, in all technical matters"
	C27: "We already established a Corporate Responsibility (CR) staff department in 2015, which, together with an interdisciplinary CR board, defines the strategic direction of all CR activities across the individual business units, which are supported by the CR staff in this process."
Communication & education	C01: "In 2022, all buyers were specifically trained on principles of ethics and responsible sourcing through workshops. The primary goal has been and continues to be to raise awareness among all stakeholders about their actions and their impact in the production countries."
	C03: "Sustainability management is not just about questioning the use of resources, technology and processes. It is also essential to involve and integrate the staff in the process. In addition to many small measures, our sustainability ambassadors are an important factor in developing a sustainable corporate culture."
	C18: "[…] We have also created an FAQ on our Fair Wear membership and its requirements for all colleagues in our in-house and sales teams, to guarantee correct communication toward our dealers. We also use guidance documents to inform our dealers how they can communicate with end customers about our collaboration with Fair Wear."
	C20: "We encourage open communication within our team. To this end, we meet regularly in discussions and focus meetings to make relevant topics accessible and create space for constructive dialogue, for example in our sustainability project group, which includes all departments."
Implementation & coordination	C03: "Together with the Sustainability Manager, measures are developed for the individual company divisions, thus setting the course for a sustainable future. Our Sustainability Manager acts as a hub for everyone and everything related to sustainability."
	C18: "[...] it coordinates the implementation of measures and communications. Our sustainability officer is the point of contact, both internally and externally, in all technical matters."
	C22: "The CSR department is responsible for the strategic and operational coordination and implementation of sustainability in all areas of the company. The four-person team ensures that future-oriented sustainability guidelines are defined and adhered to – focusing on the supply chain and products in particular."
	C22: "To ensure successful implementation, we have assembled the "CARBON ACTION CIRCLE", a dedicated team to coordinate the necessary steps, continuously monitor the process and measure the annual progress of the reduction."
	C23: " As a central point of contact, the team [Global Sustainability & Supplier Relationship Management] is responsible for the further development and implementation of our sustainability strategy."
	C28: "All sustainability-related activities are coordinated by an interdisciplinary CSR team. […] They introduce topics and ensure the implementation of sustainability goals in their areas of responsibility."
Monitoring & reporting	C14: "To ensure direct communication and strategic planning, we aim to conduct on-site visits to our garment manufacturers and suppliers. We will introduce management consultations on sustainable practices and review the agreed sustainable measures through regular audits and evaluations."
	C18: "[The sustainability officer] documents the indicators and the values of performance indices, directs the annual internal audits and drafts the sustainability programme. The responsible officer reports regularly to company management and cooperates closely with other designated officers in-house (e.g. for industrial health and safety)."
	C23: "The Global Sustainability & Supplier Relationship Management department reports directly to the executive board as a central staff unit for the entire group. This ensures that sustainability issues and requirements are integrated into the corporate strategy and projects as well as incorporated into the management target structure via relevant KPIs."

Sustainability-related communication, cooperation and collaboration

As previously outlined, one of the core responsibilities of sustainability management in the case study companies is to engage both internal and external stakeholders, raise their awareness of sustainability issues, and empower them to actively contribute to achieving sustainability objectives. Four stakeholder groups emerged as particularly significant and relevant in this context (Figure 37).

Firstly, employees were consistently identified as a key stakeholder group for embedding a sustainability-oriented corporate culture. They are also perceived as an important driver of sustainability performance. This is reflected in practices aimed at raising awareness and integrating employees into sustainability-related activities. For example, C22 noted that "employees also learn about the company's sustainability efforts during the onboarding process and as part of regular informative events", while C27 reported to hold "[…] regular trainings for purchasers to raise awareness for the impact of purchasing practices". These examples indicate that employees are systematically informed about the objectives, rationale, and measures associated with sustainability initiatives, enabling them to align their behaviour and contribute to implementation.

Secondly, supply chain partners, such as direct suppliers, are described as actively involved in sustainability efforts to raise awareness, especially on human and labour rights, through targeted information sharing and training. This early engagement is understood by companies as a way to mitigate risks and initiate change beyond the company's immediate sphere of influence. In most companies, initiatives are developed and implemented in cooperation with private sector actors, non-profit organisations, or local NGOs. C23 for instance "worked with Fair Wear [Foundation] to conduct training sessions for workers and management at 15 suppliers". These collaborations are presented by the organisations as mechanisms to promote sustainable practices across their supply chains and support long-term changes on both social and environmental levels.

Customers and consumers represent the third stakeholder group, particularly for clothing manufacturers (NACE 14) who maintain direct contact and dialogue with consumers. In the context of sustainability communication, their role is considered highly significant. The objective is interpreted as to raise awareness and foster knowledge regarding sustainable products and responsible consumption behaviour. Activities in this context range from educational campaigns on the impacts of fast fashion and the benefits of sustainable consumption (e.g., C17) to guidance on the proper use, care, and

maintenance of textile products (e.g., C02) or appropriate disposal and recycling options to support a more circular approach to product lifecycles (e.g., C15, C18).

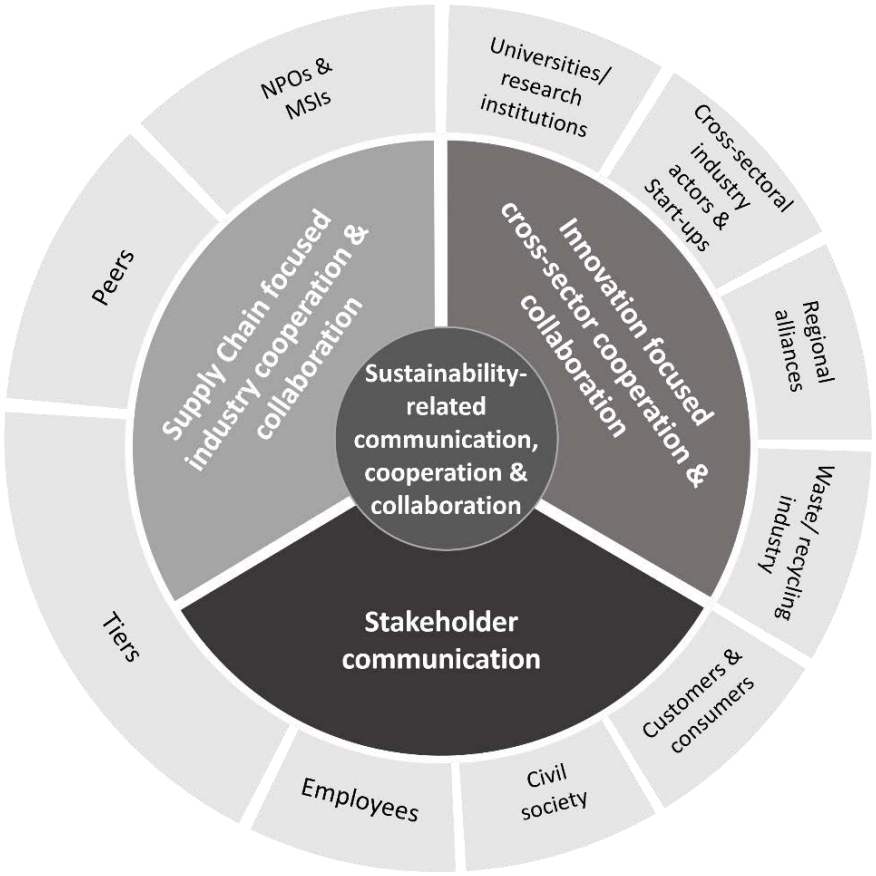
The fourth stakeholder group that emerged from the analysis is civil society, who is primarily engaged through regional initiatives and communication on sustainability-related topics. For instance, C05 is an active member of a regional initiative for sustainable economic development, which “has made it their mission, among other things, to strengthen ecological awareness in the region’s business enterprises and among the population”, while C03 is engaged in “direct dialogue with society through presentations and events at [their] company or externally”. This suggests that companies seek to inform and involve local communities, recognising their importance in fostering broader societal awareness and support for sustainable development. Table 18 provides further illustrative references on stakeholder groups and engagement from the case study companies.

The analysis further indicated that companies across different sizes and both sub-sectors described active involvement in a wide range of regional and international sustainability projects and initiatives. These collaborative efforts span the entire value chain, from raw material sourcing to end-of-life recycling, and are categorised, based on the analysis, into two main types: supply chain-focused industry cooperation and collaboration, and innovation-focused cross-sector cooperation and collaboration (Figure 37). Supply chain-focused industry cooperation and collaboration primarily entails partnerships with supply chain actors (tiers and peers) (C01, C13, C18, C22, C28), as well as engagement in non-profit organisations (NPOs) and multi-stakeholder initiatives (MSIs) (C12, C13, C19, C23, C24, C29). These joint efforts are designed to pool resources to reduce social and environmental risks along the supply chain, ensure compliance with international standards, and drive systemic improvements across production contexts. Innovation-focused cross-sector cooperation and collaboration emerged as particularly relevant for driving sustainability-related changes, as it was associated with innovation in materials, products, processes, and business models. Reported partnerships include research institutions (C01, C09, C27) cross-sectoral industry actors and start-ups, local alliances (C04, C05, C18, C25, C28), as well as actors from the waste and recycling sector (C04, C06, C14). C25 described such collaborative activities as a powerful lever to accelerate necessary change: “The more we connect as an industry, i.e. brands, manufacturers and retailers, and work together to improve the sustainability of our products, the faster we can drive the necessary change”. Similarly,

C05 views such partnerships as the foundation for innovation and the long-term competitiveness of German companies: “Close cooperations with leading machine manufacturers and research institutes ensure high product quality and form the basis for innovations made in Germany”. Table 19 provides an overview of illustrative references for sustainability-related cooperation and collaboration approaches reported by the case study companies.

Figure 37

Types and partners of sustainability-related communication, cooperation and collaboration identified in the case study companies



(NPO = Non-Profit Organisation; MSI = Multi-stakeholder initiative)

Taken together, the findings suggest that sustainability in the case study companies is understood and addressed as a shared responsibility. This involves intensive communication and interaction with key stakeholders to foster knowledge and competences, as well as cooperation and collaboration with partners along the value chain to reduce negative environmental and social impacts. Beyond that, opening to and increasingly networking with actors from other sectors and industries seems to play a central role in driving the development of sustainable solutions and innovations.

Table 18

Illustrative references on sustainability-related stakeholder involvement and engagement from the case study companies

Stakeholder group	Illustrative references
Employ-ees	C03: "[…] employees are therefore sensitised to sustainability issues in training courses and workshops."
	C18: "All of our employees know our strategy and support it."
	C22. "[…] employees also learn about the company's sustainability efforts during the onboarding process and as part of regular informative events."
	C27: "[…] regular trainings for purchasers to raise awareness for the impact of purchasing practices."
Supply chain partners	C13: „In order to identify risk situations and nip them in the bud, the Fair Wear Foundation offers "Workplace Education Programmes" on a variety of topics. We always try to ensure that these are scheduled for our manufacturing partners."
	C18: "In partnership with [name], a German service provider in the field of social dialogue with a focus on the textile sector, we have also developed training programmes for workers that focus on the topics of gender, health and safety, social dialogue, and grievance mechanisms."
	C23: "[…] we worked with Fair Wear to conduct training sessions for workers and management at 15 suppliers in our supply chain. The training promotes mutual understanding and strengthens processes and structures in the factories."
Customers & consumers	C02: provides tips for consumers on their website on "how to care for our products to maximise their lifespan, how to darn and sew them after accidents and how to use them for other purposes"
	C15: provides tips und links for consumers on their website, „on what you can do, if you no longer wear your [C15] products or they are worn out"
	C17: provides a guide to conscious fashion consumption in their blog to: "educate customers about fast fashion and its impact, and offer a more sustainable alternative"
	C18: "encourage consumers to give their used clothing a second life (clothing exchange or donation, upcycling) or, at the very least, to commit it to proper recycling."
	C19: "In the future, we want corporate fashion to not only look good, but also always use natural resources responsibly. We have set ourselves the goal of raising awareness of this issue among our customers and encouraging them to use appropriate fabrics, accessories, and packaging."
	C22: "We encourage our B2B customers to bundle their orders. We are aware that dealers are walking a fine line in this respect. Customer service and speed, flexibility, storage capacity, capital investment and more have to be weighed up against environmental and economic sustainability. Nevertheless, we can see huge potential for savings and are determined to raise the necessary awareness among buyers."
Civil society	C03: "It is not only in the Partnership for Sustainable Textiles that we foster dialogue with civil society. We maintain a direct dialogue with society through presentations and events at our company or externally."
	C05 is an active member of a regional initiative for sustainable economic development, which "has made it their mission, among other things, to strengthen ecological awareness - in the region's business enterprises and among the population"
	C28 initiated a regional initiative to switching to renewable energy sources through workshops on "the involvement of [name of place] residents, the use of photovoltaics and climate-friendly mobility"

Table 19

Illustrative references on sustainability-related cooperations and collaborations from the case study companies

Type of cooperation / collaboration	Partners	Illustrative references
Supply chain focused industry cooperation & collaboration	Suppliers / Tiers	C01: "Since 2022, we have initiated a project in collaboration with the German development agency (GIZ) and several clients to increase the supply of organically grown cotton. This initiative supports 450 farmers in Gujarat, Western India, in transitioning from conventional to organic cotton cultivation."
		C13: "Sustainability is best accomplished together, which is why, in spring 2024, we invited our customers and supply-chain partners to a sustainability forum in Cologne. The event slogan was “TOGETHER. SUSTAINABLE. SUCCESSFUL.” This type of collaboration with our partners in the textile chain gives us new perspectives and enables us to develop new sustainability concepts."
		C28: "Together with our partners in the supply chain, we have made enormous efforts to massively reduce greenhouse gas emissions in the manufacture of the materials for our products."
		C18: "We have had a close and trusting working relationship with our largest production plants in Turkey and Bangladesh for more than 20 years. We have grown together, and together we drive the continuous improvement of social and environmental standards."
	Peers	C01: "As an SME, we realise that individual brands generally don't have enough leverage to implement measures with long-term effects. Not to mention sufficient budget and human resources. When several brands join forces, they pool their experience, knowledge and clout."
		C13: "In 2019, [C13] joined forces with Fairtrade and other partners from the work clothing industry to launch the pilot project Supporting Fairtrade Cotton, the aim of which is to increase the percentage of fairly traded cotton in the industry."
		C18: "Together with the clothing company OLYMP Bezner KG, we mastered the challenging task of developing a social audit system adapted to our specific needs, the iMPACT Program."
		C22: "Without additional creativity or changes in cash flow, the CSR budgets of individual companies would not be sufficient to generate the necessary resources for the far-reaching and long-term changes required. However, the European outdoor industry has strong connections and - generally speaking - a very similar understanding of sustainability, which offers it a great opportunity to tackle these challenges in a different way: With a collaborative approach."
		C28: "Together with nine other outdoor brands, [C28] has been involved in the European Outdoor Group's (EOG) Carbon Reduction Project since 2021, which aims to reduce greenhouse gas emissions at the material supplier level."
	Non-profit organisations & multi-stakeholder initiatives	C12: "Where we have little influence, we enter into partnerships with other players. This includes, for example, industry or multi-stakeholder initiatives."
		C13: "There are, however, various different approaches and ideas that we are developing together with the Fair Wear Foundation (FWF) and the Partnership for Sustainable Textiles to successively improve wages and salaries [in the supply chain]."
		C19: "However, sustainability can only be implemented holistically if social and environmental risks are recognised along the supply chain. Collaboration with national and international institutions and independent organisations is essential for the communication with customers and partners, as these partnerships enable an objective assessment of such risks.”
		C23: "As we are only one player among many in the international textile supply chain and many challenges are systemic, we need cross-sector collaboration. That is why we work with recognised national and international partners such as the Fair Wear Foundation, the International Accord for Health and Safety in the Textile and Garment Industry, the Partnership for Sustainable Textiles and the Zero Discharge of Hazardous Chemicals (ZDHC) organisation."
		C24: "[C24] collaborates with MADE in Myanmar, the Multistakeholder Alliance for Decent Employment in Myanmar, and in Bangladesh with the RSC, the Ready Made Garment Sustainability Council.”
		C29: "Only together is it possible to exert a long-term positive impact on people and the environment. That is why we are involved in various associations — to learn from one another and to implement joint projects."

Table 19: Continued

Type of cooperation / collaboration	Partners	Illustrative references
Innovation focused cross-sector cooperation & collaboration	Universities/ research institutions	C01: "To make sure we stay up-to-date with the latest findings, we regularly engage with representatives from the fields of science, business and independent organisations. This allows us to continually develop new recyclable products and solutions."
		C09: "In the coming years, we will therefore be working together with the Institute of Materials Science at Hof University of Applied Sciences on the development of innovative tube and furniture designs that enable the sensible further processing of heterogeneous textile waste."
		C27: “We are also in contact with RWTH Aachen University to support their research into recycling with expertise, labour and goods”
	Cross-sectoral industry actors & Start-ups	C04: "Our "Open Innovation" concept brings together like-minded market participants and helps to identify unmet consumer needs and to develop corresponding solutions."
		C05: "Close cooperations with leading machine manufacturers and research institutes ensure high product quality and form the basis for innovations made in Germany."
		C18: "The founders of the young company passionately care about quality and share our values. They see the collaboration with [C18] as a great opportunity and want to expand their textile production together with us to create a responsibly managed production site that can serve as a role model for others. This offers us the wholly new opportunity to help shape the working conditions at a partner company from the beginning.”
		C25: "The more we connect as an industry, i.e. brands, manufacturers and retailers, and work together to improve the sustainability of our products, the faster we can drive the necessary change [...].”
		C28: "In cooperation with the Finnish forestry specialist UPM, [C28] is working on what it claims is the first fleece jacket made from wood-based polyester. The two companies want to show that the textile industry can already switch to renewable materials today and are working flat out to produce larger quantities for the entire industry."
	Regional alliances	C04: "A major initiative in this regard is the transition of our energy supply to hydrogen, for which we are joining as a founding member of the Hydrogen Alliance of the Danube Region Kelheim-Regensburg."
	Waste/ recycling industry	C04: "To take a step further in the direction of developing resource- and waste-reducing solutions, we initiated a commercial collaboration with Renewcell, a sustaintech company based in Sweden. Together we will collaborate on developing commercial scale production of superior quality viscose fibres using Renewcell's 100% textile recycled material Circulose®."
		C06: "The partnership includes cooperation in the development and marketing of yarns and fabrics made from Itochu's Renu recycled polyester fibre blended with wool for the worsted yarn industry."
		C14: "Together with our recycling partners, we are creating the opportunity to further reduce the use of virgin raw materials in a sustainable way, therefore a closed-loop model is currently being tested and co-developed for this purpose.”

Business model adaptation

The integration of social, environmental, and economic dimensions into both strategic development and organisational structures suggests that business models – that is, the way companies operate (Magretta, 2002; Teece, 2010) – are undergoing change. They are increasingly designed to align profit generation with the minimisation of resource consumption, waste generation and the reduction of negative social and environmental impacts related to the business activities (Bocken et al., 2014). For the analysis of these changes, a theory-informed coding approach was adopted, in contrast to the general inductive procedure applied in the data analysis. The documents and interview transcripts were systematically examined and coded with regard to practices related to sustainable and circular business models, following the classification presented in Section 2.4.2 from Bocken et al. (2014); Ritala et al. (2018) and Pieroni et al. (2020). Based on this, a consolidated framework was developed comprising nine business model categories and 24 archetypes (Table 20). Only two of these categories pursue purely sustainability-related goals as defined by the TBL without explicitly following CE strategies, while the other seven categories focus on sustainability by actively aiming to narrow, slow, or close resource flows.

Table 20

Overview of business model categories and archetypes applied for theory-informed coding approach

Focus	BM Categories	BM Archetypes
Sustainability	**Social and environmental profit**	Adopt a stewardship role
		Re-purpose for society/ environment
Sustainability	**Collaborative impact**	Develop scale up solution
		Inclusive value creation
Sustainability & CE	**Demand and consumption reduction**	Dematerialised services
		Demand reduction services
		Encourage sufficiency
Sustainability & CE	**Collaborative consumption**	Sharing economy
		Sharing or pooling systems
Sustainability & CE	**Product-service systems**	Access model
		Performance or result model
Sustainability & CE	**Long life**	Lifetime products
		Products with life extension services
		Hybrid model
Sustainability & CE	**Next life**	Direct reuse
		Next life sales
		Product transformation
		Extending resource value
Sustainability & CE	**Sustianable and circular sourcing**	Asset management
		Industrial Symbiosis
		Natural / circular / renewable material and energy
Sustainability & CE	**Sustainable and circular production and distribution**	On demand
		Cleaner production and ecoefficiency
		Collection, take back, and reprocessing of used products and materials

Source: Compiled by the author based on Bocken et al., 2014; Ritala et al., 2018 and Pieroni et al., 2020

Table 21

Coding rules for categorising practices related to sustainable and circular business models

For an overview of associated references from the case study companies, see Appendix C.

BM Categories	BM Archetypes	Code Definition
Social and environ-mental profit	Adopt a stewardship role	Passages describing practices in which companies take on responsibilities beyond their core business to ensure the health and well-being of stakeholders, society or the environment (e.g.,transparent and/or certified supply chains, fair trade, active environmental/biodiversity protection).
	Re-purpose for society/ environment	Passages describing corporate practices that prioritise environmental and social aspects over profit maximisation or that are aimed at solving specific social or environmental problems (e.g. B Corp certification, social enterpise, not for profit, orientation at economy of common good).
Demand and consumption reduction	Dematerialised services	Passages describing practices where physical infrastructure, assets, or products are replaced with digital or virtual ones.
	Demand reduction services	Passages describing practices where companies provide solutions that moderate or reduce the use of energy and resources by individuals or organisations.
	Encourage sufficiency	Passages describing practices facilitating sustainable consumption and product life extension at customers and consumers.
Collaborative consumption	Sharing economy	Passages describing practices facilitating the sharing of products, assets, or services owned by individuals without monetary exchange.
	Sharing or pooling systems	Passages describing practices where products, assets, or services owned by individuals or organisations are shared, lent, or pooled among multiple users through transaction.
Product-service systems	Access model	Passages describing practices aimed at offering temporary access to products instead of ownership, e.g., through leasing or renting.
	Performance or result model	Passages describing practices aimed at offering performance or result related to a product, rather than through product ownership.
Long life	Lifetime products	Passages describing practices where durable and repairable products are offered.
	Products with life extension services	Passages describing practices where durable and repairable products and corresponding services are offered aimed at extending their lifespan.
	Hybrid model	Passages describing practices where companies sell durable products and offer short-lived components or consumables (aka Razor-and-Blade business model).
Next life	Direct reuse	Passages describing practices aiming at facilitating reuse of used or unwanted products through second-hand markets, redistribution, or exchange.
	Next life sales	Passages describing practices aiming at the take-back of used or unwanted products through convenient systems to the manufacturer, in order to extend product value through refurbishing, remanufacturing, or resaleing for subsequent use.
	Product transformation	Passages describing practices aiming at take-back of used or unwanted products through convenient systems to the manufacturer to increase product value through the reuse of components, the reconditioning of items or their repurposing for new applications.
	Extending resource value	Passages describing practices aiming at take-back of used or unwanted products through convenient systems with the aim of recycling, reusing or recovering them.
Collaborative impact	Develop scale up solution	Passages describing practices aimed at facilitating sustainable innovations, e.g. through cooperative or network-based approaches such as open innovation, crowdsourcing models, or incubators.
	Inclusive value creation	Passages describing practices that explicitly aim to include disadvantaged or marginalised groups (e.g. the bottom of the pyramid) in value creation or to create appropriate offerings for them.
Sustainable and circular sourcing	Asset management	Passages describing practices aimed at optimising the use of assets (e.g. buildings, vehicles, equipment) through pooling, sharing, lending, reuse, refurbishment or resale in order to reduce underutilisation or extend the asset life.
	Industrial Symbiosis	Passages describing practices where waste streams (products, materials or by-products) from production/manufacturing are turned into valuable inputs for other processes or products.
	Natural / circular / renewable material and energy	Passages that describe strategies where value is created by sourcing circular inputs such as recycled or natural materials, renewable energy or ensure non-hazardous chemicals input to reduce environmental impacts.
Sustainable and circular production and distribution	On demand	Passages describing practices or approaches in which products are only manufactured after customer demand has been confirmed, to avoid overproduction, excess inventory, and waste.
	Cleaner production and ecoefficiency	Passages describing practices, or approaches in production / manufacturing or distribution aimed at increasing material productivity, energy and resource efficiency or reducing waste, emissions or environmental pollution.
	Collection, take back, and repro-cessing of used pro-ducts and materials	Passages describing practices aimed at facilitating collection and processing of end-of-life products /materials.

These categories indicate strong overlaps with the inductively derived themes that will be presented later in this chapter, underlining that all practices identified ultimately relate to value creation and reflect how companies attempting to achieve economic success through sustainability. At the same time, the coded practices represent individual measures that can be assigned to certain archetypes, but do not necessarily reflect the entire business model of the respective company. The analysis further suggested that only a limited number of archetypes are widely applied across companies, while the majority occur as isolated practices within individual companies (Table 22). Overall, a heterogeneous picture emerged from the analysis. The four business model archetypes cleaner production and eco-efficiency, natural/circular materials and renewable energy, adopt a stewardship role, and lifetime products emerged as the most widely diffused. Notably, all of these approaches are directly linked to products or to production and supply chain processes. By contrast, more transformative approaches related to downstream value delivery, such as those focusing on product-services systems were rarely found.

A notable finding is that none of the case study companies were found to employ performance-based PSS models. The case study includes companies from the workwear sector (e.g., C14, C18, C21) as well as from the bed linen sector (C02), where performance models could have been expected. In such models, it is not the product itself that is sold, but the service outcome, such as always clean and well-maintained workwear or hygienic and undamaged bed linen. Instead, the business models of these companies were based purely on the sale of products. Similarly, collaborative consumption or practices related to use phase extension (e.g., repair, rental, or resale), were found only sporadically. However, a clear difference emerged between textile companies and clothing companies: clothing companies appear somewhat more active, which can be interpreted in relation to their closer proximity to, and direct interaction with, end consumers. Nevertheless, the overall diffusion remains low. This pattern suggests that companies tend to implement selective practices related to resource efficiency and circularity, thus favouring incremental rather than transformative innovation, while large-scale business model innovations remain the exception. In sum, the analysis indicated that although many companies apply individual practices aligned with sustainable and circular archetypes, these remain fragmented and do not yet amount to fully integrated sustainable business models. More detailed analyses of individual aspects are presented below.

In all of the 29 (100%) companies, practices emerged that aim to increase material productivity and resource efficiency in manufacturing while reducing waste and emissions. Moreover, 28 (97%) companies reported to increasingly turning to natural or recycled materials as well as renewable energy in production processes. These two approaches were interpreted as being driven primarily by cost considerations. Nonetheless, they may contribute to an absolute reduction in resource use and waste generation and thereby to sustainable development, while at the same time strengthening competitiveness. However, they cannot be seen as sufficient to achieve a comprehensive sustainability impact and should therefore be combined with other, particularly downstream-oriented approaches (Bocken et al., 2014; Welch & Soufani, 2024). Approaches indicating that production processes are being innovated to create value from waste and thereby close resource loops - by integrating residual materials, production waste, or even end-of-life products into value creation - remain rare. Only 10 of 29 (34%) companies reported such practices, with very limited evidence of business model innovation was found in textile companies (NACE 13). One of the few innovative examples in this sector is provided by C09, which is experimenting with innovative upcycling strategies for unavoidable production waste to seating furniture, noting that “the resulting products should be marketable for [C09] or direct partners”.

The limited evidence of business model innovation in textile companies can be interpreted in light of their predominant role as B2B suppliers delivering on order to other textile or clothing companies, positioning them at a distance from the consumer market and constraining opportunities to develop alternative or additional value streams from circular practices. These observations are consistent with the argument by Bocken et al. (2018) that business model innovation is typically initiated by focal companies, which subsequently involve relevant supply chain partners

This is illustrated by the company C13, where “cut waste from production is collected and recycled into new yarn by a partner company. The recycled yarn is then used for the production of the new shirts”. Likewise, C28 uses leftover materials to “produce limited editions in smaller quantities, which are sold through the regular channels”. Other companies primarily generate value by collecting waste separately and selling it to recyclers, or - as in the company C04 - by using it for energy generation, whereby “waste generated on-site is thermally recycled within the plant”.

Furthermore, 27 of 29 (93%) companies reported to actively assume responsibility for protecting people and the environment, aligning their business activities accordingly, for example by monitoring and disclosing supply chains and their associated social and environmental impacts, and by introducing relevant sustainability labels. Such practices are perceived as a means to enhance market reputation and influence demand, thereby strengthening competitive positioning (Bressanelli et al., 2021). This development appears to be shaped by growing societal awareness and increasing legal requirements for corporate due diligence. Demonstrating such practices transparently is perceived by companies as a means of strengthening their competitive position. As textile companies operate upstream of clothing companies and other B2C-oriented industries, forming an integral part of their supply chains, this may help to explain why these approaches are similarly prevalent across companies in both subsectors. The archetype lifetime products emerged as another widely diffused approach, identified in 19 of 29 (66%) companies. This indicates that many T&C companies focus on high-quality, durable products that can be sold at correspondingly higher prices in the market, with the assumption that such products are also used for longer and replaced less frequently, as illustrated by this quotation from C17: “Instead of owning countless inferior garments that lose their shape after a few washes, slow fashion focuses on timeless designs and high-quality workmanship”. In the majority of these companies (12 of 19; 63%), practices aligned with the archetype encourage sufficiency were also identified. These include measures to promote sustainable consumption and the extended use of textile products by consumers. Alongside awareness campaigns on the impacts of fast fashion, these practices include providing extensive information, video tutorials, and blogs to support consumers in properly caring for and performing minor repairs on high-quality textile products.

By contrast, practices corresponding to the archetype re-purpose for society/environment were found in only 10 of 29 (35%) companies, indicating limited prevalence. In its full form, this archetype refers to companies that explicitly dedicate their purpose and core business to addressing social or environmental challenges, thereby creating value and earning revenues not primarily for profit, but to cover costs and reinvest in problem-solving (Bocken et al., 2014; Ritala et al., 2018). None of the companies studied here adopted this archetype in its entirety. Instead, the identified practices indicate

that profits are used to contribute to specific societal and/or environmental causes without these issues being integrated into core business operations. This primarily takes the form of donations to relevant organisations or financial support for specific projects. Such activities are therefore less to be understood as business model approaches in the sense of value creation, but rather as expressions of corporate citizenship. This aspect is explained in more detail in the next section.

Table 22

Practices related to sustainable and circular business models adopted in the case study companies

BM categories		BM archetypes	NACE and company code																													Total
			NACE 13											NACE 14																		
			C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	
Value delivery & capture	Social and environ-mental profit	Adopt a stewardship role	X		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	27
		Re-purpose for society/ environment		X				X			X									X				X	X		X	X		X	X	10
	Demand and consumption reduction	Dematerialised services	X	X																											X	3
		Demand reduction services																														0
		Encourage sufficiency		X			X				X						X		X	X				X	X	X	X			X	X	12
	Collaborative consumption	Sharing economy																														0
		Sharing or pooling systems																														0
	Product-service systems	Access model																						X						X		2
		Performance or result model																														0
	Long life	Lifetime products		X	X		X		X		X				X	X	X	X	X	X			X	X	X	X	X	X		X	X	19
		Products with life extension services																						X		X				X		3
		Hybrid model																														0
	Next life	Direct reuse																									X			X		2
		Next life sales								X							X							X						X		4
		Product transformation													X																	1
		Extending resource value	X														X			X		X			X	X	X	X	X			9
	Collaborative impact	Develop scale up solution						X												X					X		X			X		5
		Inclusive value creation	X																	X				X	X			X				5
Value creation	Sustainable and circular sourcing	Asset management	X						X	X	X															X						5
		Industrial Symbiosis	X	X	X						X					X														X		6
		Natural / circular materials and renewable energy	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	28
	Sustainable and circular production and distribution	On demand							X		X	X	X																			4
		Cleaner production and eco-efficiency	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	29
		Collection, take back, and repro-cessing of used products and materials / Create value from waste	X		X	X					X				X	X				X				X						X	X	10
		Total	9	7	6	4	5	5	6	5	9	3	4	3	6	6	7	4	5	10	3	4	4	11	9	8	9	7	4	13	8	

Innovative approaches to value capture and delivery, based on principles of product or material reuse as well as service-oriented business models, were only found sporadically, with hardly any corresponding practices identified among textile manufacturers (NACE 13). More general and non-specific statements regarding business model innovation - such as those made by C01 and C03 (Table 23) - indicate that textile manufacturers may have begun to consider business model adaptation. However, there is little evidence to suggest that clearly defined approaches have yet been developed.

Table 23
Illustrative references on general business model adaptation

Company	Illustrative references on business model adaptation
C01	"In the near future, we wish to transform our business model from an assembly-line economy to a circular one"
C03	"New target for the 2024/2025 environmental programme: Evaluation of possible concepts for a circular economy model for hotel bed linen, including the integration of a process-based software solution"

Whereas some changes related to value capture and delivery are already playing a role in companies in the clothing industry (NACE 14). The analysis indicated that companies operating in the clothing industry (e.g., C22, C24, C28) offer repair services and spare parts to extend the lifespan of products. In addition, rental and second-hand models (C22, C28), are being tested and implemented as part of business model innovations. In contrast, typical fashion providers such as C23 appear to face greater challenges in adopting new business models due to organisational and economic considerations: "The goals are clear. But we are looking back on a long history and complex structures and cannot start from scratch overnight. We also have to take economic factors into account. We want to reorganise and inspire our customers with quality and inspiring products and thus counter ultra-fast fashion". These findings suggest that, in the field of business models, different concepts are associated with different outcomes, and that no one-size-fits-all solutions exist.

In summary, the findings indicate that changes towards the adoption of sustainable and circular business models in the case study companies have so far primarily focused on incremental adjustments and on the upstream value chain. The practices identified place particular emphasis on the ecological and social impacts associated with the production and use of existing products. By contrast, more holistic and radical approaches addressing multiple business model archetypes, which are discussed in the literature as potentially enabling new markets and associated production and consumption patterns, were found only to a very limited extent.

Corporate citizenship activities

As outlined before, beyond their core business-related strategies and activities, the case study companies are actively engaged in typical corporate citizenship (Matten & Crane, 2005) initiatives. These include, on the one hand, philanthropic activities such as donations for social and cultural causes, sponsorships, and community-based pro-

jects (e.g., C02, C03, C20, C23). Some companies, such as C18 and C28, have established their own foundations to support social and charitable projects through financial contributions and in-kind donations. On the other hand, companies also support local and regional environmental protection initiatives of various kinds, which can in some companies also be interpreted as part of their public relations strategies. For instance, C01 participates in litter-picking campaigns to preserve the natural environment of the region, C03 plants one tree per employee each month, while others redesign their outdoor spaces to create habitats for insects and small animals. Table 24 provides an overview of illustrative philanthropic and nature conservation measures identified in the case study companies.

Table 24

Illustrative references on corporate citizenship activities from the case study companies

corporate citizenship activities	Illusrative references
Philanthropic activities	C02: “We at [C02] regularly support many different projects and donate to humanitarian aid organisations when there is a current need."
	C03: "We are part of our homeland, our homeland is part of us. In line with this conviction, we get involved locally: As a sponsor of local clubs, be it in the promotion of youth sports, in perimeter advertising on local football fields or in equipping sports teams."
	C09: " […], we also support kindergartens, schools and societies in our community."
	C12: "We sponsor regional sports clubs to promote the link between sport and young people."
	C18: ”In addition to donations of clothing by the company, we contribute to the common good by supporting projects through our company trust – the [C03]-Foundation.”
	C20: "Every year we support charities, various hospitals, various local associations, various citizens' initiatives, the Pina Bausch dance theatre.”
	C23: "Our responsibility goes beyond the specific product and is also reflected in our social commitment to Special Olympics Germany and our support in crisis situations such as the earthquakes in Turkey and Morocco, where we regularly donate clothing."
	C28: "Together with the [C28] Foundation, we at [C28] are committed to going beyond our own endeavours to preserve our environment and strengthen civil society."
Nature conservation	C01: “We collected rubbish along the banks of the Alster lake in Hamburg, from the Seeve River in Jesteburg by canoe, and at our headquarters."
	C02: "Furthermore, our large, natural outdoor area is very important to us and we do a lot - together with the Southern Black Forest Nature Park - to maintain it and further develop it with local plants for the Black Forest insect and animal world."
	C03: "Since 2018, we have supported the Plant-for-the-Planet project. On behalf of [C03], one tree per employee is planted every month in Campeche (Mexico)."
	C09: In order to create habitats for animals and plants, the area around the production site is extensively planted. This includes a mixed forest of spruce, fir and pine trees, a wildflower meadow, a herb meadow and two landscaped fish ponds. In 2021, we also planted 30 native fruit trees in our wildflower meadow and, together with a local beekeeper, created a home for over 2,000 bees.”
	C12: "We have planted a flower meadow next to our warehouse building in Wettringen to protect insect species and create a natural habitat.”
	C18: "From dry stone walls on the company grounds to a 10,000m2 wildflower meadow to the extensive green roof: we are already doing a lot to promote biodiversity at our site."
	C28: "Our goal is to turn our company premises into a habitat for native plants and animals, thereby contributing to the preservation of biodiversity."

To summarise, at organisational level sustainability emerged as beeing firmly embedded in the case study companies’ strategic orientation, organisational structures, and business model elements. Driven by international policies and frameworks and regulatory requirements, the companies actively define strategic sustainability objectives

and translate them into operational practices through dedicated organisational units and structures. Communication, cooperation, and collaboration with stakeholders along the value chain - and beyond – are seen of central importance. The organisational change process thus appears to follow a top-down approach, driven by sustainability-related strategic objectives and external requirements, which leads to structural and cultural changes within the companies and is primarily reflected in product- and process-related changes. These two latter aspects will be examined in detail in the following sections.

5.2.2 Products

The analysis indicated that, regardless of size or subsector, all 29 (100%) case study companies reported practices aimed at reducing the environmental impacts of their products. However, the scope and structure of these strategies and activities vary among the companies. Four overarching themes emerged from the analysis: product design and development, material selection, certification, and packaging (Table 25). These are explained in detail below.

Table 25

Product-related sustainability strategies and activities in the case study companies

Companies / Themes	NACE 13											NACE 14																		Total
	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	
Product design & development	x	x		x		x							x				x	x		x	x	x	x	x	x	x		x	x	**16**
Material selection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	**29**
Certification	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	**27**
Packaging	x	x					x		x			x			x			x				x	X	x			x	x	X	**13**
Total	**4**	**4**	**2**	**3**	**2**	**3**	**3**	**2**	**3**	**2**	**2**	**3**	**3**	**2**	**2**	**2**	**2**	**4**	**2**	**3**	**3**	**4**	**4**	**4**	**3**	**3**	**3**	**4**	**4**	

Product design and development

Design-related measures refer to product development activities in which sustainability criteria or requirements are systematically integrated with the aim of minimising the negative impacts of a product throughout its life cycle. Such measures were identified in 16 of 29 companies (55%). Notably, only about one third of the textile companies (4 of 11, or 36%) reported considering such aspects in product development, whereas two thirds of clothing companies (12 of 18, or 67%) stated to integrate corresponding principles into their design and development processes. One possible interpretation of this disparity relates to the operational focus of textile companies, which often operate

on a contract basis. Rather than primarily developing new products for the market themselves, they produce or refine materials according to their customers' requirements. As one interview respondent (C07) explained: "we produce what our customers want from us". It can therefore be assumed that, even if not explicitly reported, such principles are nevertheless incorporated within the product portfolios of textile companies in order to meet the requirements of their customers, particularly those from the clothing industry they supply.

One of the few reported approaches from the textile industry include the development of new sustainable product innovations that may serve as substitutes for less sustainable alternatives. For instance, C04 reported to collaborate with partners to develop reusable menstrual underwear made from natural fibres as an alternative to disposable single use hygiene products (Table 26). This indicates that textile companies are engaged in innovation projects with partners to create more sustainable product solutions. Other companies, particularly in the clothing sector, explicitly reject fast fashion and frequent collection changes by focusing on the development of timeless and durable garments. This is illustrated by sportswear manufacturer C22: "we focus upon design and colour trends as well as fits that last well beyond one season". Similarly, C17 states: "Our designs are classic and versatile; they should fit seamlessly into any wardrobe and be able to be worn for years".

Companies are also developing internal guidelines and tools to support sustainable product development. These relate to product features, raw materials, and repair or reuse potential. The statement of C25, a producer of textile membranes and outdoor products, illustrated the importance of collaborative approaches for sustainable products along the value chain. The company has developed a workshop programme and a "responsible design guide" for fashion designers that includes topics such as eco- and circular design, as well as strategies and practices related to creativity, innovation, and recycling. C28 and C29, on the other hand, demonstrate how internal guidelines on repairability are influencing product design: C28 developed a "repair index", which ensures that "the repairability of all products is considered and systematically assessed already during the design and product development phase". Meanwhile, C29 states that its clothing is "designed in such a way that it can be quickly and easily repaired – from minor repairs to the replacement of individual components". As longer product life cycles inherently result in fewer repeat purchases and thus lower sales volumes, these

product strategies are accompanied by new service offerings such as repair or rental services, which have been discussed previously in the business model section.

Material selection

Material selection emerged to play a critical role in sustainable product strategies, as it forms the basis of all textile products. Accordingly, all 29 (100%) companies reported on sustainability-related material strategies or activities. For instance, C14 focuses one of its sustainability projects on “increasing the proportion of sustainable fibres and materials in the product portfolio”. C01 aims to “increase the proportion of organic cotton to 70% and expand [the] portfolio of products containing recycled synthetic or cotton inputs”. Third-party sustainability certifications and standards were identified as part of these efforts, relating to the ecological or recycled origin of materials. For instance, C29 has set the goal of “increasing the proportion of sustainable materials, and sustainable production in [certain collections] to more than 70% by 2028, independently verified”. When selecting materials, companies also reported to increasingly adopt a life-cycle perspective (e.g., C01, C27) in selecting materials with minimal negative environmental and social impacts along their life cycle.

Certification

Beyond this, companies refer to third-party product and material certifications and labels at the product level as a means of communicating their sustainability efforts to consumers. C28 illustrates: “When we began to consistently shift our product development towards sustainability in 2009, awareness of the ecological and social aspects of clothing was just beginning to emerge. We were approached from all sides with requests not only to manufacture ‘better’ products because they were more environmentally friendly, but also to make them recognisable as such in stores”. Commonly referenced standards include the Global Organic Textile Standard (GOTS), the Global Recycled Standard (GRS), OEKO-TEX certifications, the Green Button, and the Cradle to Cradle certification. In addition, C28 has developed its own standard and product certification, which, according to the company, exceeds the requirements of all existing standards. However, the use of standards and certifications varies significantly across the case study companies and provides only limited insight into the overall sustainability of a textile product, as each standard addresses different sustainability dimensions (Table 27). For instance, 22 of 29 companies (76%) reference the OEKO-TEX

Standard 100, which only certifies that a product is free of harmful substances (OEKO-TEX, 2025). The GOTS label, which is used by 11 companies (38%) for at least part of their product portfolio, is awarded to textile products that are “made from at least 70% certified organic natural fibres” (Global Standard, 2023). The GRS certification, used by 10 companies (34%) for selected products, is “intended for use with any product that contains at least 20% recycled material” (Textile Exchange, 2017, p. 6). The companies also indicate that standards and certifications do not apply to their full product range but only to specific collections or product lines. For instance, C18 notes: “we are expanding our GOTS collection made of organic cotton certified in accordance with the Global Organic Textile Standard: in addition to T-shirts and polo shirts, from 2024 it also includes sweatshirts and hoodies”. Similarly, C09 explains: “All recycled yarns that we source for our second life collection are GRS certified. As a company, however, we are not GRS certified”. C29 states that “over 60 products are already certified [with the Green Button], with continuous expansion”. These findings indicate that sustainability-related product certifications are gaining in importance and have led even textile manufacturers - who do not sell directly to consumers - to adopt certifications for their materials (Table 27), to ensure that the final textile products (such as garments) can be certified easier. The large number of certifications suggests that there are not yet any uniform standards for the objective assessment of the overall sustainability of a textile product and that partial certifications for various aspects have established instead. However, the wide variety of certifications is perceived by companies as making it difficult to navigate the certification landscape (C09, C28).

Packaging

In addition to the products themselves, packaging was identified as an aspect increasingly addressed within corporate sustainability strategies. This is particularly apparent among companies in the clothing industry whose products are marketed to retailers and end consumers. While C12 states that it “only uses sustainable packaging material for new products”, other companies have developed more comprehensive approaches. For example, C18 and C23 have established detailed sustainable packaging strategies that address both material selection and end-of-life considerations. C27, meanwhile, consulted with a number of experts and research institutes to evaluate its packaging practices. The result, as the company notes, was the conclusion that “there are two

reasonable options: keep using plastic bags and recycle them or eliminate plastic entirely". The company decided for the elimination. These examples illustrate the effort and diverse approaches companies are taking to align packaging practices with broader environmental objectives.

In summary, product-related sustainability strategies and activities constitute a central element of the sustainability-related practices identified across the case study companies. The analysis indicated a shared orientation towards integrating sustainability considerations across different stages of the product life. This includes an increasing focus on certified sustainable materials, innovative, durable and repairable design, and responsible packaging - highlighting a broader commitment to a sustainable value proposition. Table 26 provides a summary of the product-related strategies and activities together with illustrative references from the case study companies.

Table 26

Illustrative references on product-related strategies and activities from the case study companies

Product related strategies & activities	Illustrative references
Product design & development	C01: “Sustainability and fashion are by no means mutually exclusive. This is demonstrated by „undyed“ textiles, where dyeing is omitted. This approach enables resource-efficient production and contributes to environmental protection.”
	C04: "The development of a sustainable menstrual underwear made of biodegradable and renewable materials while maintaining high performance values is a promising application that should be further considered to reduce waste and create a circular approach. [...] However, this should not be limited to period underwear but should also serve as an example for other textile products.”
	C22: "strategic, long-term planning of new collections and their launch dates is more important than ever. A two-year cycle means that the products must feature genuine, reliable and consistently functional innovations. In addition, we focus upon design and color trends as well as fits that last well beyond one season.”
	C25: “[C25] has already developed a Responsible Design Guide. Here we provide strategies and impulses from eco-design to make responsible decisions under fair conditions in the sense of the circular economy."
	C28: „We have developed a repair index that is used to consistently consider and systematically evaluate the repairability of all [C28] products right from the design stage and throughout the entire product development process.“
	C29: “Instead of a throwaway mentality, we focus on repairability: our clothing is designed so that it can be repaired quickly and easily. From minor repairs to replacing individual components, our service ensures that your workwear remains reliable for a long time."
Material selection	C01: "When selecting materials, [C01] always integrates the aspect of sustainability in its assessment and seeks environmentally friendly alternatives where possible. We are increasingly taking into account the entire life cycle of products […].”
	C02: "From now on we use 100% TENCEL™ Lyocell for the lying surface of our [product name] (instead of 50% cotton and 50% polyester) and do not use the anti-mite treatment (biocide). […] One component of textile sustainability is the use of plant-based additives. For this reason, we are no longer finishing our products with silk proteins of animal origin, but with the naturally based alternative argan oil.”
	C27: "It is strategically anchored that a product life cycle assessment takes place at the beginning of every product development. This means that we review fabric collections and consider which materials we want to use to manufacture products and what impact they will have. Whether it's organic cotton, polyester, silk, etc."
	C04: “The wood used for viscose production in [C04] comes exclusively from certified, sustainably managed forests.”
	C14: "Another project focuses on increasing the proportion of sustainable fibers and materials in the product portfolio"
	C18: "The [C18] product range is constantly expanded with innovations made from sustainable raw materials certified to the most demanding international standards.”
	C21: "Our aim is to increase the relative proportion of products made from sustainable materials in our product portfolio over the coming years. In addition to recycled raw materials, this also includes organic natural fibres".
	C23: "We rely on the use of more sustainable materials, for example certified organic cotton or recycled polyester. Step by step, we are integrating these into all our products. […] By 2028, 70% of the main materials we use should come from more sustainable sources."
	C28: “The [C28] material policy defines which materials are permitted in our products and which conditions must be met during raw material extraction, cultivation, and processing.”
Packaging	C01: "All GOTS articles will come in sustainable or recycled packaging.”
	C02: "After 2 years of intensive research, we are very proud to present our new, plastic-free packaging."
	C07: "We mainly use cardboard boxes/interlayers made from recycled waste paper. We do not use stretch film around the pallets when delivering our products."
	C12: "We only use sustainable packaging material for new products."
	C18: "We are creating a comprehensive sustainable packaging strategy."
	C23: "In 2022, we developed an internal packaging guideline for the first time to help colleagues throughout the organisation make more sustainable decisions."
	C27: "[C27] consulted a number of experts and research institutes on packaging, looked at plastic alternatives made from corn and much more. Our conclusion was that there are two sensible options: Keep and recycle plastic bags or entirely eliminate plastic. We decided to eliminate.”
	C28: "[C28] deals extensively with the issue of packaging and is constantly trying to reduce it or replace it with recycled alternatives.”

Table 27

Overview of product-related sustainability certifications held by the case study companies (Note: The certifications have been verified for each company via the websites of the certifying organisations)

	Certificate	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	Total
Güner Knopf/ Green Button	- German governmental seal for textile products - Sets binding requirements to protect people and the environment - Certifies products whose production complies with at least 46 social and environmental standards	X													X		X		X	X	X	X					X		X	X	**10**
Global Organic Textile Standard (GOTS)	- Certifies textile products that consist of at least 70% certified organically produced natural fibres, excludes harmful chemicals and guarantees minimum social standards from the raw material to the finished product	X				X		X				X	X						X	X		X			X			X	X		**11**
Oeko-Tex	- Comprises various labels and certifications for textiles: - **Standard 100** certifies that a product is free of harmful substances - **Made in Green** = Standard 100 + traceable supply chain	Standard 100 Made in Green	Standard 100	Standard 100 Made in Green	Standard 100	Standard 100	Standard 100	Standard 100	Standard 100	Standard 100	Standard 100	Standard 100 Made in Green	Standard 100	Standard 100 Made in Green			Standard 100 Made in Green		Standard 100	Standard 100	Standard 100 Made in Green	Standard 100				Standard 100	Standard 100 Made in Green	Standard 100 Made in Green		Standard 100 Made in Green	**22**
bluesign®	- Provides a standard for chemical management to minimise the impact of chemicals used on people and the environment.						X																		X	X			X		**4**
Fairtrade	- Certifies goods that originate from fair trade and whose production complies with social, ecological and economic criteria. Offers two certifications for textiles: - **Fairtrade Cotton:** product is made from fairly produced and traded raw cotton that is traceable through all production stages and was separated from non-fairly traded cotton during processing. - **Fairtrade Textile Production:** textile products have been produced and traded sustainably and fairly along the entire supply chain.	Fairtrade Textile Production		Fairtrade Cotton								Fairtrade Cotton					Fairtrade Cotton				Fairtrade Cotton										**5**
Global Recycled Standard (GRS)	- Certifies products that contain at least 20% recycled material - each stage of production is required to be certified, beginning at the recycling stage and ending at the last seller in the final business-to-business transaction.					X	X	X	X			X							X			X		X	X				X		**10**
Cradle to Cradle Certified ™	- Assesses the safety, recyclability and responsibility of materials and products against five categories of sustainability performance: material health, product circular economy, air and climate protection, water and soil conservation, and social fairness	gold																	bronze		silver										**3**
	Total	**5**	**1**	**2**	**1**	**3**	**3**	**3**	**2**	**1**	**1**	**4**	**2**	**1**	**1**	**0**	**3**	**0**	**5**	**3**	**4**	**4**	**0**	**1**	**3**	**2**	**1**	**2**	**4**	**2**	

5.2.3 Processes

Across business and value creation processes, various strategies and practices were identified that address environmental and social impacts associated with corporate operations. Regardless of the size or subsector, all case study companies demonstrate active efforts to reduce and avoid negative impacts linked to their business activities. Four overarching themes emerged from the analysis in this context: risk management, cross-supply chain transparency, responsible procurement and production practices and greenhouse gas (GHG) emissions reduction (Table 28). The specific design and implementation of these strategies and activities vary among the case study companies and are described in detail hereafter.

Table 28

Process-related sustainability strategies and activities identified in the case study companies

Themes \ Companies	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	Total
Risk management	X	X	X	X	X			X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	25
Cross-supply chain transparency	X	X	X	X	X	X	X		X		X		X	X	X	X		X	X		X	X	X	X	X	X	X	X	X	24
Responsible procurement & production	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	29
Ghg emissions reduction	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	28
Total	4	4	4	4	4	3	3	3	3	2	4	3	4	4	4	4	3	4	4	3	3	4	4	4	4	4	4	4	4	

Sustainability-related risk management

Activities related to the analysis, assessment, and management of social and environmental risks were identified in 25 of 29 (86%) case study companies. These include practices concerned with identifying potential negative impacts within internal company processes as well as across supply chain activities, and with addressing such impacts through corresponding measures. It should be noted that, with the exception of companies C04 to C11, all case study companies are members of the Partnership for Sustainable Textiles, which requires the implementation of structured risk assessment processes. Among the non-member companies (C04–C11), which are not subject to this requirement, only half reported having conducted such structured approaches. While the remaining four companies do not operate structured sustainability-related risk management systems, they reported undertaking measures related to reducing negative impacts.

These findings indicate that all case study companies address potential negative impacts associated with their business activities. Structured approaches to risk assessment along the individual companies' supply chains are predominantly driven by human rights and environmental due diligence (HREDD) requirements and tend to focus primarily on upstream supply chain activities. C03, for instance, referred to its approach as risk-based supply chain management, whereby "various indicators are used to identify risks of potential negative impacts on people and the environment" in different sourcing countries, and corresponding measures are derived accordingly. These approaches are guided by frameworks such as the OECD Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector (OECD, 2018) or the requirements of the German Supply Chain Due Diligence Act (BMZ, 2023). Within the empirical material, identified risks therefore predominantly relate to human rights and environmental protection in the upstream supply chain, while downstream-related risks are only marginally addressed. Table 30 provides an overview of illustrative references related to risk management from the case study companies.

Cross-supply chain transparency

The companies tend to associate transparency closely with risk management, describing it as a means of identifying potential risks and negative impacts and of developing corresponding measures. External pressures - particularly from customers requesting evidence of sustainable practices and from legal requirements - are frequently referred to as influencing transparency-related activities among the case study companies. However, initiatives to collect and share data on processes and their impacts vary among companies. For example, C01, states that it is "committed to transparency and responsible business practices" along the global supply chain: "We recognize the importance of supply chain knowledge to ensure accountability, legal compliance, and risk mitigation. Transparency fosters trust, strengthens collaboration, and enhances our ability to respond effectively to risks. Therefore, we oblige our business partners to disclose all processing steps and facilities involved in the manufacturing of products purchased by [C01] on request." C04 similarly refers to pressure from the downstream actors: "We have focused a lot on the topic of traceability, because the requirements of brands in the textile industry are constantly increasing. The need to be able to trace where the products come from and where they might go to". Across the case study companies, various measures related to transparency across supply chains and

operational processes were identified (Table 30). These include auditing practices (C19), supplier questionnaires (C02, C16, C29), and the use of traceability platforms (C01, C14, C16) to enhance transparency on material origin and adherence to environmental and social standards. However, companies report persistent challenges in accessing transparent information beyond direct suppliers (Tier 1). For instance, C29 points out that while risks can be more accurately assessed at the level of direct partners due to long-standing partnerships and reliable certifications, significant transparency gaps persist further upstream: “In these areas, we see substantial intransparency regarding the origin of the materials used in our workwear”. Similarly, C19 states that “one of the biggest challenges remains the full traceability of our supply chain, especially for materials sourced from regions with limited infrastructure for transparency and sustainability”. This suggests that companies perceive significant challenges in operationalising sustainability objectives across their extended supply chains. These challenges are discussed in more detail in Section 5.4.

Responsible procurement and production processes

All 29 (100%) of the case study companies reported practices related to responsible procurement and production processes that address potential sustainability risks (Table 28). In 20 of 29 companies (69%), these practices are also accompanied by independent certifications (Table 29). Of these 20 companies, 9 (45%) refer to the implementation of environmental and energy management systems certified under schemes such as the European Eco-Management and Audit Scheme (EMAS), OEKO-TEX STeP, ISO 14001 or ISO 50001 (Table 29). With regard to procurement practices, 23 of 29 companies (79%) reported that their business conduct and supplier relationships are guided by a code of conduct that is contractually binding for their supply chain partners**.** These codes primarily relate to requirements associated with human rights and environmental due diligence (HREDD) along the supply chain. In 13 of these 23 companies (57%), compliance with the codes of conduct is reported to be assessed by third-party organisations such as the Fair Wear Foundation or BSCI, while in the remaining 10 companies (43%) compliance is monitored through voluntary self-reporting mechanisms (Table 29). As illustrated by C03: “We also expect our business partners to be guided by the principles of [our] Code of Conduct and to commit themselves to upholding human rights, labour, social and environmental standards in their processes”.

Some companies also reported an emphasis on shorter supply chains involving local or European partners or refer to requirements for suppliers to hold independent certifications. For instance, C10 states that it sources most of its fabrics “from German suppliers with high quality standards and, when selecting raw materials, [to] prefer European printing inks approved by the GOTS standard”. C15 reports relying on a few direct production partners at limited European sites, where “the textiles are manufactured exclusively in sewing facilities with verified environmental and social standards”. Similarly, C29 states to only work with production partners who can demonstrate compliance with environmental and social standards through independent certifications such as EMAS, ISO 14001, or OEKO-TEX STeP.

Table 29

Overview of social and environmental-related process certifications held by the case study companies (Note: The certifications have been verified for each company via the websites of the certifying organisations)

	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	Total
EMAS			X	X																								X		**3**
OEKO-TEX® STeP			X		X																									**2**
ISO 14001			X	X	X	X		X			X			X				X										X		**9**
ISO 50001				X	X	X		X																						**4**
Fair Wear Foundation													X					X				X	X	X		X		X		**7**
Amfori BSCI	X											X				X					X				X		X			**6**
Individual code of conduct*		X	X	X	X	X		X						X	X				X										X	**10**
Total	**1**	**1**	**4**	**4**	**4**	**3**	**0**	**3**	**0**	**0**	**1**	**1**	**1**	**2**	**1**	**1**	**0**	**2**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**1**	

*Individual Codes of conduct are not subject to independent auditing or certification but are based on voluntary self-commitment

Price negotiations are referred to as another approach associated with responsible procurement practices, particularly in relation to wage levels paid by suppliers. For example, C14 states: “Through regular wage gap analyses, we aim to minimise this risk within our supply chain. To best support our business partners, we are continuously working on forward-looking production planning and fair price negotiations”. Furthermore, the introduction of complaints mechanisms was identified as part of the practices discussed in relation to the anonymous reporting of risks and violations associated with company and supply chain processes, as illustrated by the example of C18: “Worker grievances represent an important resource for us for the assessment of partner risks and help us identify measures needed in the supply chain”. These examples

again illustrate that supply chain-related activities tend to focus primarily on direct suppliers while risks associated with lower tiers of the supply chain, are not actively addressed, which indicates a lack of transparency.

In addition to human rights-related due diligence obligations, the reduction of pollutant emissions - particularly with regard to chemicals and water pollution - emerged as an important aspect across processes and supply chains discussed by the case study companies. The activities identified relate primarily to two aspects: the reduction of chemical use and wastewater treatment practices addressing the discharge of pollutants and chemicals into natural water bodies. Among companies operating their own production facilities in Germany (e.g., C03, C04, C05, C10, C11), these practices are frequently associated with references to compliance with strict legal regulations and cost considerations. By contrast, German companies that do not operate their own production facilities in Germany but source from international suppliers report a stronger emphasis on cooperation and monitoring at supplier level in relation to chemical and wastewater management (e.g., C01, C18, C20, C23). A frequently mentioned example is collaboration with the Zero Discharge of Hazardous Chemicals (ZDHC) initiative - a multi-stakeholder platform that develops and implements guidelines and tools for the responsible use and management of chemicals in textile supply chains. Its overarching goal is to eliminate hazardous substances from the textile value chain (ZDHC, 2025).

Greenhouse gas emissions reduction

Across the case study companies, climate change mitigation is primarily discussed in relation to measures addressing direct ghg emissions (Scope 1 and 2). These include references to transition towards renewable energy sources at company-owned sites as well as process-related energy efficiency initiatives aimed at reducing energy consumption. For example, C01 reports: “A large open area of the company is equipped with PV panels […] we feed between 215,000 and 240,000 kWh of electricity into the grid each year. That is around three times as much electricity as we consume ourselves […]”. In this regard, the practices described show relatively limited variation across companies. By contrast, Scope 3 emissions - arising from indirect sources such as upstream and downstream supply chain processes - are addressed to a lesser extent in the accounts of the case study companies, although they are associated with a substantial share of overall emissions. These emissions are frequently described as

lying beyond the companies' direct sphere of influence. As C03 notes: "An analysis of the individual areas shows that the greatest share of greenhouse gas emissions is generated in Scope 3. [...] The company's greatest influence on total emissions, however, lies in Scope 1 and 2". However, in some cases, practices to reducing Scope 3 emissions were identified. These include measures associated with logistics and transportation, as illustrated by an example from the interview with C24, who notes: "We aim to minimise air freight wherever possible and have set specific air freight targets for each department". Furthermore, companies refer to supporting business partners along their supply chain in reducing emissions. For instance, C22 and C28, meanwhile, collaborate with other companies through a shared fund to implement decarbonisation projects in textile-producing countries in Asia. According to C28, "the strongest lever for CO_2 savings lies in phasing out coal" from supply chain processes. However, the example of C23 points to the considerable effort associated with quantifying Scope 3 emissions, which is described as a prerequisite for developing more targeted supply chain–related measures. The company reports: "In order to better assess the emissions arising in our supply chain, a survey involving a total of 278 suppliers was conducted for the first time in 2024. Based on the results, we can both assess emissions more realistically and engage in individual dialogue with suppliers to jointly develop measures and targets".

Overall, the case study companies display broad awareness of sustainability-related risks and apply various risk management practices and process-related standards across value creation processes. The analysis suggested that ongoing dialogue and collaboration with suppliers and other actors along their supply chains are considered relevant by the case study companies. At the same time, the practices described are largely concentrated on internal company processes and direct suppliers (Tier 1), with lower-tier supply chain partners only marginally reflected. This indicates that an expanded focus beyond Tier 1 may be necessary to more comprehensively address risks and related measures, particularly with regard to downstream processes such as product use or disposal, which currently receive limited attention.
Table 30 provides an overview of illustrative references to process-related sustainability activities from the case study companies.

Table 30

Illustrative references on process-related strategies and activities from the case study companies

Theme	Illustrative references
Risk Management	C01: “Through risk analysis, we identify potential and actual risks at the country, product, and supplier or supply chain levels, as well as for the business model.”
	C03: "We pursue a risk-based approach in our supply chain management. The country risk analysis forms the basis for measures and requirements."
	C04: "We expanded our value chain engagement by implementing a supplier questionnaire screening conformity with all relevant environmental, working condition and compliance matters. This helps us to better understand our own upstream impacts."
	C13: “In the risk analysis, we examine and evaluate key risk factors that influence the topic of sustainability. [...] Our risk analysis is based on the OECD guidelines and is the foundation of our commitment to responsible company practices.”
	C16: "We carry out regular risk analysis for our own supply chain in order to identify risks at an early stage. We analyse and evaluate the risks, act immediately and take appropriate measures."
	C18: "Our annual analysis of sector-specific risks according to the ‘OECD Due Diligence Guidance for Responsible Supply Chains in the Garment and Footwear Sector’, which we have supplemented to include country-, partner-, and product-specific risks.”
	C24: "[C24] employs a multi-layered monitoring process tailored to the specific risk levels. This approach helps us prevent issues and drive continuous improvements.”
	C28: "In order to assess and prioritise the various risks, [C28] carries out a risk analysis at country level, as well as a risk analysis at factory level for producers."
Cross-supply chain transparency	C01: "We continuously strive to enhance transparency within the deeper supply chain. Through our proprietary [traceability] tool, we ensure full transparency of certified product supply chains."
	C02: “Supplier questionnaire for more transparency in progress”
	C03: "We keep the number of different suppliers low and build on long-term, transparent supplier relationships. [...] Since 2022, [C03] has procured some of its goods directly from the producers. This strategic decision enables the company to correspond directly with the raw fabric producers in Pakistan."
	C14: "The company relies on close partnerships with certified production facilities and ensures a transparent supply chain through digital traceability.”
	C16: "The Label Check lets you track exactly in which countries and factories which production step took place via a QR code or a product ID. So you always know that you are making a responsible purchase decision."
	C19: "One of the biggest challenges remains the full traceability of our supply chain, especially for materials sourced from regions with limited infrastructure for transparency and sustainability. However, we are working to close these gaps by entering into new partnerships and expanding our audits.”
	C29: "Since 2023, we have been sending out our annual sustainability questionnaires via Retraced.[…] We see a considerable lack of transparency regarding the origin of the materials used for our workwear. This results in a clear need for action in order to recognise actual risks in these production stages and to derive and implement measures."
	C16: "We asked all of our external producers to fill in the questionnaire including the Code of Labour Practices and to send us some information about Code of Conducts or whether they are a member of any association (e.g. FWF, BSCI). The request is made by [C16] at least once a year."
Ghg emission reduction	C01: “Our Green Factory is part of our sustainable supply chain in India. The majority of the energy it uses originates from regenerative sources.”
	C02: "We have climate-certified our company and our products. This means that [C02] offsets all (still) unavoidable emissions through the financial contribution of various certified climate protection projects. The calculation of our ‘CO2 footprint’ is carried out by ClimatePartner Deutschland GmbH."
	C03: "We have been using 100% green electricity since January 2024. Thanks to this switch, we have been able to save 603 tonnes of CO2 emissions."
	C03: "When analysing the individual areas, it becomes clear that the greatest greenhouse gas emissions are generated in Scope 3. [...] But, the company's greatest influence on total emissions is particularly in Scopes 1 and 2.”
	C05: "The curve showing CO2 emissions at [C05] is pointing steadily downwards. Between 1998 and 2020, we reduced them by two thirds. To achieve this, we had to take a critical look at our consumption. In 2011, we introduced an energy management system for this purpose."
	C07: "[…] For this process, mainly electricity is used, which is why we are increasing our investments in solar power to reduce our carbon footprint."
	C09: "We use carbon offsetting to offset our emissions and achieve climate neutrality.”
	C13: "Discussions with suppliers about installing photovoltaic systems to reduce greenhouse-gas emissions in the supply chain […] In the reporting year, our Pakistani partner began meeting its energy needs through a photovoltaic system."
	C22: "[C22] and nine other members of the Supply Chain Decarbonization Project – a community initiative of the European Outdoor Group (EOG) – identified hotspots for CO2 emissions in the supply chain and determined possible measures for lowering these emissions."
	C28: "By far the largest proportion of emissions is generated in the production of materials. The enormous savings in this area were achieved primarily through a joint project with a pioneering character within the outdoor industry and in cooperation with selected suppliers. The strongest lever for CO2 savings lies in phasing out coal.”

Table 30: Continued

Theme		Illustrative references
Responsible Procurement and Production Processes	HREDD certification & auditing	C01: "In 2022, a total of 127 social audits were performed of the tier 1 suppliers for textiles and hardware that were active during the reporting period (compared to 62 in 2021 and 87 in 2019)."
		C08: "We evaluate our suppliers on their responsibility towards their employees. 37% of our raw materials used in 2020 came from suppliers with a certified occupational safety and health management system (e.g. ISO 45001). We intend to further increase this share in the future."
		C12: "It is stated clearly in both our minimum standards and purchasing contract that every supplier of [C12] is required to have a valid BSCI certification so that we can ensure that each sector risk is assessed."
		C13: "The FWF [Fair Wear Foundation] principles are implemented and monitored at the manufacturing partners by means of regular visits, training, audits and follow-up action plans."
		C21: "We only enter into co-operations with production partners who have passed our internal audit."
		C22: "We do this with the support of independent auditors, who implement checks according to defined, internationally recognized standards, and by continuously working closely with our partners on equal terms and through regular on-site visits."
		C23: "In order to identify risks and ensure our set standards and guidelines along the supply chain, we regularly carry out audits at our suppliers' production units."
		C25: "[C25] is amfori BSCI member. Our direct business partners […] are amfori BSCI verified. Furthermore, we are intensively working on integrating the deeper supply chain (Tier 2 and 3, particularly our laminating partners and dyers) into the BSCI audit process as well."
		C27: "In our own factories, we have our own team of trained inspectors who regularly check and ensure compliance with corporate due diligence requirements. […] All factories where we have our products manufactured are regularly audited by independent institutes and monitored by a non-governmental organisation."
		C28: "The entire site in [palce] is environmentally EMAS certified."
		C29: "Cooperation with recognised certification systems and standards is an integral part of our approach. The OEKO-TEX® STeP certification of the garment factories focuses on recognising and avoiding the potentially negative effects of chemicals in the manufactured articles and on the environment, as well as the risks during application and use."
	Code of conduct & complaints mechanisms	C01: "This Supply Chain Code of Conduct [...] summarizes all requirements regarding social and environmental standards and integrity that we pose on our supply chain partners. This includes our direct and indirect suppliers and such in the deeper supply chain as well as agencies or other intermediary organizations. [...] As a member of amfori, we require all our suppliers in high-risk countries to provide an effective system for receiving and addressing employee complaints and suggestions."
		C03: "We also expect our business partners to be guided by the principles of this Code of Conduct and to commit themselves to upholding human rights, labour, social and environmental standards in their value creation processes."
		C23: "We have established an onboarding process that verifies compliance with international human rights and environmental standards at potential production facilities before business commences. If the outcome of the review is positive, our suppliers undertake to comply with the requirements of our Code of Conduct."
		C29: "Our Declaration of Principles and the Code of Conduct form the cornerstone for all forms of collaboration with our partners."
		C04: "We have implemented a whistleblowing hotline in 2022."
		C12: "We take the concerns and needs of our employees very seriously. Worker complaints can be submitted anonymously to the dedicated email address […] – for example to report violations of our Social Code of Conduct (SCoC)."
		C13: "Our membership of the Fair Wear Foundation (FWF) means that the staff of our manufacturing partners have access to a well-established complaints management system."
		C20: "We have developed and implemented a complaints mechanism to protect the people who work for us - in our own organisation and with our partners"
		C27: "We work together with the Fair Wear Foundation, which operates hotlines and contact points for employees in our sourcing countries."
	Local sourcing / supplier cooperation	C02: We work with a portfolio of very good and long-time partners and our own companies [...]. We are in constant dialogue to guarantee the longevity of our products, but also to coordinate our efforts towards greater sustainability at all levels and to develop and try out ideas together."
		C03: "We keep the number of different suppliers low and build on long-term, transparent supplier relationships."
		C04: "An example of our responsible sourcing policy is that we source as many raw materials as possible locally, to reduce transport distances."
		C05: "We source our raw materials exclusively from safe countries where fair trade is guaranteed and child labor is excluded. We also attach great importance to short transport routes and sustainable fiber production."
		C10: "We purchase most of our fabrics from German suppliers with high quality standards and, when selecting raw materials, we prefer European printing inks approved by the GOTS"
		C18: The fact that we have known almost all of our production partners for decades helps in this context. We are regularly on site and talk to each other to find out how things are going at their companies and how we can support our partners."
		C21: "Our production partners can evaluate various aspects of our procurement practices. These include the appropriateness of lead times, payment terms, clear and open communication, etc. Once the survey has been completed, we discuss the aspects that need to be improved and try to find a mutually satisfactory solution."

Table 30:* *Continued

Theme		Illustrative references
Responsible Procurement and Production Processes	Price negotiations	C01: "We have almost fully utilised our Indian production facility. We pay a higher price there, which we pass on to our customers."
		C13: "Our approach includes linking our price negotiations to demonstrable wage increases. […] We have been analysing the wage structure of our manufacturing partners since 2012. Using regular monitoring, we collect data on the wages in the individual departments, stat utory minimum wages, wages agreed upon through collective bargaining and living wages. Doing so requires continuous discussions between us, the management of the manufacturing partners and the employees in the production facilities."
		C14: "In addition to the mandatory signing of the Code of Conduct, we have set ourselves the goal of minimising this risk in our supply chain through regular wage gap analyses. At present, we can assume that, following the relevant efforts and close cooperation with our business partners, living wages will be paid at least at the apparel stage (Tier 1)."
		C15: "We pay attention to ethical purchasing practices and do not exert any price pressure on our producers."
		C18: "We do not set target prices, but instead explain to our partners what we want to develop together with them. Then we ask them what they need to produce the products in question in the desired quality, because you can only pay fair wages if the production costs were calculated fairly."
	Chemicals reduction & wastewater treatment	C01: "Our wet processing facilities have adopted the ZDHC Waste Water Guidelines. These guidelines define a single, unified quality standard for the discharge of waste water into the environment that goes beyond regulatory compliance."
		C03: "Compliance with legal requirements from the Wastewater Ordinance is ensured by the daily controlling and checking of the mixing and equalisation basin by trained staff. In addition, there are regular and independent inspections conducted by the responsible monitoring authorities and contracted service providers."
		C04: "[C04] was the first company in the world to invest in state-of-the-art BIOHOCH® reactors for wastewater treatment. At over 95 %, these reactors have a significantly higher degree of purification than previous processes. [...] The wastewater produced in the process is returned to the Danube and compliance with the strict emission limits is monitored by the local water management authorities." C04: "The ZDHC guidelines provide manufacturers[...] with uniform criteria for measuring indicators such as wastewater, air emissions and other process-related parameters. The measured data is independently monitored and published"
		C05: "The modern equipment and optimised processes in our dyeing plant ensure exceptionally economical water consumption. And not only that: thanks to the modern dyeing processes, the OEKO-Tex certified dyes and auxiliaries as well as our many years of experience, we manage to comply with the waste water limits according to ZDHC and STeP."
		C18: "By 2025, we want all wet process facilities to undergo annual audits to analyse the actual human-rights and environmental risks, to record their untreated-water, wastewater and sewage sludge data, and to have signed the Zero Discharge of Hazardous Chemicals Programme (ZDHC) Manufacturing Restricted Substances List (MRSL) and apply its principles to guide their actions in chemicals management."
		C20: "All the manufacturers we source from have a wastewater management system and have been informed by us about the ZDHC wastewater guidelines."
		C23: "Of the suppliers in wet process stages and with whom we placed orders in 2023, 85.8% used the digital MRSL Chemical Inventory Tool or carried out ZDHC wastewater tests."

5.2.4 Summary

The findings indicate that the case study companies recognise sustainability-related risks associated with the T&C industry and address them through a range of practices and developments across the three change dimensions of organisation, products, and processes. Sustainability emerges as an important strategic orientation, reflected in structural and cultural integration within the case study companies, but also in the initiation of strategic partnerships - both within and beyond their supply chains. These partnerships are described as being related to innovation activities, competitive positioning, and engagement with broader political and societal agendas, such as the SDGs and climate change mitigation. The findings further indicate that the strategies and activities of the case study companies have so far primarily focused on individual products and materials, as well as on production and procurement processes. Most companies refer to sustainability-related risk management practices, increased transparency along their supply chain, and measures addressing chemical use and ghg emissions. These practices predominantly concern companies' own operations and those of their direct partners (Tier 1), while deeper supply chain tiers and downstream processes are only marginally addressed. Targeted adjustments to business models - particularly with regard to innovative approaches to value delivery and value capture - were identified less frequently. The findings further indicate that sustainability strategies and activities are often closely associated with CE concepts and practices. Their implementation within the case study companies is examined in greater detail in the next section.

5.3 Implementation of the Circular Economy (RO2 – Q2)

The analysis indicated that 20 of 29 companies (69%) refer to a dedicated CE-strategy or explicitly mention the CE in sustainability-related documents thereby establishing a connection between sustainability strategies and activities and CE-related concepts. A sectoral comparison showed that within the textile segment (NACE 13), slightly more than half of the companies 6 of 11 (55%) - refer explicitly to CE-related strategies and practices, whereas in the clothing segment (NACE 14), 14 of 18 companies (75%) do so (Table 31).

Table 31

Overview of strategic and operational engagement in the CE in the case study companies

NACE Code	13											14																		Total
Company	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	
Dedicated CE strategy or CE reporting	X		X	X		X			X		X		X	X	X	X		X		X		X	X	X	X	X	X	X	X	20
Operational practices/ measures related to CE mentioned in reporting/ interview	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	29

The thematic analysis resulted in a set of eight themes reflecting CE-related practices across the case study companies. These themes were subsequently mapped onto the three circular economy strategies of narrowing, slowing, and closing resource flows (see Section 2.3.2.2) (Table 32 and Table 33). Through this analytical step, it became apparent that practices contributing to at least one of these CE-strategies are present across all 29 (100%) case study companies. This analytical interpretation is supported by interview accounts, in which company representatives described specific CE-related practices as part of their broader sustainability activities.

Table 32

Rules for categorising practices related to the CE under the CE strategies identified in Section 2.3.2.2

CE Strategy	Coding definition
Narrowing	Practices that aim to achieve more with less by increasing efficiency in product design and/or production processes, thereby reducing input requirements (e.g., materials, energy, water, chemicals).
Slowing	Practices that seek to extend the useful life of products, materials, and/or equipment (e.g., through high durability, repairability, reuse)
Closing	Practices that focus on recycling or recovering of materials from used products or from process waste. Includes both closed loops (same product /company) and open loops (different product/company), as well as ultimate energy recovery.

Source: The author based on Bocken et al., 2016; Farooque et al., 2019 and Kirchherr et al., 2022

Table 33
Practices related to the CE-strategies narrowing, slowing, and closing identified in the case study companies

CE-Strategies	Themes
Narrowing	Reduce resource consumption
	Reduce waste and scrap
Slowing	Durable products and materials
	Extension of product lifespan
	Extension of lifespan of machines and equipment
	Waste utilisation
Closing	Active recycling of products and materials
	Design, development, and use of recyclable products and materials

The implementation and application of individual CE-strategies vary across the case study companies. Practices associated with eco-efficiency and linked to the narrowing strategy are particularly widespread. Only in the case of one clothing manufacturer (C21) no practices were identified in publicly available sustainability-related information and documents that directly indicated an active reduction in the use of resources (e.g. water, energy, materials). Sector-specific differences are also apparent. Companies in the textile sector (NACE 13) tend to place greater emphasis on practices related to the reduction and utilisation of waste and production scrap, whereas companies in the clothing sector (NACE 14) more frequently refer to practices focusing on product and material durability (Table 34). These differences can be related to the core activities of the respective subsectors, with textile manufacturers being more production-oriented and clothing companies focusing primarily on design and development, while production processes are largely outsourced. The findings on the individual CE-strategies and practices are presented in detail below.

Table 34
Overview of CE strategies and practices observed in the case study companies

NACE Code	Company	Size	Narrowing		Slowing				Closing	
		Theme	Reduce resource consumption	Reduce waste and scrap	Waste utilisation	Durable products and materials	Extension of product lifespan	Extension of lifespan of machines and equipment	Active recycling of products and materials	Design, development, and use of recyclable products and materials
13	C01	SME	X						X	X
	C02	SME	X	X	X	X	X		X	X
	C03	SME	X	X	X	X	X		X	
	C04	Large	X	X	X		X		X	X
	C05	SME	X			X	X	X	X	
	C06	SME	X	X	X	X	X		X	X
	C07	SME	X	X	X	X			X	X
	C08	Large	X	X	X				X	
	C09	SME	X	X	X	X	X	X	X	X
	C10	SME	X	X				X		X
	C11	SME	X	X	X	X	X	X	X	X
13 Total:		11	11	9	8	7	7	4	10	8
			100%	82%	73%	64%	64%	36%	91%	73%
14	C12	SME	X				X		X	X
	C13	SME	X	X	X	X			X	
	C14	SME	X	X	X	X			X	
	C15	SME	X	X	X	X	X		X	X
	C16	SME	X	X		X			X	
	C17	SME	X			X				
	C18	SME	X	X	X	X	X		X	X
	C19	SME	X						X	
	C20	SME	X	X					X	X
	C21	Large		X		X			X	
	C22	SME	X	X	X	X	X		X	X
	C23	SME	X	X	X	X	X		X	X
	C24	SME	X	X	X	X	X		X	X
	C25	SME	X		X	X	X		X	X
	C26	Large	X	X		X	X		X	
	C27	SME	X			X	X		X	X
	C28	SME	X	X	X	X	X	X	X	X
	C29	Large	X	X	X	X	X			X
14 Total:		18	17	13	10	15	11	1	16	11
			94%	72%	56%	83%	61%	6%	89%	61%
13 & 14 Total			28	22	18	22	18	5	26	19

5.3.1 Narrowing Resource Flows

As outlined in Section 2.3, the narrowing strategy is conceptualised as focusing on reductions in resource consumption and environmental impacts. However, measures associated with this strategy are also discussed in the literature as being applicable within linear production systems and, when implemented in isolation from other strategies, are not considered indicative of a broader transition towards CE-principles. Instead, they are commonly associated with efficiency-oriented approaches and cost reduction (Bocken et al., 2016; Geissdoerfer, Morioka, et al., 2018). Two main practices

associated with this strategy emerged from the analysis: the active reduction of resource consumption in products and processes, and the reduction of waste and scrap during manufacturing and broader business processes.

Reduce resource consumption

Across the case study companies, practices related to reducing resource consumption were widely reported, with 28 of 29 companies (97%) referring to corresponding practices. These practices predominantly relate to water, energy, and chemical use, particularly within production processes in textile companies (NACE 13). The specific approaches described vary depending on manufacturing type and product characteristics. While nearly all companies reported to implementing energy efficiency measures – which are frequently discussed in connection with high energy costs in Germany – companies operating water- and chemical-intensive processes more often describe practices aimed at reducing water and chemical inputs and their associated impacts (C02, C03, C04, C05, C06, C07, C08, C10, C11, C25). In the accounts of the case study companies, efficiency considerations, cost aspects, and regulatory requirements were repeatedly associated with these activities. For instance, C02 states that “consumption has been reduced as far as possible and the finishing processes optimised for decades due to the high German environmental standards, but also to minimise costs”. Similar practices are also described at international production sites, as illustrated by C06: “Recognising the substantial water usage in dyeing and treatment processes, we are investing in technology to minimise water consumption and wastewater production. A testament to this commitment is our new dye house in Vietnam, equipped with the latest technology”.

Technological and digital innovations are further described as contributing to reduced resource use across product development, production, and administrative processes. Examples include the use of innovative dyeing methods, such as spinneret dyeing (C25), or the introduction of 3D software, which C01 refers to as having significantly reduced the need for physical samples, photo shoots, and customer presentations, while C02 reports a significant reduction in paper consumption because “around 99% of our customers […] receive a paperless invoice”.

In addition, companies report the use of alternative materials and resources as a means of reducing reliance on natural and fossil inputs. For instance, C04 is exploring alternative raw materials, such as food or agricultural waste and by-products, to extract

cellulose fibres instead of using virgin wood fibres. The use of fossil-based materials like polyester shows a mixed picture: some companies report to deliberately rely on polyester, citing its lower consumption of natural resources and greater durability (e.g., C09 and C25), while others (C10, C15, C22, C42) report an intention to reduce fossil-based materials. C15, for instance, states the objective of “reducing fossil-based materials such as plastics”, and C24 “uses lyocell as an especially ecological alternative to conventional man-made fibres and cotton”.

Despite the breadth of practices reported and a generally high degree of transparency regarding activities, publicly available sustainability reporting rarely included quantified, comparable data. From an analytical perspective, this could be interpreted as reflecting a selective emphasis in external communication: while companies openly describe practices and initiatives, systematic quantitative comparisons - particularly those that might reveal limitations or trade-offs - tend to be omitted from public reporting. As a result, assessing whether these practices contribute to absolute reductions in resource use independent of output growth remains challenging. A comparison of C18’s sustainability reports for 2022 and 2024 conducted by the author indicates that, while energy and water consumption and waste volumes increased at the German site alongside company growth, natural gas consumption and ghg emissions were reduced (Table 35). From an analytical perspective, this example suggests that absolute decoupling of economic growth and resource use (as outlined in Section 2.3.2) may be achievable in specific areas, but is not yet evident in a comprehensive or consistent manner across the case study companies. The limited availability of supply chain–level data further contributed to a fragmented understanding of overall resource use trends.

Table 35

Comparison of sales development and resource consumption at C18 headquarter based on data from publicly available sustainability reports

Indicator \ Year	2022	2024	Delta
Revenue	**93.4 Million €**	**134.1 Million €**	**+ 44%**
Electricity purchased	228,896 kWh (100% green)	261,446 kWh (100% green)	**+ 14%**
Natural gas for heating	878,008 kWh (10% biogas)	677,736 kWh (10% biogas)	**- 23%**
Water consumption	1,579 m^3	5,291 m^3	**+ 235%**
Waste generated	221 t	234 t	**+ 6%**
Ghg emissions	4,865 t CO_2E	3,631 t CO_2E	**- 25%**

Reduce waste and scrap

Waste reduction and avoidance were described as significant concerns with such practices reported more frequently by companies from the textile industry (9 of 11 companies, 82%) than from companies in the clothing industry (13 of 18 companies, 72%). Cost considerations associated with waste management and disposal are frequently referred to as influencing these practice as illustrated by statements from C10 and C28. C10 notes: “We carefully evaluate where we can reduce waste, particularly since we have to pay for disposal”. Similarly, C28 reports: “The punching waste from polyethylene is recycled. However, remnants from coated tarpaulin materials currently have to be disposed of as residual waste. This is frustrating and expensive – that’s why we’re looking for ways to recycle these materials as well”. Across the T&C industry, waste arises at different stages of production and processing; nevertheless, the practices described in relation to waste reduction are largely comparable across the case study companies. A range of practices related to reducing textile waste generation emerged: In the context of production processes, practices aimed at minimising material waste - such as during fabric cutting or the processing of remnants - were identified. For instance, C06 refers to “overhauling our production processes to decrease waste”, while C09 uses “leftover yarns for the selvages” and optimises “the bobbin size to optimise yarn consumption and reduce waste”. Additionally, quality management systems are described as contributing to waste reduction by enabling the early identification of production errors and thereby preventing defective products and material waste (C04, C08). In public communication, some companies highlight the high quality of their products and materials, although a direct link to waste reduction is often not explicitly made. This connection, however, was repeatedly articulated in the interviews, where economic motives for such practices also became apparent. For instance, C08 explains: “We aim for real-time error detection to minimise waste, so that as soon as a defect is detected, we can intervene before too much low-quality material is produced”. Futhermore, make-to-order production (C07) and the use of innovative design and production methods and technologies (C28) are reported as practices employed to avoid overproduction and reduce process-related waste (see Table 36 for illustrative references).

In summary, practices associated with the narrowing strategy were widely identified across the case study companies and are frequently discussed in relation to both economic and ecological considerations. While these approaches are linked to reductions

in resource consumption and waste generation, they primarily reflect efficiency-oriented practices focused on internal processes and cost considerations, rather than being framed as part of a broader CE approach aimed at achieving absolute decoupling of economic growth from resource use.

5.3.2 Slowing Resource Flows

Compared with the narrowing strategy, practices associated with the slowing strategy were identified somewhat less frequently across the case study companies (Table 34).

Four main themes emerged that were associated with extending the useful lifespan of products and materials: waste utilisation, product and material durability, extension of product life, and extension of machine and equipment lifespan. Sectoral differences are apparent here. Companies in the textile industry (NACE 13) more frequently refer to practices related to waste utilisation and the extension of machines and equipment lifespan, whereas companies in the clothing sector (NACE 14) more often describe practices aimed at enhancing product and material durability.

Waste utilisation

Waste utilisation describes practices in which waste streams are redirected and used as inputs for other processes or products. Such practices were identified in almost three quarters (8 of 11, 73%) of the textile companies, but only in 10 of 18 (56%) of the clothing companies. This difference can be interpreted in relation to the outsourcing of production processes in the clothing industry, which may constrain companies' influence over relevant waste streams. Across the case study companies, practices related to waste utilisation include the separation of different waste categories and the identification of options for selling or recycling these materials, rather than disposing of them (C02, C03, C04, C06, C14, C18, C23). In addition, companies highlighted the existence of secondary markets for by-products. For instance, short fibres that cannot be processed into yarn remain valuable inputs for other industries. This is reflected in the statement by C06: "Our main revenue driver when it comes to waste utilisation is selling our waste. We have different types of waste with varying lengths and qualities at multiple stages, and even our combings are of interest to those who need shorter fibres". Among clothing companies in particular, waste utilisation practices are more often described in relation to the resale of faulty or unsold goods at reduced prices, as well as the upcycling of leftover or waste materials into new products. For example,

C25 and C28 report the joint launch of an upcycling store with eBay, described as being oriented towards the “value-preserving reuse of leftover materials”.

Durability of products and materials

Practices related to enhancing the durability of products and materials were identified in 15 of 18 companies (83%) in the clothing sector (NACE 14), whereas in the textile sector (NACE 13), 7 of 11 companies (64%) reported such practices. Companies frequently describe their products and materials as having longer lifespans, which is discussed as contributing to competitive positioning, particularly in relation to lower-cost imports from Asia that are described as being of inferior quality. C02, for instance, states that it stands for high-quality and durable textile products and promotes “the appreciative and slow consumption of high-quality products with a long life cycle”.
Among brand manufacturers, these practices are framed as part of their value proposition, as C24 outlines: “we are now introducing extended warranties, which further underscores how crucial this is for us […]”. Two main approaches emerged in this context: a design-oriented approach, in which product development is aligned with durability criteria such as ease of care and reparability (C22, C28, C29); and a quality-oriented approach, where high-quality materials and workmanship are seen as essential to long product lifespans (C14, C15, C17, C18, C21, C29).

Extending the lifespan of products and materials

Producing durable products and materials does not necessarily result in long-term use. Among the case study companies, a range of practices, services, and innovations related to extending the actual lifespan and utilisation of products were identified. In the case of clothing manufacturers (NACE 14), 11 of 18 companies (61%) report such measures. These primarily include repair and care services (e.g., C22, C23, C24, C28) as well as rental services (C22, C28), which are described as contributing to the continued use of products and are discussed in connection with changing consumer expectations and business model considerations, as outlined in the findings on business models.
Among textile companies (NACE 13), 7 of 11 (64%) reported practices related to extending the lifespan of materials. These include reusable packaging, which is described as being associated with longer use cycles of packaging materials and reduced packaging waste (C02, C03, C04, C06, C09, C11), as well as the provision of information and guidance on the proper care of textile materials (C04, C09).

Extending the lifespan of machines and equipment

Practices related to extending the lifespan of machinery and equipment were also associated with the slowing strategy, but were less prevalent among the case study companies. Such practices were identified in 4 of 11 (36%) textile companies (NACE 13) and in only 1 of 29 (6%) clothing companies (NACE 14). In these cases, the practices described primarily relate to the maintenance, repair, and modernisation of existing machinery, as well as the reuse of equipment, rather than its replacement with new installations. For example, C28 reports that its trade fair booths are designed and constructed for multiple uses. Similarly, C05 refers to the potential role of digitalisation in this context, stating: “In the past, maintenance intervals were based on rough estimates and experience, such as assuming that a carding set would last around three months. However, with modern testing procedures and technologies, these intervals have been extended significantly”. These practices can be interpreted as being associated with both resource conservation and cost considerations.

In summary, practices associated with the slowing strategy constitute an important aspect of CE–related activities in the case study companies. By focusing on durability and quality, and by referring to practices aimed at preserving the value of products, materials, and equipment over extended periods, these measures contribute to both, waste reduction and resource conservation. However, the options available to companies to foster this strategy are more limited than for others, as they lack control over the actual use phase of their products and materials.

5.3.3 Closing Resource Flows

The closing strategy is conceptualised as encompassing practices related to recycling, specifically the recovery of raw materials for use as inputs in new products and materials. Two main categories of practices emerged in relation to this strategy across the case study companies: Firstly, practices related to the reuse of materials and resources, and secondly, design-oriented practices focused on developing products and materials that are described as being suitable for recycling into secondary materials.

Active recycling of products and materials

Recycling activities represent a key mechanism for closing material flows within the CE. Such practices were identified in 26 of 29 (90%) case study companies, spanning

both sectors equally. However, the data indicateed that these practices are often limited to specific product ranges (C23, C28) or constitute only a certain share of a product's or material's total content, as illustrated by C19: "In 2024, we increased the proportion of recycled materials in our products by 10%. For 2025, we have set the goal of raising this share to 20%".

In addition, companies refer to practices related to the recycling of process waste, which is particularly relevant among textile companies (NACE 13) where waste streams can be substantial. These practices are described as being associated with a reduced reliance on virgin resources and lower waste volumes. For example, C05 states that it uses "25 per cent recycled material from spinning pre-stages and downstream processes" to produce one of its yarns, further explaining: "what we reduce in process waste, we save in new raw cotton". A key challenge emerges with regard to the availability of post-consumer waste for recycling. Companies' influence over disposal practices during the use phase is described as limited, which complicates the recovery of materials for recycling. In response, clothing manufacturers and brands report conducting initial trials to take back used garments (e.g., C18, C23). However, these initiatives are described as being implemented at the individual company level and remaining at an early stage; no established or fully functioning take-back systems were identified across the case study companies.

Design, development, and use of recyclable products and materials

The second theme relates to the extent to which products and materials are designed and developed with recyclability in mind. Practices suggesting that products, materials, components, and, in some companies, packaging are designed with recyclability in mind were identified in 8 of 11 (73%) textile companies (NACE 13) and in 11 of 18 (6%) clothing companies (NACE 14) (Table 34). Companies emphasised that implementing such practices requires close coordination across the value chain. This includes working with recycling partners to better understand design requirements, as well as engaging with supply chain partners to ensure that these requirements are considered throughout different production stages (e.g., C24). Companies refer to the use of clear specifications and design guidelines for product development (C01, C23, C24, C28), as well as to intensive cooperation with value chain partners (e.g., C11, C28). Notably, no references to formal certification schemes or standards were identi-

fied in this context, which suggests limited standardisation regarding recyclability requirements. This finding is consistent with those of Diekel et al., who observed a lack of emphasis by eco-labels on the recyclability of textile products as early as 2021. Instead, companies describe the development of internal guidelines for recyclable products (e.g., C23, C24, C28), without reference to standardised recycling processes. Taken together, this suggests that many of these practices are still at an early stage of development. Nonetheless, in the outdoor and sportswear segments (e.g., C24, C28), companies report having introduced few fully recyclable products, although no experience regarding their actual return or recycling has yet been described, due to their recent market introduction.

In summary, practices associated with the closing strategy relate to both the reuse of existing materials and the development of products that are described as being designed for recyclability. While challenges remain - particularly with regard to the collection of post-consumer textiles and the development of fully recyclable products and corresponding processes - the data indicated ongoing efforts to close resource flows. These efforts are reflected in reported practices such as the integration of recycled materials, references to improvements in reverse logistics and recycling processes, and the advancement of recyclability-by-design approaches. Table 36 provides illustrative references for the individual CE-strategies and associated practices from the case study companies.

5.3.4 Summary

The findings indicate that the three CE strategies - narrowing, slowing, and closing - are not implemented to the same extent across the case study companies (Table 34). Practices associated with narrowing were identified most frequently, reflecting their strong link to resource efficiency and waste reduction and their alignment with current regulatory and operational requirements. Their integration is described as comparatively less complex, as such practices can often be implemented within existing processes. In contrast, practices related to slowing and closing were observed less often, as they typically require more fundamental adjustments to product design, sourcing of materials and collaboration across the value chain. While some initial approaches - such as repair and care services or rental models - were reported, enabling companies to influence product lifespans, the actual duration of use ultimately remains largely beyond their control.

Table 36

Illustrative references on CE-strategies and related practices implemented in the case study companies

CE strategies	Themes	Illustrative references
Narrowing resource flows	Reduce resource consumption	C01: "[…] precise 3D models allowed us to provide clear specifications to suppliers, resulting in fewer prototypes. […] We also use animations to replace photo shoots and customer presentations, saving additional resources."
		C02: "Textile finishing is a highly complex process that uses a relatively high amount of water and energy […] consumption has been reduced as far as possible and the finishing processes optimised for decades due to the high German environmental standards, but also to minimise costs."
		C04: "Where water is required as a reaction medium in the process flow, we try as far as possible to use the water several times, thus saving resources."
		C05: "To keep the water consumption required for dyeing as low as possible, we rely on modern machinery. In this way, we have been able to reduce water consumption per kg of yarn by around 25% in recent years. […] The optimisation of the dyeing processes has also contributed to saving water."
		C06: "Recognising the substantial water usage in dyeing and treatment processes, we are investing in technology to minimize water consumption and wastewater production. A testament to this commitment is our new dye house in Vietnam, equipped with the latest technology."
		C10: "We have been able to significantly reduce costs by installing a water recycling system specifically designed for this purpose. In addition, the recent change from rotary screen printing to digital printing has resulted in considerably lower water and energy consumption."
		C12: "[…] now that holiday requests, pay slips, etc. are digital, we have been able to reduce paper consumption in our company by one third."
		C22: "Digital color management offers a number of benefits: […] Reducing the number of physical lap dips required, saving on materials and costs as a result."
		C25: "With a 3D material library, physical samples become largely obsolete. The possibility for our customers to see their desired colours and prints virtually in advance on the corresponding material also saves us a lot of sampling."
	Reduce waste and scrap	C04: "We reduce waste by integrating quality assurance measures to ensure optimal production outcomes."
		C03: "The KPI "offcuts in g/m" provides information about the offcuts per meter produced in the production process. The aim is to keep this value as low as possible […]."
		C07: „We only produce to order, so we only have what I would call normal production waste, which is simply due to the machines and no waste caused by overproduction."
		C08: "We aim for real-time error detection to minimise waste, so that as soon as a defect is detected, we can intervene before too much low-quality material is produced."
		C06: "We are overhauling our production processes to decrease waste."
		C28: "[…] more than forty models are planned to be produced in the [German] manufactory in the future in line with current industry standards, with shorter lead times, and with reduced material waste."
		C29: "As much fabric as possible is already saved in CAD during the design phase - we utilise 92% of the fabric on average, resulting in only 8% waste."

Table 36: Continued

CE strategies	Themes	Illustrative references
Slowing resource flows	Waste utilisation	C02: "Since 1997, our textile waste (…) has been collected and recycled by the French company KATZ. The newly recovered, recycled blended yarn is used to make felt fillings for the automotive industry and various cleaning products."
		C09: " Starting in November 2023, we received funding for the next 30 months to research the recycling of process-related selvedges and fabric waste for the production of fabric tubes as seating furniture."
		C04: "Defective goods, as long as they are in acceptable condition and not heavily contaminated, are sold as B-grade products."
		C24: "For example, in our own service factory, we create items like bags from these materials. All of our posters and banners, which are made of textile, are collected from our stores and points of sale, then transformed into bags. These are often used as giveaways and feature interesting designs and images. We are actively working on many projects to reuse waste in this area."
		C06: "Our main revenue driver when it comes to waste utilisation is selling our waste. We have different types of waste with varying lengths and qualities at multiple stages, and even our combings are of interest to those who need shorter fibers. If we simply sell our waste in bulk, we generate significantly more revenue compared to all our recycling efforts, and it doesn't appear that this will change."
		C28: "We are convinced that creative ideas can turn supposed rubbish into valuable resources for new, fantastic unique items. That is why we have set up our upcycling manufactory and can save our residual materials from the rubbish bin with our new upcycling collection. […] After setting up our upcycling manufactory, the second step was to establish an external upcycling community and materials exchange in cooperation with other companies, schools and creative people. Our aim is to create a platform on which companies, including ourselves of course, can make valuable leftover materials available for upcycling projects."
	Durability of products & materials	C02: "With very high-quality raw materials, we lay the foundation for our longlasting products" […] We see our company philosophy confirmed in the SLOW movement."
		C24: "Longevity has become a core focus for us […]. We're introducing extended warranties, which further underscores how crucial this is for us [...]."
		C14: "When developing our products, we place great emphasis on quality, because the higher the quality of our products, the more durable and therefore sustainable they are."
		C15: "Our products are designed to last longer and outlast short-term fashion trends thanks to high-quality materials and timeless design."
		C18: "We do not sell short-lived, mass-produced goods of lesser quality: our garments can be worn for a long time without loss of style, comfort or quality."
		C25: "Our membrane is developed in such a way that it does not lose its function even after a long time and after repeated washing."
	Extend product lifespan	C09: "We offer training and even provide support to end consumers. […] we have a service hotline where they can ask questions like how to deal with pressure marks on velour, or how to properly clean and maintain the fabric. We also advise on removing stains from materials like marker ink or nail polish. While we don't offer repairs, we do provide a care service to ensure the fabric lasts as long as possible, aligning with our commitment to durability."
		C22: "We have already taken the first measures to extend the lifespan of products with our repair & care service. […] Beyond product development, we are dependent upon the support of consumers, who have immense leverage through their usage and consumption behavior. With new business ideas such as rental models or the second life store, we already offer suitable starting points, and we want to expand these further in the future."
		C23: "After the purchase, proper care is essential. We would therefore like to inform our customers about the correct and sustainable care of garments. This helps to conserve resources and extend the life of clothing. […] we published a care guide on our website in 2023."
		C25: "If functional clothing is damaged, it does not need to be thrown away. Cracks and holes can be sealed again with the right materials and the know-how of our repair partners."
		C28: "To ensure that products are not stored unused […] we offer the option of renting them" […] For the care and repair of our products, we offer instructions, spare parts and services such as a waterproofing and repair service and cooperate with external service providers such as the Repair Cafés and iFixit" […] [C28] supports the private resale of used products on a "re-commerce platform" on eBay. From 2025, there will also be a purchase option, i.e. end consumers will have the opportunity to sell used products back to us."
	Extend lifespan of machines & equip.	C28: "We try to use all the modules we build [our trade fair booth] with at least three times. In many cases, we even manage to do this much more often."
		C09: "To minimise the amount of scrap metal generated, defective machines or machine parts are rebuilt or repaired in our highly specialised metalworking shop."
		C05: "In the past, maintenance intervals were based on rough estimates and experience, such as assuming that a carding set would last around three months. However, with modern testing procedures and technologies, these intervals have been extended significantly."
		C10: "Our stretching frame is older than I am, but with proper maintenance, it still makes sense to keep it running."
		C11: "We have implemented proactive maintenance, [...], based on this knowledge, components are replaced at appropriate intervals."

Table 36: Continued

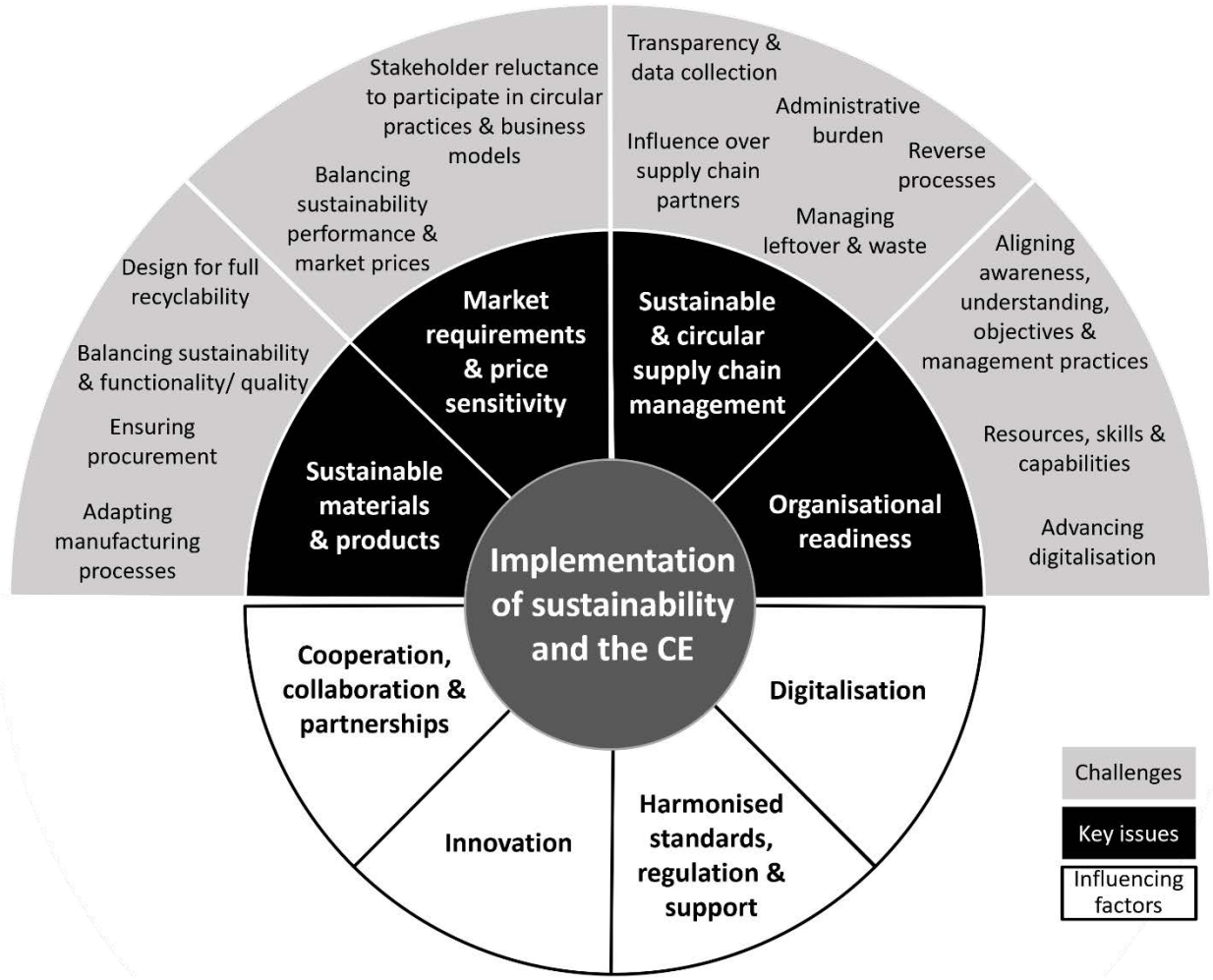
CE strategies	Themes	Illustrative references
Closing resource flows	Recycling of products and materials	C01: "Customers can either integrate their workwear into an existing recycling concept from C01 or collaborate with us to create a custom concept."
		C06: “We also have our own ‘recycled product’ [made from recycled fibres], which sells steadily.”
		C08: "In our effort to sell products with the smallest ecological footprint possible, we make systematic use of recycled raw materials. "Our carbon fiber nonwovens are made entirely from remainders of carbon fiber production. These pre-consumer resources are thus not only spared from incineration; they are also turned into innovative products […]."
		C03: “By using our caustic recovery plant, a caustic regenerate with up to 75 % waste caustic can be obtained.”
		C05: "For [product], we use 25 per cent recycled material from spinning pre-stages and downstream processes. What we reduce in process waste, we save in new raw cotton.”
		C06: "[C06] already processes various recycled raw materials in its GRS-certified yarns. However, with Renu fibres and filaments, it is now able to offer unique wool blends with recycled polyester on the market that are made exclusively from textile waste.”
		C13: "Cut waste from production is collected and recycled into new yarn by a partner company. The recycled yarn is then used for the production of the new shirts. We are starting with 10 per cent recycled production waste per T-shirt, with the prospect of gradually increasing the percentage of recycled yarn.”
		C18: "We are one of the first German textile companies to realise a genuine circular economy together with customers and partners: we take back worn-out products and use their recycled fibres for our new circular label [name] closed loop wear.”
		C19: "In 2024, we were able to increase the proportion of recycled materials in our products by 10%. For 2025, we have set ourselves the goal of increasing the proportion to 20%."
		C20: "We process materials from Seaqual because this reduces plastic waste in the oceans"
		C23: "We are increasingly using recycled fibres, which are obtained from old clothing or plastic bottles, for example. At least 20% of the main material in our 360° denims consists of certified recycled cotton obtained from old textiles.”
		C27: “In the near future, goods will be taken back and professionally recycled in all stores and online"
		C28: "In the 2024 Summer Collection, more than 70 % of all [C28] products are already made from more than 50 % recycled or bio-based materials; in the 2025 Summer Collection, this will reach almost 90%.”
	Recyclable products and materials	C01:"From the product development stage, a possible second life of the product at the end of its usage is considered. A specially developed guideline recommends measures […].” C01: “All packaging should be recyclable and meet current legal requirements. We prohibit single-use plastics in retail packaging […].”
		C10: “We stopped printing at the seam, which means the fabric remains clean and can be more easily recycled.”
		C23: “We have formulated clear requirements and guidelines as part of the [name] collection and have also created a Circularity Guide.”
		C11: “We’re already working with designers to use only specific dyes and chemicals, so the product can be recycled later.”
		C24: "Recycling is made possible by clever design and the use of innovative technology. The [special collection] are designed as a mono-component products. This means that only one material is used in the product."
		C28: “With our [product], we are taking the first steps towards recyclability by converting the products in line with the circular economy: The zip and the associated tape have been converted to PET polyester for recyclability. Instead of blended fabrics, we use special yarns made from recycled PET polyester. Parts that are not made of PET are colour-coded and can be easily replaced [...].”

5.4 Key Issues, Challenges and Influencing Factors (RO2 – Q3)

The findings from the document and interview analysis indicated that the case study companies are confronted with a range of challenges in their transition towards sustainability and the CE. These span across all three change dimensions - organisation, products, and processes - and are described as being closely interrelated. In addition, several influencing factors emerged from the analysis that support companies in addressing these challenges. Overall, four key issues emerged, to which a total of fourteen distinct challenges were assigned; these are presented and outlined in Sub-section 5.4.1. By contrast, four groups of factors were interpreted as influencing the implementation of sustainability and the CE in the case study companies (Figure 38), which are presented and outlined in Sub-section 5.4.2.

Figure 38

Overview of key issues, challenges and influencing factors related to the implementation of sustainability and the CE identified in the case study companies



5.4.1 Key Issues and Challenges

This section outlines the four key issues identified in relation to the implementation of sustainability and the CE in the case study companies and describes the challenges associated with these issues.

Issue 1: Sustainable materials and products

Transitioning to more sustainable materials and products is described as playing a central role in advancing sustainability and the CE, as already highlighted in Section 5.2.2. At the same time, the analysis indicated that this transition is associated with a range of challenges. In this context, four groups of challenges were identified:

Firstly, manufacturing processes in companies are largely described as being designed and optimised for conventional and virgin materials. The processing of alternative materials, particularly recycled fibres and fabrics, is reported to require different or additional processing steps, which are associated with inefficiencies and rising costs within existing processes. For example, recycled natural fibres such as wool or cotton are described as having shorter fibre lengths than virgin fibres, while synthetically recycled fibres are reported to exhibit more variable quality standards and colour variations. As a result, processing such fibres and materials is associated with increased efforts in inspections, testing, process adjustments, and approval procedures (C04, C06, C07, C09, C11). In some companies, processing such fibres and materials is described as not being possible at all with existing equipment, necessitating investments in new, specialised machinery (C04, C08, C11). C22 further stresses that “we must think and act in a holistic way”, pointing to the need to consider the environmental and social impacts associated with such process changes. Overall, this challenge is primarily related to the process dimension, which is described as requiring adaptation to handle fluctuations and limitations in the processing of sustainable materials without compromising quality, sustainability performance, or efficiency.

Secondly, the procurement of recycled or other alternative materials, compared to conventional ones, is described as presenting challenges in terms of price, quality, and availability. Companies report facing a restricted supply of verifiably sustainable materials, such as certified organic cotton and wool or recycled synthetic fibres (C02, C06, C22). Furthermore, recycled materials such as polyester or cotton are frequently described as offering lower quality while being more expensive than their virgin counterparts (C02, C09, C10, C11). This was interpreted as complicating both the planning

and implementation of manufacturing processes and the development or conversion of products using more sustainable materials. This challenge is therefore primarily associated with procurement processes and product-related decisions, indicating that structural barriers persist that currently limit the competitive availability of sustainable alternatives compared to conventional materials.

Thirdly, due to perceived reductions in qualitative performance of sustainable alternatives and challenges related to their processing, companies report quality-related issues in the resulting products and corresponding reactions from customers and consumers (e.g., C05, C06, C07, C28). C05 stated in the interview that for their customers, qualitative parameters of a yarn are the top priority, “and if we cannot deliver that, they simply do not buy”. This indicates that perceived compromises in quality and performance are closely linked to economic considerations, often limiting large-scale substitution of conventional materials by more sustainable ones. Similarly, C23, a fashion brand, highlights this tension: “We try to combine all aspects. But with individual products you have to weigh things up carefully – on the one hand, recyclable products are the big goal and we want to continuously increase the use of recycled materials. On the other hand, this reduces durability because the quality becomes worse.” C02 likewise decided against using recycled polyester, as the resulting limitations in durability “do not fit in with our philosophy of slow fashion”. This challenge is primarily associated with the product dimension, requiring approaches that integrate alternative materials without undermining durability, safety, or customer expectations.

Fourthly, as discussed in Section 5.2, CE practices emerged as forming an integral part of corporate sustainability strategies. In this context, the development and production of products and materials that can be fully and efficiently re-transformed into equivalent raw materials is described as a complex challenge. Companies refer to pursuing different approaches, such as mono-material designs (C15, C24, C25) and compatible finishes and treatments (C25). However, the development of recyclable products and materials is associated with greater effort and potential compromises in functionality, durability, or aesthetics (C15, C18, C24, C25). This is interpreted as affecting efficiency, economic performance, and competitiveness, as illustrated by C18: “Particularly intricately finished and durable workwear trouser models and outdoor jackets have so far been difficult to almost impossible to design for recyclability. Our existing NOS collection’s transition to more sustainability can therefore only take place gradually and often takes longer than we would like, as finding and assessing new materials and

manufacturing methods takes a lot of time". Accordingly, this challenge is primarily linked to the product dimension, indicating that potential responses require intensive information exchange and collaboration between actors across the T&C value chain.

Issue 2: Market requirements and price sensitivity

Heterogeneous market requirements and high price sensitivity in the T&C sector are described as constituting another central challenge for the transition towards sustainability and the CE.

Firstly, challenges related to the processing and production of more sustainable materials and products (see Issue 1) are associated with higher production costs, which are frequently discussed as resulting in higher market prices for sustainable products. At the same time, the analysis points to a tension faced by companies: while awareness of and demand for sustainability are described as increasing (C09, C23, C27), the market continues to be characterised by high price sensitivity and a comparatively low willingness to accept price differences relative to conventional alternatives (e.g., C04, C07, C09, C23, C28, C29). Statements such as that of C29, who describes it as "very difficult to strike a balanced relationship between product price and sustainability criteria", illustrate the uncertainty and tension companies report in this regard. This challenge is described as spanning all three change dimensions, as potential responses are discussed in relation to multiple levels, including reducing production and administrative costs, investing in targeted communication, or developing alternative business models.

Secondly, initial experiences reported by several case study companies indicate reluctance among customers and consumers to actively participate in circular practices and business models such as take-back schemes, resale processes, or service-based models including rental or repair. These experiences are described as limiting the current economic viability of such initiatives, which in turn constrains their further professionalisation, scaling, and the development of supporting infrastructure, particularly where sufficiently large return volumes are required (C09, C22, C24, C28). These observations are evident not only in B2C contexts but also in B2B settings, as illustrated by C06's example of a circular logistics concept based on reusable folding boxes, which was discontinued due to insufficient participation from customers and logistics providers.

At the same time, the analysis suggested that many of the initiatives described remain individual and isolated, being tied to specific firms and products, while no examples of collaborative approaches were identified. Taken together, this suggests that fragmented solutions may limit perceived user-friendliness and stakeholder benefits, pointing to the relevance of more holistic and user-oriented approaches that integrate all three change dimensions in order to create sufficient incentives for participation and to support the development of economically viable circular business models. This interpretation is consistent with the findings of Abdelmeguid et al. (2022) and Vehmas et al. (2018) who emphasise the importance of information provision and stakeholder involvement - whether consumers or other actors - for generating awareness and motivation to engage in circular practices. Accordingly, isolated company-specific approaches are interpreted as being of limited suitability for establishing circular business models. The analysis therefore suggested that the challenge lies less in the development of alternative models per se than in understanding existing market structures, requirements, and consumption practices. Addressing this challenge is discussed as requiring concepts adapted to these conditions and involving relevant stakeholders across sales and procurement markets.

Issue 3: Sustainable and circular supply chain management

Establishing, controlling, and optimising sustainable and circular supply chains is regarded as key prerequisites for the transition towards sustainability and the CE in the case study companies (see Sections 5.2 and 5.3). In this context, five groups of challenges were identified:

Firstly, a lack of transparency across the value chain emerges as a key challenge reported by all case study companies. Global and fragmented production networks, particularly in the clothing industry, are described as complicating traceability of origin and risk assessment. This is associated with significant demands on time and human resources for collecting, analysing, and reporting sustainability-related data -whether for due diligence obligations and customer information (C01, C13, C16, C19, C21, C23, C26, C28) or for the calculation of carbon footprints (C01, C04, C05, C07, C08, C18, C22, C28).

This suggests that the lack of transparency is linked to supply chain partners being unknown, being unable to provide accurate, complete, or standardised data (C02, C03, C06, C23, C27, C28, C29), or being unwilling to disclose information (C06, C15, C21). This challenge is primarily associated with the process dimension, indicating that companies are confronted with the need to develop approaches for efficiently - and, where possible, automatically - collecting, analysing, and reporting supply chain data, while deriving appropriate measures. At the same time, such approaches need to account for the perspectives of supply chain partners, in order to ensure that processes remain manageable and efficient for all actors involved and thereby support broader acceptance. As C22 emphasised: “For manufacturers it is a huge challenge if ten brands confront them with ten different questionnaires and requirements”.

Secondly, the collection and evaluation of such data, together with the proliferation of overlapping national and international legal requirements, certification schemes, customer-specific demands, and reporting obligations, are described as resulting in significant administrative burdens. Companies in the textile industry (NACE Code 13) report increased complexity, duplication of work, and higher human resource requirements, for instance when conducting similar audits for different customers (C05) or providing comparable, yet not identical, information via questionnaires (C04) or online platforms (C06). Companies in the clothing sector (NACE Code 14) additionally refer to rising regulatory requirements and the multitude of standards, labels, and certifications as a source of administrative burden (C15, C22, C23, C24, C27, C28, C29). This challenge is primarily associated with the process dimension and is discussed in relation to the need for sector-wide standards, more harmonised requirements, and integrated software systems to reduce administrative effort.

Thirdly, given the highly interconnected nature of supply chains, achieving sustainability objectives and implementing CE principles is described as depending on the integration of supply chain partners. For German companies, however, the analysis indicated that exerting influence over suppliers is frequently perceived as difficult. The smaller the company or the lower its purchasing volume with specific suppliers, the less leverage it is reported to have to drive improvements (e.g., C06, C09, C21, C22, C25, C27, C29). As C06 vividly put it, efforts to promote change in wool production were “like fighting a fire hose with a child’s water pistol”. This perceived lack of influence is also reported to affect areas such as complaints mechanisms, living wage pay-

ments, or the reduction of environmental impacts. This challenge is primarily associated with the process dimension and is discussed in relation to the relevance of pooling resources and strengthening collective awareness and influence among supply chain partners in order to support compliance with due diligence obligations.

Fourthly, leftover and waste materials resulting from T&C production steps, are reported to be reused or recycled to a limited extent. Barriers include logistical challenges related to the reuse or recycling of leftover materials from production in Asia, which typically remain there due to customs regulations and costs, with their subsequent handling often remaining unclear given limited recycling infrastructure (C22, C24, C28). Even within Germany, companies refer to challenges in identifying efficient solutions for unavoidable production waste and leftovers, such as those arising from minimum order quantities (C09, C10, C28). This process-related challenge is discussed in relation to the need for improved planning and recovery approaches to better align production, logistics, and recycling activities.

Fifthly, the development of such solutions, for example the establishment of take-back and recycling systems, is described as facing additional barriers. These systems are reported to depend on large and consistent material flows, which remain limited due to underdeveloped infrastructure (C22, C23) and low levels of consumer and customer participation, as discussed in Issue 2. Effective return processes are described as requiring optimised logistics, scalable collection networks, and reliable partners for sorting and recycling, which are currently reported as insufficient (C11, C15, C18). Textile recycling technologies are further described as facing limitations, particularly for blended materials (C06, C11). This challenge spans both the process and organisational dimensions, as it is discussed as involving not only infrastructural investments but also the development of business model approaches that enable products and materials from different lifecycle stages to be reintegrated into the T&C value chain.

Issue 4: Organisational readiness

The implementation of sustainability and the CE is described as being strongly shaped by company-internal conditions, including the readiness of organisations to adapt to associated objectives and requirements. In this context, three major challenges emerged from the analyisis:

Firstly, the development of a shared awareness and commitment among employees and managers across departments is described as a key prerequisite for embedding sustainability strategies and CE principles within companies and beyond. In practice, however, the analysis indicated that companies frequently encounter insufficient knowledge or divergent interpretations of sustainability objectives (C22, C24, C29), alongside conflicting priorities between business areas (C01, C09, C27). This is described as potentially creating tensions between functions such as product development, quality management, and marketing, as departments operate with different performance indicators or market requirements in mind. This challenge is primarily associated with the organisational dimension, with companies referring to the relevance of clear strategies, defined responsibilities, and communication measures, as well as the integration of sustainability and CE considerations into management processes (C27), in order to foster a shared awareness and organisational culture.

Secondly, companies report being confronted with the replacement of fragmented and manual processes (e.g., C02, C06, C07, C08, C09, C28, C29) by integrated, digitalised, and seamless systems that operate consistently across departments, sites, and supply chain partners. This includes the modernisation of ERP systems, quality control, and data management systems, as well as the use of IoT and AI to enable the real-time capture, processing, and sharing of sustainability-, traceability-, and operations-related data. While many companies report having initiated such developments to varying degrees, barriers persist, including limited acceptance and insufficient competences related to the effective use and further development of digital systems among employees and supply chain partners (C01, C04, C09, C25, C29). This challenge is primarily associated with the organisational and process dimensions and is discussed in relation to the need to address gaps in digital competences and acceptance alongside technological investments. Data and system security also emerged as critical concerns, as illustrated by C26, who experienced a cyberattack that disrupted internal processes for several months.

Thirdly, addressing these challenges is described as being contingent on the availability of sufficient financial and human resources, as well as relevant organisational capabilities and skills (C04, C06, C09, C22, C28). This issue is reported as being particularly pronounced among smaller companies, which face limited financial resources

and comparatively high relative costs for certifications, licences, IT infrastructure, and skilled personnel (C06, C09). This challenge is likewise primarily associated with the organisational dimension, with companies referring to the importance of long-term strategic commitment, resource allocation, and prioritisation by management, alongside practices related to recruitment, skills development, and staff retention, as well as securing appropriate financing options, in order to maintain competitiveness.

5.4.2 Influencing Factors

In addition to the challenges identified, the case study findings also point to several factors described as facilitating the advancement of sustainability and the CE. These factors shape how companies respond to existing challenges and barriers, as well as the perceived pace and scope of the transition. Four overarching categories of influencing factors emerged from the analysis, each relating to different dimensions of organisational, product, and process adaptation. These factors are presented in detail hereafter.

Influencing factor 1: Cooperation, collaboration and partnerships

Fostering cooperation, collaboration, and partnerships with actors within and beyond the T&C value chain is described as a central factor in advancing sustainability and the CE. In the case study companies - particularly in the clothing sector (NACE Code 14) - numerous initiatives were identified that relate to the challenges outlined above. These initiatives were identified as relying on collaboration with a wide range of actors, including suppliers (C18, C21, C22, C24, C28, C29), recycling companies (C15, C18), industry associations (C06, C22, C25), research institutes (C22), and NGOs or non-profit organisations (C02, C22, C28). Such partnerships enable knowledge exchange, resource pooling, and the joint development of solutions that would be difficult to achieve independently. Collaborative platforms and industry-wide projects allow companies to tackle systemic challenges - such as recycling infrastructure, life cycle assessments, or living wages - by harmonising requirements and standards, supporting suppliers in meeting them (C02, C18, C21, C22), coordinating and testing take-back systems (C15, C18, C28), and driving joint innovation (C22, C28). Taken together, the findings suggest that collaboration and partnerships are perceived as key drivers in accelerating the transition towards more sustainable and circular practices in the T&C industry.

Influencing factor 2: Innovation

Innovation emerged as another key factor in overcoming challenges. Developing new materials, products, processes, and specialised tools is associated with resource conservation, waste reduction, and increased efficiency, thereby safeguarding the long-term competitiveness of German companies. Practices identified in the case study companies include the creation of specialised software systems for supply chain management and regulatory compliance (C01), the advancement of recycling technologies and processes in collaboration with specialised partners (C22, C28), as well as the development of reusable packaging materials alongside corresponding take-back schemes (C09).

Influencing factor 3: Harmonised standards, regulation & support

Another factor - one that companies can influence only to a limited extent, yet which significantly shapes their transition to sustainability and the CE - is the existence of clear legal frameworks, harmonised industry standards, and accessible financial support. These aspects were discussed in all interviews and were also reflected in several company documents.

Companies see great potential for advancing the transition in replacing fragmented approaches with binding regulations or uniform systems that impose consistent requirements on all actors, prevent misuse and excessive bureaucracy, and provide comparable information for customers, consumers, and other market participants (C04, C06, C21, C22, C24, C28). Public funding and governmental support are associated with fostering cooperation and innovation and with enhancing their financial viability. However, complex bureaucratic procedures were discussed as discouraging participation, highlighting the need for improved advisory services and clearer guidance on applying for research and funding programmes (C09, C24).

Influencing factor 4: Digitalisation

Deployment and integration of advanced digital tools and digitalised processes emerged as central organisational practices aimed at enhancing data accuracy, transparency, and efficiency in supply chain processes and sustainability reporting. Modern metering technologies, for instance, enable more precise collection, transmission, and analysis of consumption data, thereby supporting efficiency gains and facilitating new approaches to energy management (C07).

Continuous improvements in data collection also allow companies to better monitor resource consumption in other areas, such as packaging, including the share of certified and recycled materials (C28). The development of standardised and future-proof data management systems are described as enhancing the comparability and traceability of information, reducing administrative burdens, and ensuring timely, high-quality data – thereby freeing up resources for the implementation of due diligence obligations in supply chains (C21). Specialised tools, such as digital platforms that integrate all supply chain stages or specific management systems, are deployed to further support seamless traceability and targeted monitoring and optimisation of sustainability performance at manufacturers and suppliers (C18, C28). In addition, in-house IT capabilities are described as an enabler of the creation or adaptation of customised software solutions, ensuring that systems are precisely aligned with the requirements of customers, employees, and suppliers (C21).

Table 37 and Table 38 provide a summarised overview of the key issues, challenges and influencing factors related to the implementation of sustainability and the CE in the case study companies.

Table 37

Overview of key issues and related challenges associated with the implementation of sustainability and the CE as well as the affected change dimension identified from the case study companies

Key issue	Challenge	Description	Related change dimension	Reference
Use and production of more sustainable materials & products	Adapting manufacturing processes	Because of their specific properties, recycled and other alternative materials often require different, usually more complex treatment and processing steps and, in some cases, different equipment than conventional materials.	Processes	C04, C06, C07, C08, C09, C11, C22
	Ensuring procurement of recycled or other alternative materials in terms of price, quality and availability	Recycled and other alternative materials are often more expensive compared to conventional materials and there are various uncertainties such as inconsistent material properties and quality, as well as limited availability. Therefore, these are often not competitive compared to conventional materials.	Processes, Product	C02, C06, C09, C10, C11, C22
	Balancing sustainability performance and functionality/ quality requirements	The use of more environmentally friendly materials and processes often leads to qualitative limitations, for example in terms of durability, performance, aesthetics or specific customer requirements.	Product, Processes	C02, C05, C06, C07, C08, C09 C11, C15, C22, C23, C27, C28, C28, C29
	Designing/ developing materials & products for full recyclability	Fully recyclable products are still an exception, as technical recycling capabilities remain limited, and the high requirements for the materials used and for product characteristics often conflict with the function, quality, or aesthetics of the products.	Product	C15, C18, C24, C25
Heterogeneous market requirements and price sensitivity	Balancing sustainability performance and market prices	Due to the high price sensitivity in the market, it is difficult for companies to achieve higher market prices for products and materials with improved sustainability performance	Product, Processes, Organisation	C04, C07, C09, C23, C24, C26, C27, C28, C29
	Managing stakeholder reluctance to participate in circular practices and new business models	Current approaches and initiatives to extend product and material life cycles, such as take-back options, product service systems, or resale, are hardly economically viable because customer and consumer participation and the resulting quantities to be processed are too low	Product, Processes, Organisation	C06, C09, C22, C24, C28
Sustainable and circular supply chain management	Improving transparency and ensuring efficient collection, analysis and reporting of sustainability related data	Due to global and fragmented production networks, companies often lack transparency about the partners involved. In addition, collecting, analysing and reporting data on the social and environmental impacts of products and materials, as well as the associated risks in the supply chain, requires a considerable time and resources.	Processes	C01, C02, C03, C04, C05, C06, C07, C08, C13, C15, C16, C18, C19, C21, C22, C23, C26, C27, C28, C29
	Managing the administrative burden related to the multitude of legal requirements, certifications and reporting	Companies must navigate a fragmented environment of national and international standards, customer-specific requirements and initiatives from various interest groups, and comply with the associated, non-harmonised requirements. This involves increased personnel and administrative costs, which in turn leads to higher overall costs.	Processes, Organisation	C04, C05, C06, C15, C22, C23, C24, C27, C28, C29
	Strengthening the influence over supply chain partners to increase sustainability performance and ensure compliance with due diligence obligations	Due to their size, procurement-power and/or type of supplier relationship, companies often have little or no opportunity to influence social and environmental impacts and conditions along the supply chain.	Processes	C06, C09, C21, C22, C23, C25, C27, C28, C29
	Managing leftover and waste across the supply chain	The reuse and recycling of pre-production waste streams, especially leftover material from manufacturing processes, is often related to logistical, legal and economic barriers when undertaking such projects.	Processes	C09, C10, C22, C24, C28
	Building effective and efficient reverse supply chain processes	Collecting, sorting, cleaning and reprocessing textiles involves a high level of human and financial resources. At the same time, return quantities have been rather low to date, which means that the corresponding processes and business models are often not profitable.	Processes Organisation	C06, C11, C15, C18, C22, C23
Organisational readiness	Aligning internal sustainability awareness, understanding, objectives and management practices	Insufficient knowledge and differing interpretations of sustainability goals within the company, as well as conflicting priorities in different departments, can lead to tensions between corporate functions and increased workloads, resulting in resistance among employees and those responsible.	Organisation	C01, C09, C22, C24, C27, C29
	Advancing digitalisation in the company and across the supply chain to improve efficiency and collaboration	Companies are faced with the task of replacing fragmented, manual and often outdated processes with integrated digital solutions that work seamlessly across departments, locations and supply chain partners, helping to ensure compliance with due diligence and sustainability requirements.	Processes, Organisation	C01, C02, C04, C05, C06, C07, C08, C09, C18, C25, C26, C28, C29
	Securing sufficient financial & human resources, skills and capabilities to implement sustainability initiatives	The implementation of sustainability strategies often requires significant investments in technology, materials and expertise, which can pose a particular challenge for smaller companies.	Organisation	C01, C04, C06, C09, C22, C28

Table 38

Overview of influencing factors related to the implementation of sustainability and the CE as well as related change dimensions identified from the case study companies

Influencing factors	Description	Related change dimension	Reference
Strengthening cooperation, collaboration and partnerships	Partnerships, cooperations and industry-wide projects involving various stakeholders across the entire value chain and beyond serve to exchange knowledge, pool resources and enable companies to tackle systemic challenges and contribute to the development of joint solutions and innovations.	Product, Processes, Organisation	C02, C06, C15, C18, C21, C22, C24, C25, C28, C29,
Innovation	Targeted research and development of new solutions in the areas of products, materials, business models, and processes helps to address challenges, particularly those related to the immaturity of recycling technologies and the fluctuating quality, availability, and prices of alternative materials, to open up new business areas, and thus to ensure the competitiveness of companies.	Product, Processes, Organisation	C01, C09, C22, C28
Harmonised standards, regulations and support	The development of clear and binding legal frameworks, industry-wide standards and systems, as well as external support and financial incentives, offer great potential for companies to replace fragmented approaches, establish efficient processes and thereby accelerate the transition to sustainability and the CE	Product, Processes, Organisation	C04, C06, C09, C21, C22, C24, C28
Digitalisation	Digital technologies offer great potential for meeting the challenges of the transition to sustainability and CE by enabling efficient data collection and analysis as well as communication, thereby ensuring transparency and traceability along the entire value chain.	Processes, Organisation	C07, C18, C21, C28

5.5 The Role of Digital Technologies in the Transition to Sustainability and the CE in German T&C Companies (RO2 – Q4)

The document analysis suggested that Dts are addressed only marginally, if at all, in publicly available sustainability-related publications. Consequently, the interviews placed a stronger focus on the perceived links between the DTs deployed and the companies' sustainability and CE initiatives. As the findings related to the implementation of sustainability and the CE have shown, CE-related initiatives emerged as an integral component of the case study companies' sustainability strategies, even though its implementation is still at a relatively early stage. Furthermore, the findings related to the implementation of sustainability and CE practices within the companies indicates that DTs are already embedded in these processes and are perceived as potentially contributing to their advancement. Overall, DTs were consistently perceived as important enablers of operational efficiency and performance across the case study companies. At the same time, interviewees indicated that the potential of these technologies - particularly within the T&C industry - has not yet been fully exploited. Regarding the nine SMAC and BRAID technologies discussed in the literature review (see Sections 2.5 and 2.6) as potentially suitable for supporting and advancing sustainable and circular strategies and practices, the case study companies were found to be employing them to varying degrees and for different purposes. In addition, enterprise software such as ERP and management systems emerged to be particularly relevant in the

context of implementing sustainability and CE-related practices (Table 39). The application scenarios for the individual technologies in the case study companies are presented in detail below.

Table 39
Overview of digital technologies deployed or planned in the case study companies

NACE Code	Company Code	Technology									
		Social Media	Mobile Applications	Big Data/ Analytics	Cloud Computing	Blockchain	Process automation & robotics	Artificial Intelligence	Internet of Things	Digital Fabrication	Management Software/ Third Party platforms
13	C01	X	X							X	X
	C02	X									
	C03						X		X		X
	C04	X	X	X	X	X		X	X		
	C05	X	X	X	X				X		X
	C06	X				X					X
	C07	X	X	X	X				X		X
	C08	X	X	X	X	X	X	X	X	X	X
	C09	X		X							
	C10	X		X	X		X	X		X	X
	C11	X	X	X	X		X	X			X
13 Total: 11		10	6	7	6	3	4	4	5	3	8
		91%	55%	64%	55%	27%	36%	36%	46%	27%	73%
14	C12	X									
	C13	X								X	
	C14	X	X			X	X	X			
	C15	X				X					X
	C16	X	X						X		
	C17	X									
	C18	X	X		X	X	X	X			X
	C19	X									
	C20	X									X
	C21	X					X				X
	C22	X					X			X	
	C23	X	X		X	X				X	X
	C24	X	X	X	X			X	X	X	X
	C25	X			X					X	X
	C26	X				X					X
	C27	X									X
	C28	X	X	X	X	X	X		X	X	X
	C29	X		X	X	X				X	X
14 Total: 18		18	6	3	6	7	5	3	3	7	11
		100%	33%	17%	33%	39%	28%	17%	17%	39%	61%
13 & 14 Total		28	12	10	12	10	9	7	8	10	19
		97%	41%	35%	41%	35%	31%	24%	28%	35%	66%

Techology deployment mentioned in interview
Technology deployment mentioned in publicly available company documents
Social media channels existant, but not mentioned in sustainability related company documents

Social media

Except for C03, for which no profiles or information could be found in or through social media channels, all case study companies maintain their own profiles and pages on platforms such as LinkedIn, Instagram, TikTok, Facebook, or YouTube. Their use is primarily limited to marketing purposes. Sustainability-related social media content generally focuses on providing information about activities along production processes and supply chains, as well as product-related information concerning care, mainte-

nance, and disposal of T&C items. For example, C01 reports having made its “communications strategy even more systematic and consistent” and using diverse media such as podcasts or videos to inform a wider public about CE-related issues and activities in the T&C sector. C28 highlights the risk of greenwashing in this context, stressing: “We take care to avoid ‘greenwashing’ in all communication channels. In other words, we do not try to present our company as ‘greener’ than it actually is by putting a lot of effort into advertising. Instead, we adhere to the EMAS principles in our marketing: responsible, credible, innovative and transparent.” Only C15 reports actively involving consumers directly via social media, for instance by conducting “surveys via Instagram or newsletters to find out the desired sizes, colours, and cuts” to better match customer preferences, as well as encouraging product life extension through initiatives such as upcycling challenges. Similarly, C22 offers e-learning formats including quizzes and tutorials on topics such as responsible consumption and repair instructions for textile products. Social media thus appears to play a role primarily in stakeholder integration and communication and is therefore mainly associated with the change dimension of the organisation. However, when stakeholders are involved in product development, as illustrated by C15, social media could also affect the product dimension and potentially contribute to reduced resource consumption, since the risk of overproduction may be mitigated through early customer feedback - even though this cannot be substantiated by the data. Beyond this, the influence of social media applications on the implementation of CE principles appears to be limited to informing and engaging customers and consumers, thereby fostering greater awareness, more responsible consumption, and use phase extension. In turn, this may promote narrowing and slowing strategies.

Mobile applications

Mobile computing technologies - such as smartphone applications, tablets, and mobile working solutions - are widely adpopted across the case study companies. They are primarily used in connection with sustainability-related activities, especially in areas such as remote working, communication, administrative processes, and sales presentations. While the document analysis revealed references to such applications in only 5 of 29 companies (17%), 7 of 10 interviews (70%) indicated that these technologies are already in use or planned for introduction and provided examples of their relevance to sustainability-related objectives. Mobile applications were discussed in relation to

enhancing efficiency by reducing travel requirements and associated emissions while improving communication processes. For instance, C28 states that the use of tools such as MS Teams had “significantly improved efficiency” as they were “utilising fewer human resources and […] do not always have to be on site”. Similarly, C04’s sustainability report highlights that “employees’ daily commute is an important data point” within their Scope 3 emissions and that they have therefore “enabled mobile working for employees whose presence on-site is not required”. C06 also referred to initial developments of mobile applications in the field of chemical management, where transparency and traceability providers are offering simple data entry options through mobile solutions. Other companies (e.g., C01, C14, C16, C18, C23) employ similar tools to provide stakeholders across the supply chain with easy access to services such as registering returned clothing for take-back programmes or complaints related to due diligence obligations. Overall, the findings suggest that a range of mobile applications and functionalities are being used and developed to support sustainability strategies and CE-practices, though no uniform approaches have yet been established. Instead, mobile solutions are typically employed as pragmatic tools to address specific operational requirements and support process digitalisation and thus are primarily linked to the change dimensions of the organisation and processes. While the data suggests that mobile computing and applications are indirectly contributing to the CE in the case study companies by improving efficiency and reducing resource use in administrative processes – and can therefore be linked to the narrowing strategy – their broader potential to actively support sustainability and CE practices appears to remain largely untapped.

Big data and analytics

Only limited references to the deployment of big data and analytics could be identified in the companies’ sustainability-related documents. One example was found in C29’s sustainability report, which briefly mentions the development of a climate neutrality strategy: “So far, we have focused on collecting data. We will expand this during this year 2024 to improve our database. This will enable us to plan and act even more precisely.” However, 6 of 10 (60%) interviewed companies revealed further connections and provided examples of how large data sets are used in supporting sustainability activities and CE practices. The findings indicate that data from multiple sources are used to monitor and improve resource use, consumption, and overall operational

performance. Data are primarily generated through production machinery - such as spinning, nonwoven, or dyeing equipment - as well as through company-wide software systems. Both the collection and integration of these data, as well as their subsequent analysis, differ greatly in scope and maturity across the case study companies. For example, according to C07, the company´s main focus is “to be able to simply collect all the basic data” from several machinery and equipment. C24 highlighted that their company’s software analysis tools are explicitly aligned with sustainability objectives and that they “have Power BI tools to monitor whether we are meeting our goals”. By contrast, C09 reported that although their company collects diverse data from all weaving machines, “the further evaluation is consolidated in Excel”, which limits analyses to retrospective rather than real-time insights. This lack of real-time data is perceived as reducing opportunities for proactive process optimisation and waste reduction. Overall, the findings suggest that while companies acknowledge the potential of big data and analytics, it remains at an early stage of integration. Firms that already employ data collection and analysis tools state to benefit from enhanced monitoring, better compliance with sustainability objectives, and the ability to make data-driven decisions thereby supporting continuous improvement and efficiency gains (C04, C05, C08, C10, C24, C28, C29). The identified applications primarily support the narrowing strategy and mainly affect the organisational level, particularly decision-making and pursuing of strategic objectives.

Cloud computing

In line with the findings on big data and analytics, only indirect references to cloud computing could be identified in the sustainability reporting of the case study companies. For example, C25 has developed a cloud-based digital fabric library containing extensive product information, which can be accessed free of charge by product developers and designers in the downstream value chain, eliminating the need for physical fabric samples. According to the company, this “tool provides a nearly tactile experience in a far more sustainable format”. However, 7 of 10 (70%) interviews revealed connections, with cloud services primarily described as an enabler for the implementation of various sustainability strategies. These services are predominantly used to increase efficiency in development, production, and administrative processes. For instance, firms employ cloud services within their business processes to ensure data sharing and collaborative use of documents (e.g. C04, C05, C10, C24, C28), thereby

reducing redundancies and errors. This, in turn, enhances resource efficiency by avoiding defective production and reducing paper consumption. Overall, the findings suggest that cloud-based applications and tools are supporting, and in some cases directly enabling, sustainability-related strategies and practices. In practice, the companies primarily harness this potential indirectly through the use of third-party software systems, rather than through proprietary developments. Nevertheless, the identified use cases offer significant potential for the transition to sustainability and the CE, as they contribute to the absolute reduction of resource consumption and can thus support the narrowing strategy. In doing so, they affect all three change dimensions.

Blockchain-technology (BC)

The document analysis revealed direct references to the use of, or plans to implement, BC technology in 7 of 29 companies (24%). In addition, interviews with three companies, which had not provided such information in their documentation (C04, C06 and C08), reported to use or currently have plans for implementing BC-tools. For instance, C06 reported plans to replace current manual practices of data collection and transmission for material traceability with “one of these classic traceability providers such as Textile Genesis”. Overall, BC-based tools are primarily used via external platforms to increase transparency and traceability across the value chain. They enable companies to record and verify the origin and processing of materials, thereby supporting claims related to sustainability performance (C04, C23, C28). Such solutions are discussed, for example, in relation to verifying that materials are sourced from organic cultivation or produced without harmful chemicals, thus contributing to reduced resource consumption and minimised environmental impacts. The findings suggest that the effective use of BC applications depends on the active involvement of value chain partners and their willingness to share relevant data. At the same time, the implementation of BC applications, particularly in companies operating in early stages of the T&C value chain, remains associated with significant effort and multiple challenges. C04, a fibre producer, noted that while customers increasingly demand transparent information, only a few actively use the Textile Genesis BC solution employed by the company. Similarly, C06, a yarn manufacturer, highlighted both the demands of apparel producers for transparency and the substantial manual effort involved in data entry across different BC platforms. Such fragmented and non-automated practices were

discussed as raising concerns among the companies regarding the accuracy and reliability of the information captured, although interviewees described BC as having significant potential to enhance transparency and enable secure, real-time data exchange. Even if this potential is only partially realised in practice, the described use cases can be interpreted as contributing indirectly to resource conservation and the reduction of negative environmental impacts across value creation processes thereby supporting the narrowing strategy.

Process automation and robotic

The findings indicate that the use of robotics and process automation in connection with sustainability-related activities remains limited, with only 9 of 29 companies (31%) reporting relevant applications. Where implemented, these technologies are mainly applied to specific operational tasks, such as packaging or the loading and unloading of goods within production processes. The robotic systems employed can largely be described as stand-alone solutions rather than being integrated into broader digital ecosystems or sustainability strategies. Their main purpose is to enhance efficiency and productivity within individual subprocesses, as illustrated by C08´s description on automated logistics systems: “We are looking to optimise our [logistics] processes with these technologies to make them more efficient, speed up operations [. . .] and reduce resource consumption, such as packaging materials“. Another example was described by C10, who uses laser technology to detect seam sections during the printing process that are later cut off and discarded. These are skipped automatically, leaving the fabric unprinted and therefore recyclable. C28 – an outdoor brand with its own production facility in Germany – reported the use of robotics: According to the company, a fully automated production line has replaced “eight manual process steps with state-of-the-art technology” and contributes simultaneously to “significantly shorter delivery times and less material waste”. These examples suggest that automation initiatives are predominantly oriented towards efficiency and cost optimisation. Process automation also includes efforts to implement software-supported automation for ensuring due diligence across supply chains, as reported by C14, C21 and C22. For instance, C14 has implemented a digital, automated grievance mechanism that uses “automatic translation functions and a dedicated online portal for factories [to] further improve accessibility and transparency. Regular reporting ensures that all complaints are systematically analysed and integrated into the continuous improvement process”. Similarly,

C21 is developing a more comprehensive tool “intended to automate and systematise large parts of data management” related to supply chain due diligence. Overall, while robotics and process automation are not yet widespread, the use cases illustrate their potential to contribute directly to sustainability goals and CE practices by reducing waste, streamlining processes, and improving efficiency, thereby supporting the narrowing, in one single company also the closing strategy. Current applications, however, remain largely limited to isolated subprocesses and contribute only to a limited extent to the broader sustainability and circularity objectives of companies. Accordingly, the changes associated with these applications are relatively minor and affect only individual processes.

Artificial intelligence (AI)

Evidence of AI applications linked to sustainability strategies and activities was identified in 7 of 29 companies (24%). The interviews and documents indicated that firms are beginning to explore AI as a tool to support sustainable product design and resource efficiency, with most applications still at an early planning stage or in pilot operation. The diversity of potential use cases highlights the considerable promise of this technology. Interview data indicate that AI-powered camera systems are increasingly used for defect detection and are described as contributing to improved product quality and efficiency while reducing waste. For example, C08 reports about AI-based systems to monitor production processes and ensure quality: “We are performing real-time measurements so we can immediately intervene the moment a defect is detected, preventing unnecessary meters of poor-quality material from being produced, which automatically would be prepared for thermal incineration”. Similarly, C11 is “working on [systems] that can recognise different product formats using image recognition software [. . .] for scanning for defects or the quality of the product”. However, implementation is perceived as challenging, with the company being “still far from implementation — more than 1.5 to 2 years away”. Beyond production, AI is viewed as a means of assessing and optimising product sustainability performance during the design phase, enabling more informed decision-making (C10, C24). C10 describes the integration of design-oriented AI into production and energy management systems as contributing to efficiency gains, for instance through the optimisation of print designs to minimise ink and energy consumption. C14 frames AI-based sales forecasting as a means that could potentially support production planning, which, in their view, may

help to mitigate overstock and reduce unnecessary material and resource use. C18 describes AI as being applied in the identification and sorting of textiles at their recycling partner, attributing to these applications the potential to enhance process and resource efficiency and to improve recycling outcomes by facilitating the exclusion of foreign materials. Although most AI applications are still in the planning or testing stages, they demonstrate the potential to contribute to reducing waste, conserving resources, and embedding sustainability considerations throughout the entire product lifecycle—from design and production planning to end-of-life recycling—thereby supporting both narrowing and closing strategies. Overall, while the adoption of AI technologies among the case study companies remains in its infancy, their potential to advance sustainability strategies and practices through targeted changes on product and process dimensions, appears highly significant.

Internet of things (IoT)

While the document analysis revealed only limited evidence for the deployment of IoT technologies (3 of 29 companies), four of the 10 interview respondents described a range of use cases and examples illustrating how IoT technologies are integrated into T&C manufacturing processes to support the transition to sustainability and the CE. Real-time monitoring and control systems (C03, C05), often combined with the AI-based solutions discussed in the previous paragraph, are discussed as enablers for precise tracking of process parameters and targeted optimisation of energy and resource use as well as product quality, thereby reducing waste and increasing efficiency. For example, C03 uses a steam meter on its machines to “determine the exact steam consumption of each machine”, while at C05 sensors for quality monitoring on machinery and testing equipment are deployed, creating extensive opportunities “for carrying out analyses, reports, and mill certificates” (C05). Nevertheless, the analysis indicated that companies currently make only limited use of IoT in relation to sustainability objectives, pointing to unrealised potential in this area. The findings suggest that, despite the availability of machine-level data, insufficient integration between systems - both internally and across organisational boundaries - constrains more comprehensive data analysis and real-time decision-making. At the same time, initial IoT applications, such as QR codes or RFID tags on clothing products, have been introduced in some companies (e.g., C16), while others are currently preparing for their adoption (e.g., C24, C28). Similarly, tracer systems described by C04 offer a means of tracking

materials across their entire lifecycle, thereby enhancing transparency and supporting recycling efforts - particularly relevant in light of the EU's Ecodesign Regulation and the planned introduction of the Digital Product Passport. These technologies are often combined with cloud and blockchain applications, demonstrating that the integration of multiple technologies and functionalities can provide more holistic solutions to sustainability-related requirements. Taken together, these examples suggest that IoT is used to contribute to both operational efficiency gains and improved traceability and lifecycle management of products, thereby aligning production more closely with CE principles, primarily the narrowing strategy. Consistent with the critical reflections in the literature, the findings indicate that IoT technologies do not operate as autonomous systems but derive their relevance from their integration into broader socio-technical configurations that connect technological infrastructures with organisational capabilities and strategic objectives. The potential of IoT is most fully realised when combined with other technologies, such as blockchain and cloud computing, offering integrated solutions to improve resource efficiency and support circular practices. However, integrating IoT applications into wider sustainability strategies entails significant investments in system connectivity and data analytics capabilities. The findings further indicate that these developments have implications across all change dimensions. With increasing regulatory pressure for greater transparency, IoT technologies are expected to become more important. At present, however, their application remains fragmented.

Digital fabrication

Evidence on the use of digital fabrication was found in documents and interviews from 10 of the 29 companies (35%). Within product development, 3D design tools were found to be particularly widespread. These are frequently discussed in relation to virtual prototyping, thereby reducing the need for physical samples. This saves materials, energy, water, and chemicals, while at the same time lowering CO_2 emissions from sample production and transport (C01, C13, C23, C25, C29). As C23 states, these technologies deliver substantial cost savings: "The amount of money that saves is more than you could ever spend on software." Digital colour management systems and virtual material libraries are discussed in relation to further contributing to reduced resource consumption by optimising colour selection, shortening coordination processes, and avoiding unnecessary courier shipments (C22, C25, C28). C10 provides an illustrative example of resource-efficient innovation, having completely transitioned

its manufacturing process from rotary screen printing to digital printing. This shift is reported to have significantly reduced water, energy, and chemical consumption and to have eliminated excess material waste associated with machine setup processes. With regard to digital fabrication technologies, it can therefore be concluded that their potential for reducing resource consumption and waste - particularly related to product development - is increasingly recognised and implemented in practice. However, little evidence of application in production processes was identified. C10's transition to digital printing represents the only example of large-scale implementation among the case study companies. In contrast, most companies are still in an exploratory phase with regard to digital manufacturing technologies. Nevertheless, these technologies offer considerable potential to improve resource efficiency, streamline production processes, and reduce waste, making them highly relevant for supporting more sustainable practices in the T&C industry.

Other digital systems and platforms

In addition to the technologies discussed above, core business software systems - such a ERP and PDM/PLM solutions - were identified as important components of the companies' digital infrastructure. In the case study companies, these systems support a range of sustainability-related objectives and practices, particularly in relation to planning, coordination, and the management of operational processes. Furthermore, sustainability-focused specialised solutions offered by service providers are increasingly being used to ensure data transparency, traceability, and resource efficiency across the supply chain. Evidence of such applications was found in 17 of 29 (59%) companies.

The main areas of application were described as relating to the integration and management of sustainability data, both internally and across supply chains. Standardised data structures and more formalised processes for data collection, analysis, and reporting were portrayed by respondents as forming an important foundation for sustainability-related activities. These include, in particular, the monitoring of environmental and social indicators, the management of compliance requirements, and the facilitation of more transparent reporting practices (C01, C06, C07, C10, C11, C20, C21, C24, C27, C28). Several interview respondents reported ongoing or planned investments in new ERP or PDM/PLM systems to establish the necessary conditions for such activities (C06, C07, C24, C28).

In addition to enterprise software, specialised sustainability platforms and systems provided by external service providers were described as playing an important role within the case study companies. These applications were reported to range from systems used to assess and track product- and process-related environmental impacts – such as GHG emissions, chemical use, and wastewater indicators across supply chains (C01, C03, C11, C15, C23, C28) – to network-oriented platforms that facilitate supply chain traceability (C18, C21, C23, C25, C26, C28, C29).
Digital marketplaces were also described as being used to redirect products and materials that cannot be utilised or sold towards alternative applications (C08, C28).

The data therefore indicate that the case study companies aim to optimise data flows, reduce duplication, and provide verifiable sustainability data to stakeholders by combining internal digital tools with external platforms and supplier collaboration. This integration supports responsible sourcing, regulatory compliance, and CE strategies by making material flows more transparent, enabling informed decision-making, and promoting resource-efficient practices across the supply chain. The identified use cases are thus primarily associated with contributions to the narrowing strategy, and in the case of marketplaces for old or defective goods also to the slowing strategy. However, the findings also show that most companies are still at an early stage of implementation, with many systems currently in pilot or testing phases, and significant challenges remain, particularly in integrating supply chain partners into these processes and systems, highlighting that both the organisational and process dimensions are affected.

Summary

In this Section, the identified use cases for ten DTs potentially relevant to the transition to sustainability and the CE were described in detail. The findings indicate that, despite considerable variation among the individual use cases, companies tend to pursue broadly similar digitalisation practices. From the synthesis of the technology use cases and their classification according to the change dimensions and CE strategies (Table 40), four overarching findings can be derived for the industry:

Table 40

Overview of digital technology use cases related to sustainability and the CE and the affected change dimensions and CE-strategies

DT	Use cases related to sustainability & the CE	Related change dimension	Related CE-strategy	References
Social Media	- Publishing sustainability-related information for marketing purposes - Interacting /engaging with stakeholders - Educating stakeholders	Organisation	Narrowing, Slowing	C01, C02, C04, C05, C06, C07, C08, C09, C10, C11, C12, C15, C22, C24, C28
Mobile Applications	- Remote working, collaboration & communication - Virtual product presentation	Organisation, Processes	Narrowing	C01, C04, C05, C07, C08, C11, C14, C16, C18, C23, C24, C28
Big Data/ Analytics	- Collecting and analysing sustainability-related data (e.g., resource consumption) from different sources - Data-based decision making and process optimisation	Organisation	Narrowing	C04, C05, C08, C10, C24, C28, C29
Cloud Computing	- Virtual Design & Material libraries - Collaborative Data & document management	Product, Processes	Narrowing	C04, C05, C07, C08, C10, C11, C18, C23, C24, C25, C28, C29
Blockchain	- Tracking material & product life cycle - Proofing material origin and certifications	Processes	Narrowing	C04, C06, C08, C14, C15, C18, C23, C26, C28, C29
Process automation and robotics	- Reducing resource consumption & waste in production and logistics	Processes	Narrowing, Closing	C03, C08, C10, C11, C14, C18, C21, C22, C28
Artificial Intelligence	- Developing & designing products & materials - Detecting quality defects - Sorting textile waste	Product, Processes	Narrowing, Closing	C04, C08, C10, C11, C14, C18, C24
Internet of Things	- Measuring & tracking resource consumption and quality parameters - Tracking products & materials - Data sharing with stakeholders	Product Processes	Narrowing	C03, C04, C05, C07, C08, C16, C24, C28,
Digital Fabrication	- Virtual / 3D product design and prototyping - Digital colour management - Digital printing	Product, Processes	Narrowing, Closing	C01, C08, C10, C13, C22, C23, C24, C25, C28, C29
Management Software/ Third party platforms	- Data collection, analysis & reporting - Supply chain management & supplier collaboration - Remarketing of unsold/ defective goods	Organisation, Processes	Narrowing, Slowing,	C01, C03, C05, C06, C07, C08, C10, C11, C15, C18, C20, C21, C22, C23, C24, C25, C26, C27, C28, C29

Firstly, at the organisational level, communication tools - particularly social media platforms - are widely utilised across the case study companies. However, sustainability communication only rarely goes beyond traditional marketing activities to foster sustainability awareness and engagement among stakeholders. In addition, enterprise software systems such as ERP, SCM, and PDM, as well as specialised platform solutions, have emerged as particularly relevant technologies among all companies. Likewise, based on the interview analysis, it is assumed that cloud-based applications and tools for collecting and analysing large amounts of data are widely used throughout the case study companies, even though the document analysis suggests that these are not directly linked to sustainability efforts. What these technologies have in common is

their perceived usefulness for sustainability management to collect, analyse, and report relevant data and information. At the same time, the findings suggest that their relevance does not derive from isolated functionality, but from their embedding in interconnected socio-technical arrangements linking data infrastructures, organisational routines, and external stakeholders. In line with the critical reflections in the literature, DTs do not appear to operate as autonomous enablers of sustainability or CE practices; rather, their contribution unfolds through their integration into broader organisational and inter-organisational systems.

Secondly, at the process level, ongoing efforts to enhance transparency and traceability across the case study companies supply chains were identified. While intrinsic sustainability commitments were mentioned, regulatory requirements – particularly those related to due diligence obligations – were frequently discussed as key drivers shaping the deployment of DTs. In the case of platforms, which are typically operated by external software providers rather than by the companies themselves, the analysis points to a landscape of highly specialised applications, each addressing specific aspects of sustainable supply chain management. These include supply chain transparency, traceability of materials and products, chemical and wastewater management, and grievance mechanisms. In most cases, such solutions integrate multiple technologies, for example, cloud computing, blockchain, mobile applications, and AI. Notably, such platforms were often described as combining multiple technological components – including cloud infrastructures, blockchain functionalities, mobile interfaces, and AI-based analytics – rather than relying on single stand-alone tools. This suggests that their perceived relevance for sustainability does not stem from individual technologies in isolation, but from their interconnected configuration within broader socio-technical systems. The findings thus underline the importance of interconnectedness as a precondition for translating technological functionalities into meaningful sustainability-related practices.

Thirdly, although DTs were associated with supporting a range of CE-related activities, respondents more frequently associated them with efficiency gains and cost optimisation than with explicitly strategic sustainability or CE objectives. The findings suggest that technologies are predominantly supporting the reduction of environmental impacts, lowering of resource consumption, or prevention of waste generation, which allows them to be analytically linked to the narrowing strategy. In contrast, only a limited

number of companies indicate that technologies are deliberately deployed or further developed with the explicit intention of supporting the slowing or closing of resource flows.

Fourthly, at the product level, DTs were described as holding considerable potential for dematerialising design and prototyping processes, particularly through the combination of cloud-based infrastructures, AI applications, and digital fabrication tools. This potential is closely tied to the interconnected deployment of these technologies, as their relevance emerges not from isolated functionalities but from their integration into digitally supported design ecosystems linking data, tools, and actors across organisational boundaries. However, similar to the process level, respondents frequently emphasised general efficiency gains – such as accelerated development cycles, reduced resource consumption, and related cost savings – as primary motivations for their deployment. At the same time, selected examples, including digital material libraries enriched with sustainability-related information and collaborative design applications, were interpreted as indicating a broader potential of these technologies to support more sustainable and circular product development practices.

Table 41 provides an overview of illustrative references to the role of DTs and their corresponding use cases as reported by the case study companies.

Table 41

Illustrative references on sustainability-related application scenarios for digital technologies from the case study companies

DT	Illustrative references
Social Media	C01: "In 2021, we made our communications strategy even more systematic and consistent. Here are a few highlights: Branschkoll Podcast – How can the textile industry move from an assembly line economy to a circular economy? Information video about the circular economy"
	C09: "[…] the fabric always takes centre stage [in social media posts] and then we talk about our fabrics and the care properties […]"
	C15: "Customer feedback is very important to us in order to fulfil the needs and wishes of our target group as well as possible. For some product launches, we conduct surveys via Instagram or newsletters to ask about desired sizes, colours and styles. This helps us to develop exactly the right products for our customers that meet their needs"
	C15: "Upcycle your old [C15] products, share them on Instagram [...] and receive a 15% discount code on your next order for your creativity. By upcycling your [C15] products, you not only save important resources, but also inspire other people to come up with creative solutions for used textiles"
	C22: "In this LAB, we'll provide you with useful tips, tricks and tools and present inspiring mountain sports stories, solutions and entertaining tutorials so that, together, we can protect what we love"
	C28: "We take care to avoid 'greenwashing' in all communication channels. In other words, we do not try to present our company as "greener" than it actually is by putting a lot of effort into advertising. Instead, we adhere to the EMAS principles in our marketing: responsible, credible, innovative and transparent" C28: "[C28] has set up a service portal for customers who do not complain directly but have questions, criticism or suggestions. Customers can ask us questions, forward suggestions or criticism directly via our website. These inquiries are answered by a team in [C28]'s internal sales department"
Mobile Applications	C01: "For the collection of used workwear [...] registration is done via a specially created web tool or by email"
	C04: "Our employees' daily commute is an important data point [related to scope 3 emissions]. During the pandemic, we have enabled mobile working for employees whose presence on-site is not required (primarily administrative tasks"
	C06: "Mobile computing is actually starting to be used for chemical management, and ZDHC is making advances in this area and neighbouring applications. But really very detailed for chemical management. But there are things like BVE3 and BHive, they have nice approaches, also with mobile and scanners and things like that, but that's the only thing in the textile chain that I know"
	C14: "Employees can anonymously report grievances via an online ticket system (accessible via QR code). [...] It is further supplemented by a digital submission tool that provides complainants with a ticket number to track their concerns, as well as an automatic categorisation and translation function in multiple languages"
	C16: "For us, transparency is a very important concern. That's why we have developed the [traceability tool], with the help of which our customers can understand the entire manufacturing process of a [C16] product from the fiber to the finished part"
	C18: "[C18]'s commercial partners simply register worn-out clothing through an online portal and are provided with quick and easy access to recycling"
	C18: "We increasingly expand the range of our [C18] Academy with e-learning. In the future, we want to increasingly include e-learning in our further training options and facilitate educational scholarships"
	C23: "In September 2023, a topic-specific town hall meeting was held for the first time with all suppliers on the topic of sustainability. In addition to important updates on our sustainability strategy and focus projects, we had the opportunity to have in-depth discussions in digital break out rooms about respecting human rights, protecting the environment and nature as well as the circular economy and circularity. This dialogue was very valuable and will continue in the future"
	C28: "We were already doing all of this before the pandemic, including with MS Teams and cloud computing. This has led to a significant increase in efficiency. It is also worth noting that we are utilising fewer human resources and are simply more efficient as a result, and we do not always have to be on site. These web calls are now also working very well, particularly with Asia"

Table 41: Continued

DT	Illustrative references
Big Data / Analytics	C07: "Our main focus at the moment is simply on production and machinery. In order to be able to simply collect all the basic data from there and analyse it accordingly"
	C08: "In most cases, it's about improving efficiency. When we think about various data analyses, we're talking about real-time measurement systems, measurement points in general, and various software solutions that we've implemented to enable data to be read out at the touch of a button"
	C09: "Every machine has a computer that is also networked with the system. So, we get data such as how long it has been running, how often it has stopped, how many nodes were produces - basically rudimentary data. You can look at each loom individually, but then the further evaluation is consolidated in Excel [...] We tend to be reactive; we can evaluate a lot retrospectively, but we don't have any real time data. Everything has to be evaluated retrospectively"
	C11: "We use them [machine data] for process optimisation. […] so all machine data is logged for the lots that have been produced. What temperature it had, how long it ran, how much overtime it had, or whatever. It's all logged and traceable, and we then use the sum of the data to find potential for improvement. For example, if you draw conclusions from one quality to another. If you notice that one can be produced in 10 minutes less or with less water or something like that, then you try to do the same with a similar quality in the same way. [...] We also use this machine data for error analysis"
	C24: The systems are aligned with sustainability goals, which means we can monitor everything. We have Power BI tools to monitor whether we are meeting our goals in this area. This means that, in principle, all system interfaces are also involved"
	C29: "We have set ourselves the goal of developing a climate neutrality and compensation strategy by 2024. So far, we have focused on collecting data. We will expand this during the course of the year to improve our database. This will enable us to plan and act even more precisely"
Cloud Computing	C10: "We have invested so much money in IT and systems in recent years. Simply to make communication with customers easier. Many of them create their own designs, which they then finish and send to us as files. We have to save and manage these files, and the new printing machines are designed to process them directly. Our customers upload files to our server via WE Transfer and similar services"
	C25: "The Digital Fabric Library is a comprehensive online tool that offers users free access to [C25]´s diverse range of fabrics – anytime, anywhere. After logging into the [name] Cloud, users can easily browse the fabric library [...]. […] this tool provides a nearly tactile experience in a far more sustainable format"
Block Chain	C04: "To ensure complete transparency and traceability of its textile fibers throughout the entire value chain, C04 cooperates with the traceability platform Textile Genesis. Thanks to blockchain technology, the use of sustainable fibers is tracked and verified all the way from the fiber to the garment" […] "There are customers who have requested this and want to run the fibers through this blockchain platform, but not all of them yet. So there could be stronger demand."
	C14: Future goal for technological innovation: "Digital Twin of the Supply Chain: Monitoring of CO_2 emissions and water consumption"
	C23: "Together with Retraced, we have made the first products traceable and supply chains transparent and accessible. We are working to expand this further."
	C28: "Retraced supports us in an efficient and professional manner in determining key figures, assessing the status quo of a supplier, transparently mapping the supply chain, managing certifications and audits, and tracking the origin of materials. The digitalization of supply chain management is becoming increasingly important in light of the laws that will come into force as part of the EU Green Deal"

Table 41: Continued

DT	Illustrative references
Process automation & robotics	C08: "We are interested in using these technologies to optimise our processes in order to make them more efficient and faster, and to gain another advantage by incorporating the issue of resource consumption, because some of these systems are designed to use fewer resources, for example the film used for packaging"
	C09: "We have individual steps, for example a packaging machine, which is a conveyor belt where the fabric is fed in, sealed, and transported to the right place"
	C10: "We used to print over the seam. Nowadays, the machine stops before the seam because the laser detects it, then it moves over the seam and continues printing. So, I end up with the unprinted seam and only clean fabric. I then handle this differently in recycling because the fabric is uncontaminated"
	C14: "A central element of optimization is the digitization of the complaint procedure. For this purpose, a comprehensive system has been designed that digitally maps the entire process—from recording and automatic categorization to documentation. Through a ticketing system, complainants, whether anonymous or identified, can track the status of their submissions at any time. Automatic translation functions and a dedicated online portal for factories further improve accessibility and transparency. Regular reporting ensures that all complaints are systematically analyzed and integrated into the continuous improvement process"
	C21: "we initiated the development of a digital IT tool last year that is intended to automate and systematise large parts of data management. This summer, the tool will enter the pilot phase - initially in collaboration with one of our longstanding production partners, with whom we maintain a close business relationship"
	C28: "a new fully automated production line will go into operation, replacing eight manual process steps with state-of-the-art technology. [...] according to the latest industry standards, with significantly shorter delivery times and less material waste"
Artificial Intelligence	C04:"We wanted to incorporate this into product development, for example by conducting market research or simply screening which trends exist in the market. That's the direction in which we would use it, but it hasn't been examined in more detail yet"
	C08: "Our process engineering department is currently working intensively on this topic [camera systems], specifically to minimise resource consumption. This means carrying out real-time measurements so that we can intervene immediately at the exact moment a defect is detected — preventing additional meters from being produced with insufficient quality, which automatically would be prepared for thermal incineration"
	C10: "Our designers work a lot with AI. The AI in Photoshop, the built-in one, creates designs. This year we created all our designs with it. We didn't buy a single design. [...] A design costs between €300 and €500. And I bought them in Como or in Munich. We used to travel to Como with the entire team and stay there for two days. We don't do that anymore [...] we used to buy up to 100 designs a year. We would quickly be at €150,000 including travel expenses and other costs every year. We've now saved that. And those are also resources we save.]…] If there were an interface to the printer, which could then calculate, based on coverage and colour, for every design how much ink is used.[...] If I now have a design and ask what's needed for it, and give it three options, it could tell me which is the most efficient. And if I create an interface here [to the printer], that would definitely be possible, but we're not at that point yet. Even I, as someone who's not an IT specialist, can see that there are two things working side by side here that could be connected"
	C11: "We are working on robots that can recognise different types of finishes using image recognition software and then handle them in the same way a human would, as well as immediately scan the product for defects or quality. At the moment, this is done by our employees — they take a spool off the carrier and look at it: if it is completely uniform, smooth, and has no spots or stains, then it goes into the 'good' box. If they notice something on it, then it has to be reworked. We want to achieve this with robotics, with cobots, but it's a rocky path — especially with this image recognition software and so on. And also the learning process for the robot — we have to feed it with an enormous amount of data. So, based on various study data, we are planning to make progress there. But we are still far from implementation — more than 1.5 to 2 years away"
	C14: "AI-Based Forecasting: Optimization of production planning to reduce overstock"
	C18: "What makes the TURNS® fibre cycle special is the AI-based material identification. The worn-out used textiles are scanned and sorted based on their material compositions. Afterwards, the fibres are removed from the material with fine needles and are used to spin new yarns together with fresh, sustainably sourced cotton"
	C24: "If we think about the new PDM system, there are possibilities with AI to also incorporate such things — for example, having calculations on which models are sustainable and which are not. There are already ideas for that. I would say that's definitely an idea. And in our requirements management, there is also an AI group that has started looking into this internally. So, there are many departments that would like to use AI, and there are various possibilities. So yes, it's definitely planned for some time in the future"

Table 41: Continued

DT	Illustrative references
Internet of Things	C04: "We are working with FibreTrace and can implement it very well in production. We don't offer a fibre ourselves that has it [a traceable ID] integrated — the sales are handled through FibreTrace"
	C03: "Our integrated Compactomat system enables continuous display and control of shrinkage values and temperatures. Up to 10,000 separate process parameter sets can be stored by the data manager.[...] In the past financial year, the cylinder dryer was equipped with a steam meter. The advantage of this innovation lies in the newly available possibility of determining the exact steam consumption of each machine. Furthermore, the temperature control of the two new ventilation systems was optimised"
	C05: "In spinning, the decisive factor is always the yarn fineness. And in that area, we have online monitoring on almost all machines. These are funnels through which the yarn passes, and where the thickness is continuously measured. And if we move into the area of product inspection, we have online monitoring, and we also have monitoring systems on the ring spinning machines. […] All the testing devices are also networked with each other here, as well as with the machine monitoring. We have all the possibilities that exist for carrying out analyses, reports, and mill certificates"
	C24: "Starting around 2025 [...] we will also have a QR code included [in garments]. This means that the end consumer can use the QR code to see the information [...] on our website to obtain a DHL label, print it out free of charge, and then send the item back to us"
	C28: "Concerning RFID — we could say that an introduction is planned, because we have dealt extensively with RFID and the system, but there are also many reasons why we don't have it yet. [...] And I think it will also come when the digital product passport is more clearly defined — because until then, it doesn't really make sense"
Digital Fabrication	C01: "Since 2021, we have been able to view the design and fit of products in 3D thanks to the program CLO. Creating a true-to-life model of each article prevents misunderstandings on the customer and supplier side, thereby avoiding numerous prototype runs and faulty product batches. As a result, the program not only offers economic benefits, but also environmental benefits due to the prevention of resource wastage. [...] The realistic models of the articles can be placed onto 'avatars'. This makes it possible to see how a pattern or a certain style would look when the article is being worn, allowing us to better determine artwork sizes and positions in advance. Consequently, we can show our customers exactly what the article will look like when worn, without having to produce a prototype"
	C10: "The recent change from rotary screen printing to digital printing has resulted in considerably lower water and energy consumption. We are the only German textile printing company to work exclusively digitally" […] "The amount of digital ink used is minimal — only exactly what is needed is printed. So, I no longer have these quantities of leftovers like in the past, when I would pour 30% into the wastewater. We also need fewer washing baths, and there's less fabric consumption, because with rotary printing I had to adjust the print and used 20–30 metres for that, which was thrown away. This whole preliminary process and the waste is eliminated now"
	C22: "As easy as it may sound, choosing a color for fabric or other material is actually a long, complex process from the first strike-off to the sample and finally production. We are switching to a digital color management system to make this process shorter.[...] Digital color management offers a number of benefits: Fact-based decision making thanks to assessment based on spectral analysis, shortening coordination processes and lead times, reducing the number of physical lap dips required, saving on materials and costs as a result, saving CO2 by avoiding numerous courier deliveries"
	C23: "This is the game changer for solving the massive problems in our industry – through a new, seamless process from the idea to the customer. The key is that there are not two processes – a physical one and a digital one – running in parallel, with everything being done twice in the end. [...] A first step could be producing 50% fewer samples. The amount of money that saves is more than you could ever spend on software"
	C25: "The DMIx platform, developed by ColorDigital GmbH, offers innovative digital tools for collaboration in the textile industry. By using these tools, [C25] offers its brand partners seamless access to digital fabric libraries, 3D material representations, and modern color management. This digital transformation not only improves efficiency but also supports our commitment to sustainability by reducing the use of physical samples and minimizing environmental impact. [...] While we continue to use physical fabric samples when necessary, the [digital fabric] library enables our partners to explore a wide range of our fabrics virtually. This shift reduces the use of physical resources such as fabric and energy, and lowers CO_2 emissions caused by shipping"
	C28: "We are looking what we can do, especially in colour management for our lab dip dyeings, which we have completely digitalised. This means that all the colorimetric values are sent and verified digitally. Yes, so this is already being used here. Of course, not yet for all products — that again comes down to the need for human resources"

Table 41: Continued

DT	Illustrative references
Management Software / Third Pary Platforms	C01: "We are continuing to develop the back-end of our digital tool [supply chain management tool] to make it a more effective internal tool for cross-departmental supply chain management. By involving our business partners, we hope to ensure information can be provided quickly and smoothly. A significant advancement in this development is the opening of the tool to external users, such as local partners, agencies, and suppliers in our sourcing countries. Direct data entry and updates by these external users aim to make the process more efficient and avoid double entries"
	C03: "We prepared our carbon footprint using the software tool "Eco-Cockpit" from the Efficiency Agency of NRW"
	C06: "We call it our "certificate container" [within the ERP-system]. This means that our article master data is linked to certification information, because this is important for us — 25–30% of our total sales are generated with certified material, and that has to be managed accordingly. The relevant invoice texts also need to be included. All of this is managed via this container. It is linked to the article master data, and of course it also contains the dyeing specifications, especially for Bluesign and so on"
	C07: "We are in the process of installing a new ERP-system. We thought we were close to completing it, but we encountered major obstacles and now have to reorient"
	C08: "using an online marketplace for secondary raw materials. In our case, for example, rolls of 100% polyester nonwoven fabric of insufficient quality could be offered there, which might then find exactly the right partner on the other side — someone who says, "I don't need to meet those specific requirements; I just need a roll of nonwoven fabric"
	C10: "We have a standard commercial ERP-system and the printing software from the printing machines, and everything is connected via interfaces. For example, our orders go all the way to the inspection department, and when they open the order, they already have a photo of the design and the colour on their screen so they can see, "Ah, this is what I'm checking" So not just through the numbers, but also visually. […]. This ensures they open the correct file all the way through to the inspection department, so mix-ups are ruled out"
	C11: "Suppliers publish the results of wastewater and sludge tests on an online platform"
	C11: "Most customers already receive an electronic order confirmation from us, and some customers with SAP systems receive a CSV file from us in which the specifications, the final sample, and so on are all transmitted digitally"
	C15: "Internally, we work with tools such as the Higg MSI and the Higg Product Module to calculate the impacts of our materials and products and to identify more sustainable, innovative materials"
	C20: "This is currently reflected in the comprehensive overhaul of our system, from which we expect optimised processes, and thus easier work for all employees, as well as even faster and more reliable information for our customers and partners"
	C21: "We have access to a sophisticated ERP-system that allows us to digitally record and transparently evaluate all business processes. The key figures obtained in this way enable us to optimise our management practices and processes with pinpoint accuracy. The advantages of this approach are obvious: e.g. in logistics, packaging is more efficient and thus less packaging material is needed. In addition, warehouse trips and travel routes for field staff can be planned more efficiently. This saves CO2 and conserves resources"
	C24: "Internally, we have our own calculations within our PDM and ERP systems. This allows us to calculate which resources we are using and what increases we have. We do this internally with our own tools. We have so-called IBR points, which essentially indicate the water consumption of the material so that we can factor that in. That's our own internal process. [...] We are currently working on a new PDM system that we will probably implement next year, with more capabilities and also interfaces — potentially to work with Higg as well"
	C27: "We also use our own CR-tool as well as external IT tools to manage our supply chain"
	C28: "[…] supports the private resale of used products on a "re-commerce platform" on eBay. Buyers and sellers extend the lifecycle of outdoor products with their purchase or sale, preventing still-usable quality products from ending up in the trash. C28 is the first outdoor brand with which eBay in Germany has implemented a "Second Use" shop for used products. C28: "We have a new ERP system, but that took a long time. We also want a new PLM system, where we can do more reporting, including on sustainability values"
	C29: "Since 2023, we have been sending out our annual sustainability questionnaires via Retraced. The platform is continuously evolving, and we actively contribute feedback on additional features and workflows, helping to implement them as well. [...] We are planning to expand the platform [...] and further integrate it with internal interfaces. Connecting it to our interfaces is a challenge and is taking more time than originally expected (e.g., the automatic allocation of products and supply chains). We want to start with a smaller section of our product range in order to test processes and workflows"

5.6 Summary

This chapter addressed RO2 – *To research and analyse the status of the transition to sustainability, the CE and digitalisation in the German T&C industry*. This objective was divided into four sub-questions, which are revisited in this summary, with the main findings briefly presented for each.

Question 1: How are German T&C companies addressing sustainability in their corporate strategies and activities?

The findings showed that sustainability is embedded in the corporate strategies and objectives of the case study companies, guided by overarching international goals and agreements such as the SDGs and the Paris Climate Agreement, as well as by national and international regulatory frameworks. These are interpreted as key drivers and reference points for measures across all three change dimensions – organisation, products, and processes. At the organisational level, sustainability is primarily institutionalised through dedicated organisational units and responsibilities in the case study companies. They were described as primarily serving to identify and assess ecological and social risks associated with business activities, to inform the development of appropriate strategies, and to support and monitor their implementation. Communication, cooperation, and collaboration with stakeholders inside and outside the value network emerged as of particular importance – both to foster innovation that reduces negative impacts and enhances competitiveness, and to ensure compliance with regulatory requirements on due diligence along supply chains. However, holistic business model adaptations were found to play a minor role. Instead, companies tend to follow a bottom-up approach, concentrating on incremental adjustments and optimisations of existing products and processes rather than pursuing comprehensive strategic redesign. The analysis of these practices indicates that they can be interpreted as broadly aligning with CE principles.

At the product level, sustainability was described as being implemented through the formulation of requirements, guidelines, and indicators related to product design, packaging, and material selection. Product certifications were portrayed as particularly relevant mechanisms for enhancing credibility and enabling the verification of product-related sustainability performance.

At the process level, a strong emphasis was placed on enhancing transparency and traceability within value creation processes. Related practices were portrayed as

providing an important foundation for managing human rights and environmental risks in the context of due diligence requirements and for calculating carbon footprints at both company and product levels. Based on such assessments, companies reported deriving adjustments and measures related to production and procurement processes.

In summary, sustainability is interpreted as being firmly anchored in corporate strategies across the case study companies, guided by global frameworks such as the SDGs and the Paris Agreement, and operationalised through organisational, product, and process-related measures. While sustainability efforts were found to focus on risk management, compliance, and incremental improvements in products and processes aligned with CE principles, comprehensive business model transformation remains limited.

Question 2: How is the Circular Economy implemented in German T&C Companies?

The findings indicate that CE-related practices form an essential component of corporate sustainability efforts. The analysis showed that all three CE strategies – narrowing, slowing, and closing resource flows – play a role, though with differing intensity. Practices related to the narrowing strategy are most widespread, focusing on efficiency gains and cost reduction through technological innovation and process optimisation. Measures in this area also aim to reduce the negative environmental impacts of production, use, and disposal of textile products, demonstrating overlaps between sustainability strategies and CE practices. While such practices were described as contributing to reductions in resource use and waste, the findings suggest that a comprehensive decoupling of growth from resource consumption has not yet been achieved. Accordingly, efficiency-oriented initiatives, when not embedded in broader CE approaches, appear insufficient to support a more transformative implementation of CE principles.

Practices related to the slowing strategy aim to preserve resources at their highest value for as long as possible. Companies pursue this mainly through high-quality, durable products and materials. However, the findings suggest that the use phase and thus the actual lifespan of products and materials largely lie outside the companies' sphere of influence, particularly for textile companies operating in early stages of the T&C value chain. Complementary practices include service-oriented offerings (care,

repair, resale), maintenance of machinery, and reuse or repurposing of waste (e.g., upcycling, secondary markets). Practices associated with the closing strategy tend to focus on disassembling products and materials to reintegrate them into resource flows for new production. Two main practices were found to stand out here: Firstly, the development of recyclable materials, products, and packaging, which requires close collaboration along the value chain, and second, the increasing use of recycled materials. However, the proportion of recycled materials in the overall volume of materials used still appears to be relatively low, as they are mixed with virgin materials and generally limited to individual product lines.

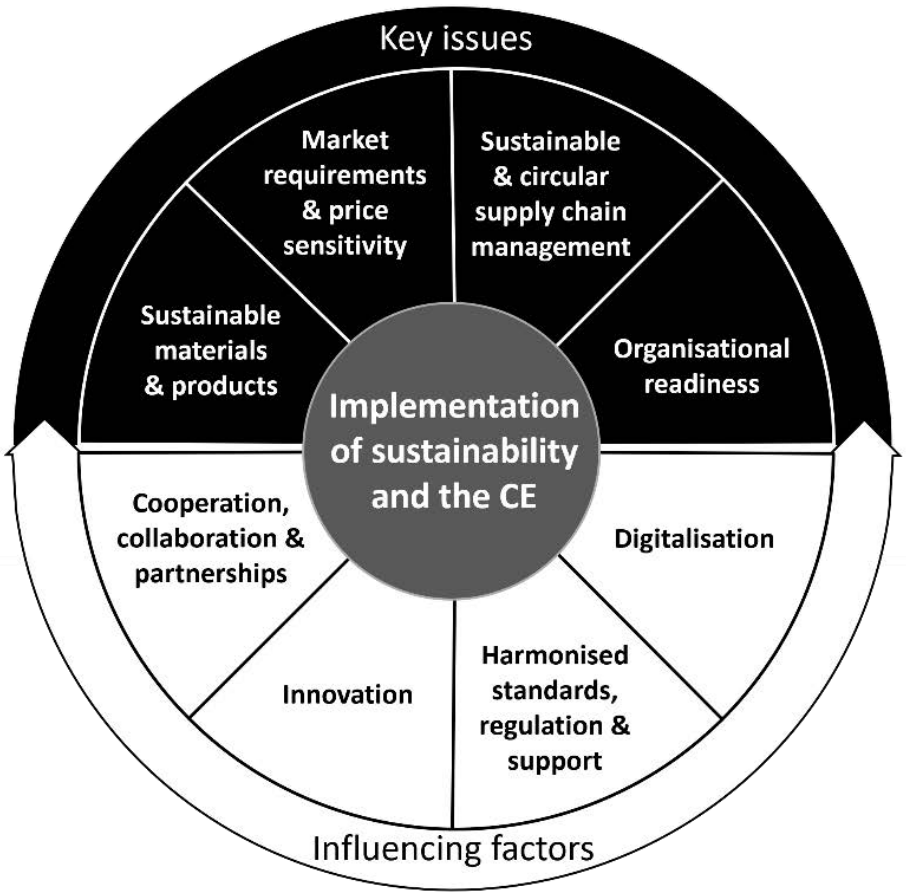
In summary, CE emerged as an integral part of sustainability efforts across German T&C companies, with implementation taking place at both product and process level, but still in an early stage. Practices are most advanced in relation to the narrowing strategy, while slowing and closing strategies are pursued more selectively and inconsistently.

Question 3: What are the key issues, challenges and influencing factors for implementing sustainability and the CE in German T&C companies?

The findings suggest that the implementation of sustainability goals and CE practices is perceived as posing considerable challenges. These challenges appear to contribute to the fragmented and inconsistent character of CE implementation across the case study companies and provide insights into the factors that may facilitate or hinder further progress. Four key issues were identified, each associated with challenges at product, process, and organisational level, which are interrelated and mutually reinforcing. Companies also pointed to challenges related to market requirements, both in B2B and B2C contexts. In addition, four influencing factors were identified (Figure 39), which appear to shape these issues in different ways and may contribute to addressing the associated challenges. Collaboration and cooperation within and beyond the value network emerged as central, with resource pooling seen as essential for developing and scaling solutions. This becomes particularly apparent in relation to innovation, which was identified as a further influencing factor in shaping how the challenges are addressed. Innovative approaches and technologies were identified as having the potential to contribute to CE practices, particularly in relation to slowing and closing resource flows. The analysis further indicated that the case study companies associate the targeted deployment of DTs and the development of related organisational competencies with progress in implementing sustainability- and CE-related initiatives, as

well as with addressing some of the challenges identified. In addition, harmonised regulations, standards, and financial incentives were viewed by companies as potentially having a positive influence on the transition to sustainability and the CE.

Figure 39
Key-issues and influential factors related to the implementation of sustainability and the CE



Question 4: What role are digital technologies playing in the transition to sustainability and the CE in the German T&C industry?

The findings indicate that DTs play a supportive, and in some companies even enabling role in the transition to sustainability and the CE. Use cases were identified for all SMAC and BRAID technologies previously considered as relevant in the literature review. Additionally, core technologies – including ERP, PLM, and SCM software as well as specialised supply chain platform systems – were identified as key IT-infrastructures for data integration, facilitating transparency, and managing due diligence requirements within sustainability management practices. Moreover, the findings suggest that the isolated deployment of individual technologies is generating only limited added

value, whereas combinations of technologies – including cloud infrastructures, blockchain functionalities, mobile applications, and AI-based analytics – were more frequently associated with the potential to address specific challenges related to the sustainability and CE transition. In this sense, respondents did not frame DTs as standalone solutions, but rather as components of broader, interconnected technological arrangements. Individual technologies and use cases were analytically linked to different change dimensions (products, processes, organisation) as well as to the three CE strategies (narrowing, slowing, and closing). This pattern indicates that DTs may play roles across multiple corporate levels; however, their relevance appears to unfold primarily through their integration into interconnected socio-technical systems that align data infrastructures, organisational routines, as well as inter-organisational relationships and collaboration. In line with the critical reflections outlined in the literature review, the findings therefore point to the importance of moving beyond a technology-centric perspective. Rather than assuming inherent transformative effects, a more holistic and integrated approach seems necessary – one that combines sustainability and CE strategies with the coordinated and context-sensitive deployment of DTs.

Summary

In sum, this chapter presented the findings of an analysis of 430 publicly available corporate documents from 29 German T&C companies and ten semi-structured interviews with corporate representatives responsible among the field of sustainability management. The data provide insight into the current state of the transition towards sustainability, the CE and digitalisation within the German T&C industry. By combining document analysis and interviews and by incorporating different subsectors and company sizes, the study was able to reconstruct a broad spectrum of sustainability strategies, CE-practices, and the role DTs are playing in this context as described by the participating companies, along with the key issues, challenges, and influencing factors associated with them.

Building on the PCF and the empirical findings, the following chapter develops an operational framework intended to synthesise these insights and to conceptually support the German T&C industry's transition towards sustainability and the CE through the considered deployment of DTs.

6 OPERATIONAL FRAMEWORK DEVELOPMENT AND ASSESSMENT

6.1 Introduction

In the previous chapter, addressing RO2, the state of the transition to sustainability, the CE and digitalisation in the German T&C industry was analysed. For this purpose, 430 sustainability-related documents (websites, sustainability reports, trade journal articles) and ten semi-structured interviews from a total of 29 companies in the German T&C industry were analysed using thematic analysis and examined regarding the elements and change dimensions of the PCF.

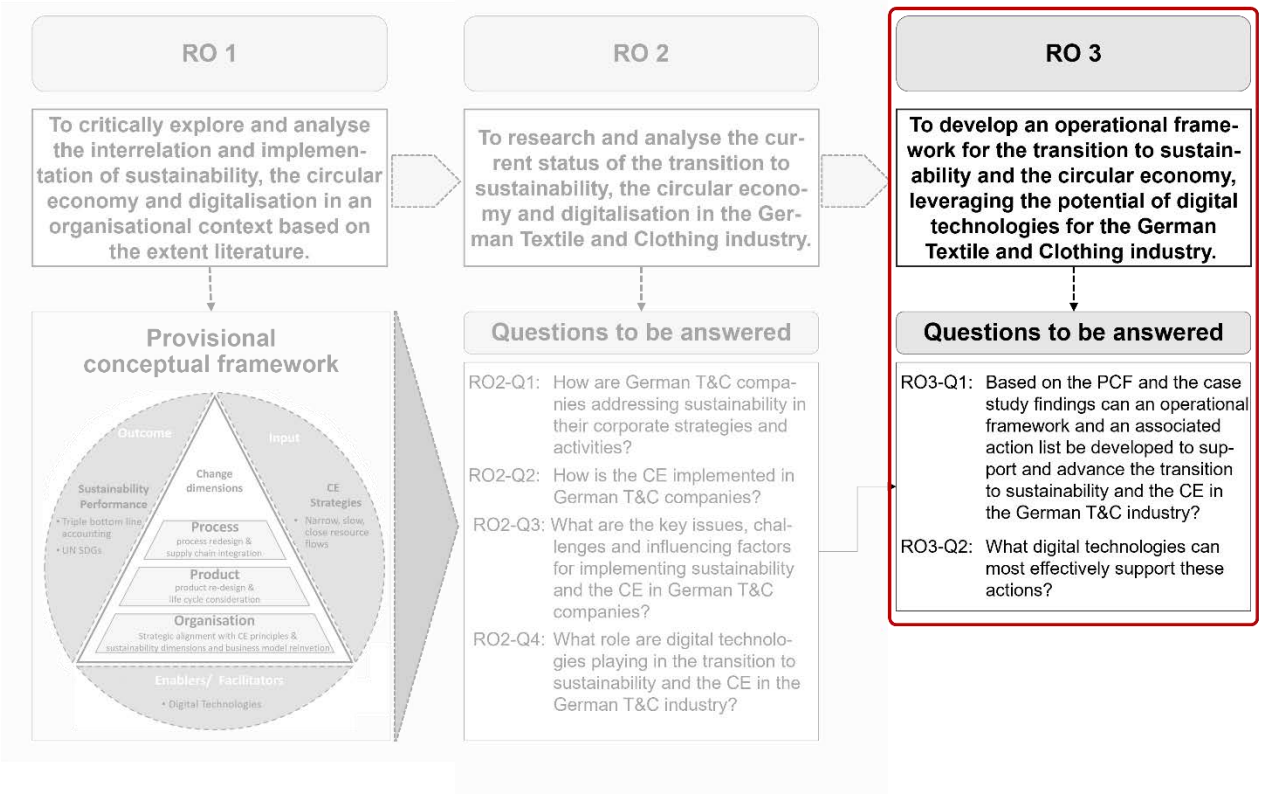
This chapter addresses RO3 by referencing to both the interview findings and the literature analysis. Further, two guiding questions were derived to ensure a structured approach (Figure 40):

RO3-Q1: Based on the PCF and the case study findings can an operational framework and an associated action list be developed to support and advance the transition to sustainability and the CE in the German T&C industry?

RO3-Q2: What DTs can most effectively support these actions?

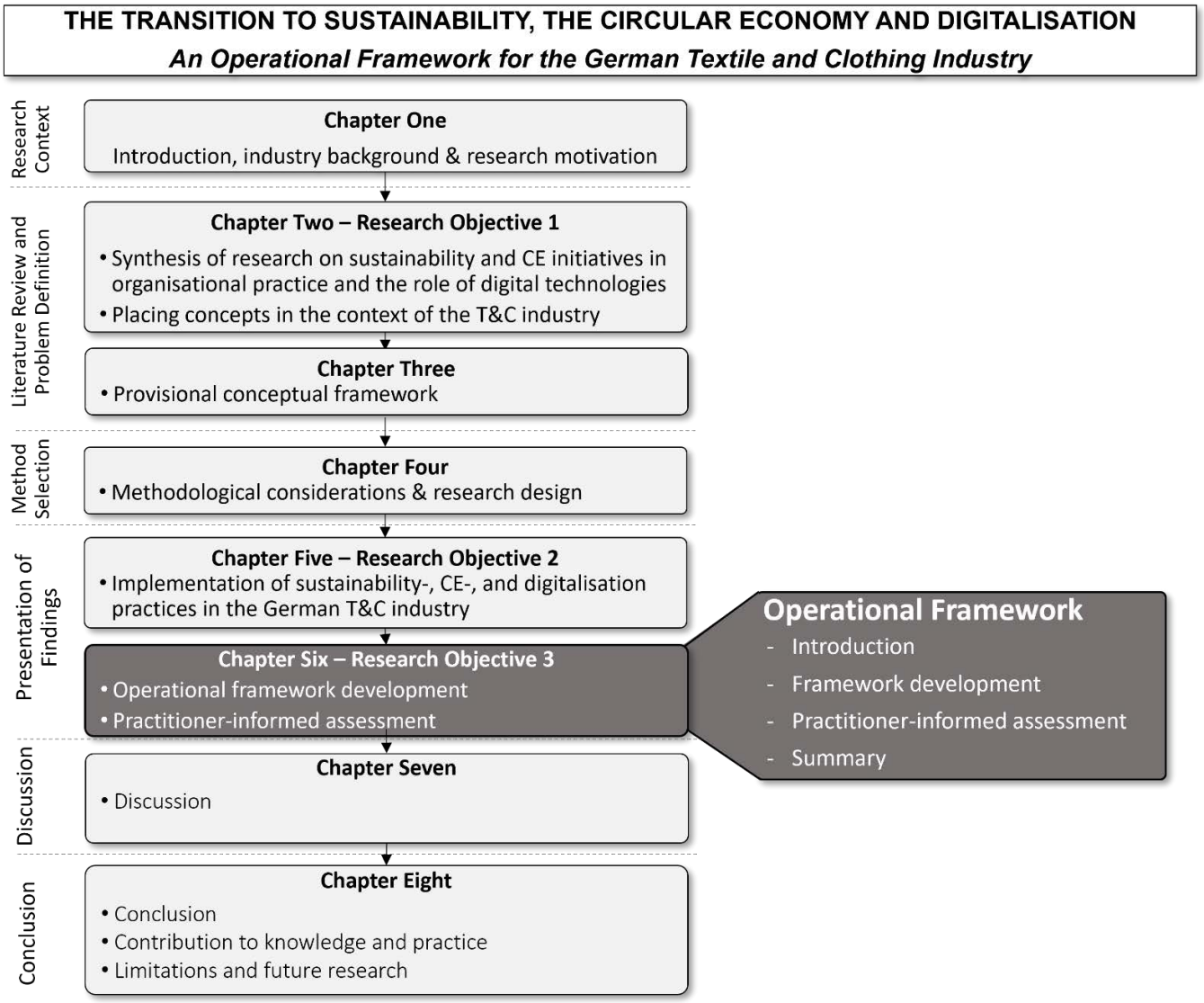
Figure 40

Research objective 3 and associated research questions addressed in this chapter



Following this introduction, the remainder of the chapter is organised as follows (see Figure 41). Section 6.2 introduces the operational framework together with the action list, both of which are derived from the PCF and the findings of the empirical investigation. The practical relevance of the framework and action list was subsequently assessed through an online questionnaire with experts from the case study companies. The results of this assessment are presented in Section 6.3. Section 6.4 concludes the chapter with a summary and provides a thematic bridge to Chapter Seven, where the findings are discussed in a wider relation to existing literature and frameworks.

Figure 41
Structure of Chapter Six in context of the thesis



6.2 Operational Framework and Action List Development

Building on the literature review, a PCF for the transition to sustainability, the CE and digitalisation was developed in Chapter Three (Figure 17). This framework encompassed three content related change dimensions as well as context-specific factors and served as the basis for the empirical analysis of approaches, strategies, and practices in 29 German companies operating across the German T&C industry. The empirical investigation aimed to develop a deeper understanding of the strategies and practices implemented in relation to sustainability and the CE in the case study companies, as well as how organisations interpret the role of DTs in this context.

The analysis of the interviews and documents suggested that the change dimensions identified in the literature – organisation, product, and processes – also constitute the central change dimensions in practice, as the strategies and activities reported by the companies could be systematically assigned to these categories. At the same time, the empirical data provides insight into how these dimensions are interpreted, prioritised, and operationalised within the organisational context of the German T&C industry. In this way, the study not only substantiates the relevance of the theoretically derived change dimensions but also elucidates how companies address and enact them in practice.

This provides an opportunity to refine the PCF. Based on the practical insights practice-oriented recommendations and technological solutions are developed by integrating change dimensions, fields of activity, challenges and influencing factors, and relevant DTs to advance sustainability and the CE in German T&C companies. It must be noted that the findings indicated both overlaps and differences in strategies, actions, and technology deployment between companies in the textile industry (NACE 13) and the clothing industry (NACE 14). While this could suggest the need for separate frameworks, the substantial commonalities justify the presentation of a general operational framework for the industry. Sector-specific approaches are only outlined where contextual differences render them necessary and advantageous, and these are explained within the respective context.

6.2.1 Operational Framework for the Transition to Sustainability, the CE and Digitalisation

Every process of organisational change is embedded within a broader context of factors that shape corporate action (Pettigrew, 1987). These factors influence both the objectives that companies pursue and how they seek to achieve them. In the PCF, such contextual factors were conceptualised as outcomes, inputs, and enablers/facilitators, reflecting the interrelation of sustainability goals, CE practices, and DTs. The empirical data gathered in this study provide an opportunity to deepen the understanding of these factors by illustrating how they manifest in practice in the German T&C industry, and by identifying additional sector-specific actions, challenges and influential factors.

Outcomes

In the PCF, the simultaneous economic, environmental, and social viability of a company, together with company-specific contributions to the SDGs, were identified as intended outcomes of change initiatives. This was also intended by the empirical data. The SDGs serve as a reference framework against which the strategic goals and sustainability activities of T&C companies are aligned to make an individual contribution to their achievement. In addition, the targets set by the Paris Climate Agreement - to limit global warming to below 2°C - and the associated need to reduce GHG emissions, provides another critical reference point for companies. Alignment with these overarching political objectives enables companies, on the one hand, to base their efforts on established references and benchmarks, while, on the other hand, leaving them considerable freedom in defining company-specific objectives, timeframes, indicators, and practices. This alignment follows the three dimensions of the Triple Bottom Line (TBL), with corporate strategies and objectives structured around economic, environmental, and social indicators - an observation also corroborated by the data. However, the empirical data also suggested that this freedom is increasingly being replaced by binding legal requirements, which drive greater standardisation of activities, practices, and indicators. National and international regulations thus constitute an additional contextual factor influencing corporate activities and shaping their intended outcomes. C22 describes this shift from voluntary to mandatory requirements as follows:

"*A lot has happened over the years. So far, we were driven by our own motivation and determination, setting our own way and seeking collaborations. Today, however, we have entered a shifting landscape of sustainability. Legal regulations have been established and they demand significant preparation, time, and effort*".

These external sustainability-related requirements should therefore not be understood as a fixed endpoint to which internal corporate changes are directed. Rather, the requirements themselves are subject to ongoing change, to which companies must continuously adapt. The findings are shaped by two interrelated dimensions. Firstly, global goals that encourage intrinsically motivated contributions, whereby companies retain considerable freedom in designing their practices and are primarily subject to market-based sanctions such as reputational risks or customer reluctance.
Secondly, binding legal requirements defined by specific obligations, targets, and indicators, which create extrinsically motivated compliance through reporting duties, comparability, and the prospect of legal or monetary sanctions in cases of non-compliance.

Inputs

Based on the findings of the literature review, the PCF conceptualised the three core CE strategies - narrowing, slowing, and closing resource flows - as input factors, since they provide guiding principles for organisational change aimed at implementing sustainability objectives. The analysis indicated that companies have implemented practices and measures corresponding to all three strategies. However, the intensity and scope of implementation varied considerably. Measures targeting cost and resource efficiency, and thus aligned with the narrowing strategy, dominate current efforts, while initiatives related to slowing and closing resource flows are still at an early stage of implementation. This indicates that the holistic integration of all three strategies - an essential feature of the CE - has not yet been achieved. Instead, practices related to the CE are largely treated in isolation and addressed through individual, stand-alone measures rather than being integrated into a comprehensive approach. For the development of an operational framework and the formulation of recommendations for action, it is therefore important to emphasise an integrated approach that combines all three strategies. At the same time, the presence of measures across all strategies can be regarded as consistent with the conceptual assumptions underlying the framework. In this sense, CE strategies provide a contextual reference point for companies to initiate change and design practices that contribute to overarching sustainability goals

and requirements. The empirical data further revealed that CE-related measures are implemented both independently and in combination with other sustainability initiatives. Most prominently, these include practices grouped under Human Rights and Environmental Due Diligence (HREDD), which involves analysing and minimising negative social and environmental impacts of corporate activities in line with global guidelines and legal requirements such as the German Supply Chain Due Diligence Act. In this context, inputs comprise both CE strategies and HREDD obligations: CE strategies mainly target environmental, resource, and energy goals, while due diligence requirements establish specific indicators and compliance measures. Although CE principles are occasionally integrated, most initiatives focus on reducing social and environmental risks within supply chains.

Enabling and facilitating factors

Digital technologies formed the third pillar of the contextual factors in the PCF. The empirical data demonstrated that all SMAC and BRAID technologies discussed in the literature review are relevant and, although to varying degrees, are being applied across the industry. In addition, business software systems and specialised sustainability platforms were identified as further relevant systems that enable and support the sector's transition. These systems combine different technologies or technological functions into integrated and specialised solutions, thereby addressing specific challenges in a targeted way. Furthermore, the findings highlighted the increasing interconnectedness of these technologies: rather than operating as isolated tools, they are embedded in broader digital infrastructures in which data flows, interfaces, and system integrations link intra-organisational units, inter-organisational partners, and external stakeholders. The findings also suggest that DTs are only partially linked to explicit sustainability goals or CE practices. Their deployment is still primarily driven by efficiency gains and cost reduction. Nevertheless, various solutions and specific use cases were identified that directly support the transition to sustainability and the CE. In this context, their transformative potential unfolds particularly where technological systems are interoperable and aligned, enabling end-to-end transparency, cross-functional coordination, and data-based decision-making across organisational and inter-organisational boundaries. What matters less to companies is the linkage of individual technologies to specific practices; rather, the crucial question is which technological functions and interconnected systems best delivering efficiency gains and maintaining

or creating competitive advantage while also support them in achieving their sustainability and CE objectives.

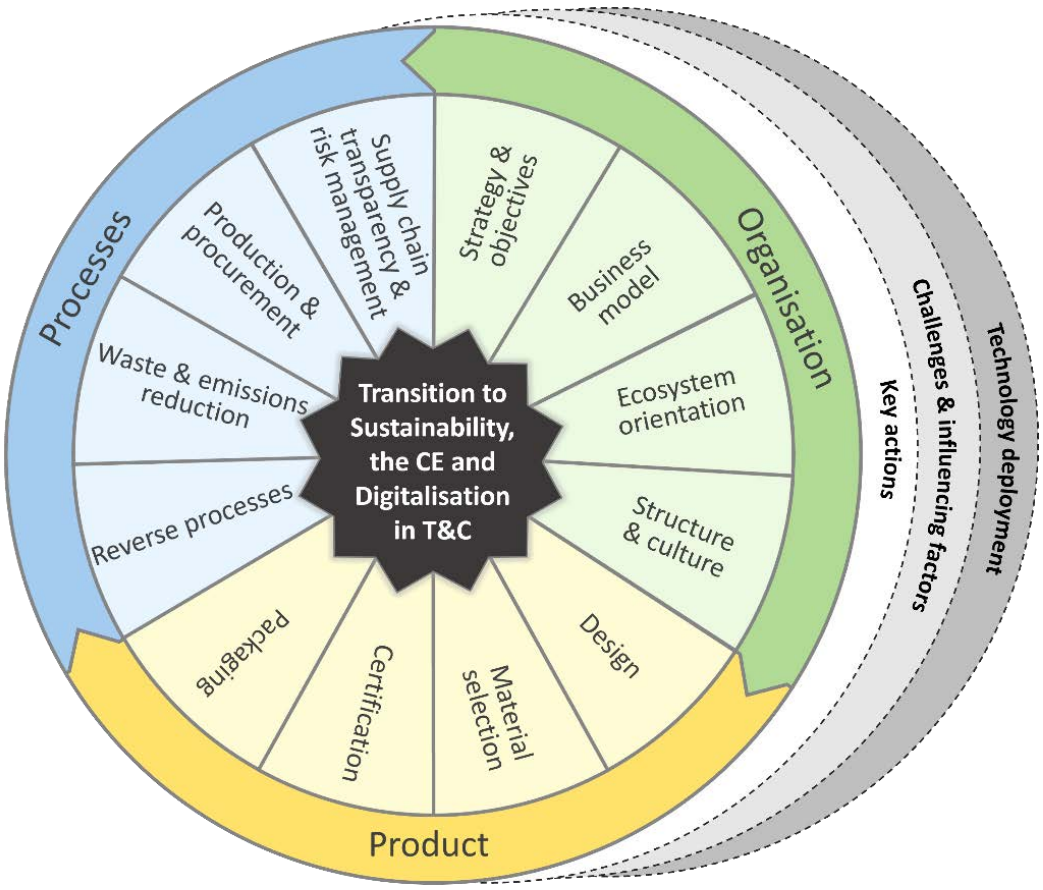
Beyond digitalisation, the analysis revealed additional external and internal enabling factors influencing the transition, namely cooperation and collaboration, innovation, and standardisation, regulation and support.

Change dimensions

In the PCF, three change dimensions were defined based on the literature review as central to the transition towards a sustainable and circular T&C industry: organisation, products, and processes. The findings suggested that these dimensions cannot be considered in isolation but are closely interlinked. Accordingly, both intra-organisational and inter-organisational activities must be aligned. These change dimensions therefore constitute the core of the operational framework (Figure 42). The growing demands on companies to align their business activities with the goals of sustainable development - particularly through political and regulatory requirements - necessitate a holistic and clearly structured approach. The principles of the CE combined with elements from HREDD have emerged as relevant reference frameworks for integrating economic success with the minimisation of negative impacts from business operations. The shift from a purely linear, profit-driven model towards a sustainable circular business approach grounded in the three dimensions of the triple bottom line requires comprehensive and systematic changes across all corporate functions and along T&C companies supply chains. Regardless of whether companies pursue a proactive or reactive approach to the transition to sustainability and the CE, they must make deliberate strategic decisions on specific changes and align all business activities with a process of continuous improvement. The organisation therefore constitutes the initial change dimension and serves as both the starting point and anchor of the transition, as it shapes and directs change in the fields of products as well as internal and inter-organisational processes. Activities in the product and process domains depend on these strategic decisions and must be closely coordinated and aligned. In the transition to sustainability and the CE, feedback loops between the change dimensions and a structured, iterative approach are therefore essential to ensure the optimal alignment of objectives and measures and to maintain competitiveness.

To ensure a clear and systematic structure for the operational framework, each change dimension is examined individually, while their interrelations are also explained, recognising that the interdependencies between them are critical to understanding the dynamics of the transition process. Therefore, each dimension is divided into specific fields of activity and will be explained from three perspectives - key actions, challenges and influencing factors as well as technology deployment (Figure 42). The operational framework is primarily based on the empirical findings. In areas where the case study companies displayed only limited progress, additional approaches and solutions were developed, informed by insights from the existing literature (see Chapter 2). Thus, it provides both practice-oriented guidance and recommendations as well as a conceptually informed structure for understanding and advancing the transition. It reflects not only the current state of implementation but also identifies future development potentials for sustainable development within and through the German T&C industry. For practitioners, it offers a structured orientation tool to reflect upon their companies' activities and decisions and to actively shape the transition towards a sustainable, circular, and digitalised industry.

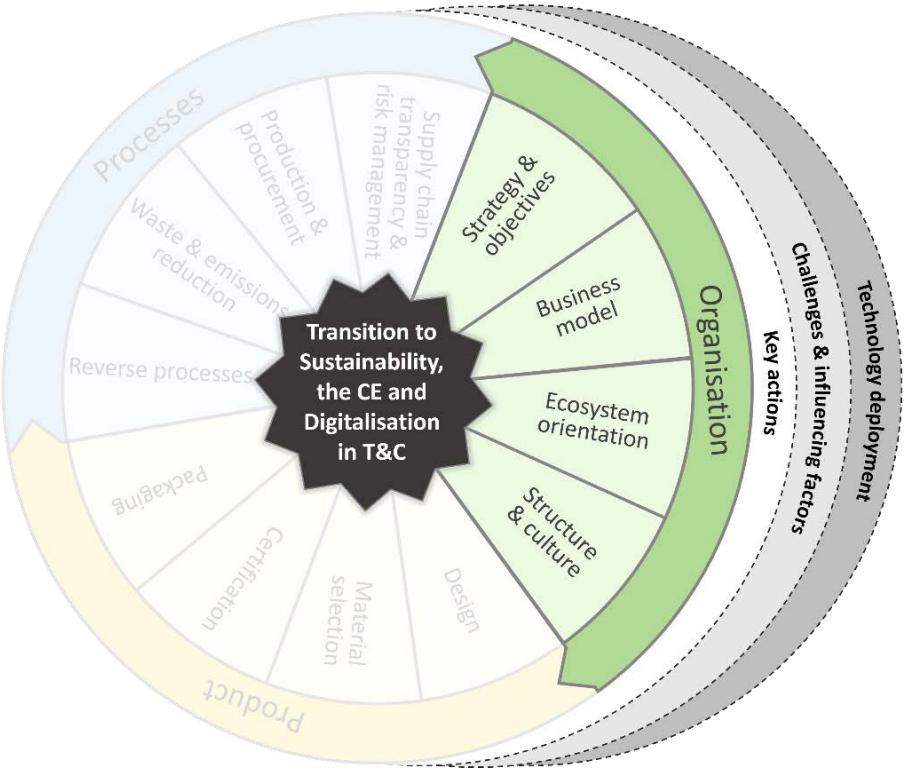
Figure 42
Operational framework for the transition to sustainability, the CE and digitalisation in the German T&C industry



6.2.2 Change Dimension: Organisation

At the organisational level, the basis for a successful transition to sustainability, the CE and digitalisation is laid by defining the objectives and initiating the corresponding changes. The framework at this level follows a top-down approach, as commitment and responsibility at the top management level are essential. The following section sets out the fields of activity, key actions, associated challenges and influencing factors, and potential DTs that can provide support on the organisational level (Figure 43).

Figure 43
Change dimension organisation and associated fields of activity



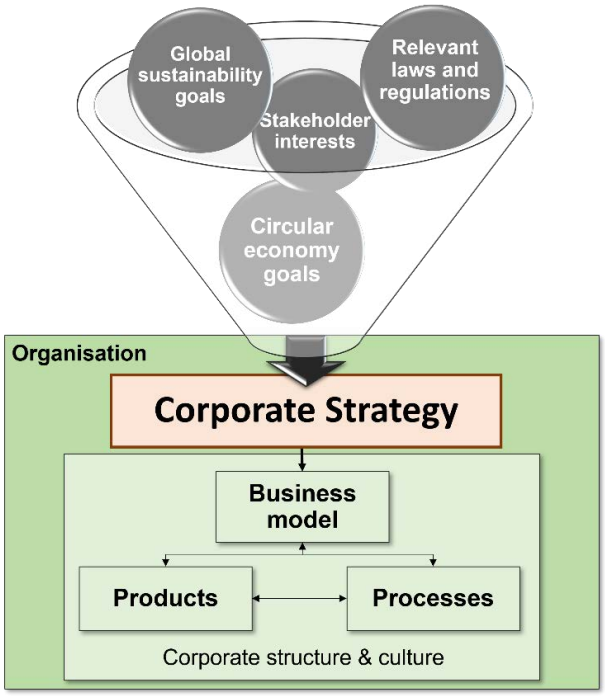
Fields of activity and key actions

Strategy and objectives

The adaptation of corporate strategy and the formulation of appropriate objectives build the starting point for the transition to sustainability and the CE. As overarching reference points and strategic guidelines, political and societal goals and agreements - such as the SDGs and the Paris Climate Agreement - serve as benchmarks. In addition, regulatory and legal requirements relating to sustainability reporting and due diligence

must be considered. However, they should not be the sole standard for setting objectives. Limiting corporate strategies and goals exclusively to compliance with legal requirements would be insufficient, as this may lead to integrating only individual aspects or making isolated adjustments within the linear economic model, rather than aligning the company with the long-term aims of the CE. Instead, corporate strategy and objectives must be aligned with global sustainability goals, the objectives of the CE, relevant legislation, and broader stakeholder interests to secure a sustainable competitive advantage (Figure 44).

Figure 44
External alignment and internal effects of corporate strategy



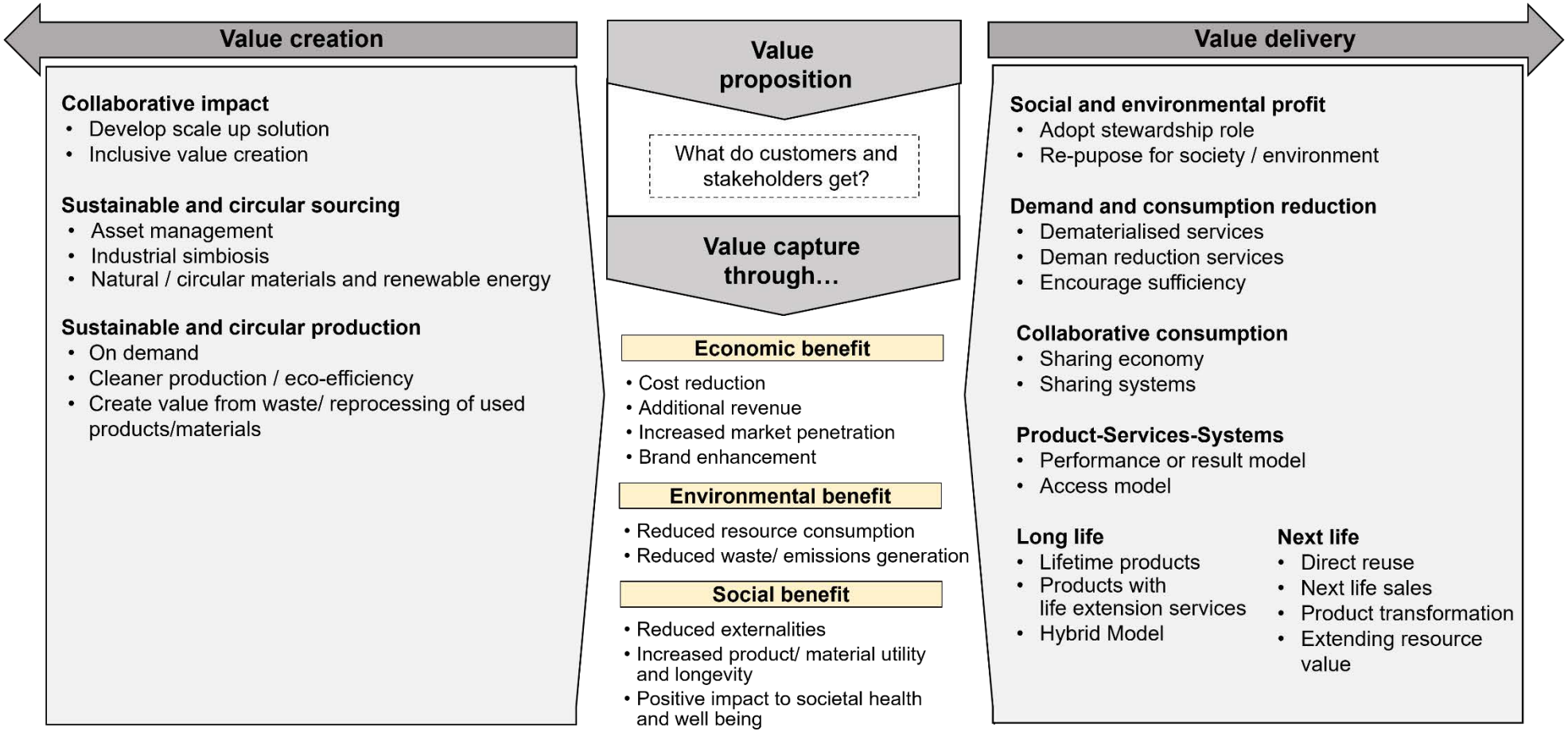
Corporate objectives should therefore be clearly defined and linked to indicators relating to financial, environmental, and social performance. On the one hand, this allows for credible and transparent evaluation and stakeholder communication, for instance through certifications and sustainability labels (Abbate et al., 2023). On the other, it ensures that strategic objectives are effectively translated into viable business models, products, processes and corporate structure and culture while also guiding the development of collaborations and digitalisation initiatives (Pieroni et al., 2021).

Business model adaptation

As the case study analysis revealed, the economic success of companies still largely depends on the sale of materials and products, reflecting a predominantly linear model. Thus, the transition to a sustainable and circular T&C industry requires business model innovation and rethinking of value propositions, value creation and delivery systems, and value capture mechanisms. Value proposition defines the benefits offered to customers and stakeholders, the value creation describes how these benefits are developed and produced, value delivery explains how they reach customers, and value capture refers to how the company generates economic, environmental and social benefits (Bocken et al., 2014; Teece, 2010). Although examples of changes to the linear model were identified in the case study companies, these were mostly incremental adjustments or extensions to individual business model elements, such as certain repair and care services or occasional rental options, rather than being embedded in holistic business models. Therefore, the literature-based potential archetypes for sustainable and circular business model innovation (based on Bocken et al., 2014; Ritala et al., 2018 and Pieroni et al., 2020 and 2021) are presented in Figure 45 and customised for the T&C context and supplemented with examples and applications from the case study companies as well as from other European case studies based on Wiegand & Wynn (2025) in Table 42. This presentation is not intended as an exhaustive list but rather as a starting point and an impetus for configuring alternative business models for T&C companies. The archetypes are divided into two groups. Firstly, those focusing on value creation and related networks, aiming to narrow, slow, and close resource flows in design, sourcing, and manufacturing processes while minimising associated negative environmental and social impacts. This includes business model approaches in the categories of collaborative impact, sustainable and circular sourcing, and sustainable and circular production. Second, approaches that focus on value delivery and customer interaction, aiming at narrowing, slowing, and closing resource flows in provision, use, and disposal of products and services while also minimising negative impacts. To configure holistic sustainable circular business models, various approaches must be integrated into a value proposition that appeals to customers and stakeholders while enabling the realisation of significant economic, environmental, and social benefits.

Figure 45

Options for sustainable and circular business model innovation



Source: The author based on Bocken et al., 2014; Ritala et al., 2018; Pieroni et al., 2020 and 2021

Table 42

Description and examples of options for sustainable and circular business model innovation

Source: The author; based on examples from the case study companies supplemented by examples from other European case studies based on Wiegand & Wynn, 2025

BM Element	BM Category	BM Archetype	Description	T&C case examples
Value delivery	Social and environmental profit	Adopt a stewardship role	Value is delivered by embedding social and environmental responsibility into core offerings. This includes ensuring transparent and certified supply chains, fair trade principles, and active contributions to environmental or biodiversity protection. Products are designed and marketed with proven social and ecological benefits. E.g., through sustainable production processes, health advantages through use, or environmentally friendly disposal options. Value is captured through enhanced brand credibility and customer trust, supported by certifications and labels that provide verifiable evidence of responsible practices.	• Full transparency and traceability of material origin and production processes (e.g., QR codes or tracer systems) • Transparent information about resource consumption and pollutant emissions of products/materials (e.g. product carbon footprint, water footprint, ZDHC compliance, etc.) • Reliable product, material and supply chain certifications and labels (e.g., Fairtrade, GOTS, OEKO-TEX, Green Button, Bluesign)
		Re-purpose for society/ environment	Value is delivered by prioritising social or environmental issues as the core purpose of the business rather than profit maximisation. Companies operating under this model prioritise the well-being of people and the planet, for example through social enterprise models, B Corp certification, not-for-profit structures, or commitments to the economy of the common good. Sales revenues are intended to cover operating costs and enable reinvestment in further initiatives that address societal or ecological challenges. Value is captured through legitimacy, trust, and recognition among stakeholders, which strengthens long-term resilience and societal relevance.	• Orientation towards economy of the common good instead of cost competition • Support of social/ environmental projects through company foundations/ trusts • Employee engagement in social initiatives (e.g., Special Olympics, litter picking) • Investment in education and training projects in less developed regions • Support of local community facilities such as childcare and public infrastructure
	Demand and consumption reduction	Dematerialised services	Value is delivered by replacing physical products or infrastructure with digital or virtual services. This shift can reduce the demand for material-intensive manufacturing, while enabling new forms of customer engagement such as virtual fashion, digital showrooms, or online collaboration platforms. However, these savings must be balanced against the material and energy requirements of digital infrastructures such as servers and data centres. Value is captured through revenues from expanded market reach, increased opportunities for customisation, and shorter delivery times, often monetised via service contracts, subscriptions, or digital product sales.	• Replacing physical product presentations or photo shoots with 3D visualisation • Replacing paper bills by electronic invoicing • Transition towards paperless office through digitalisation initiatives • Provision of digital material twins in online databases that downstream companies can access for product development
		Demand reduction services	Value is delivered by offering products or services that help individuals and organisations moderate the consumption of energy and resources. This can involve providing information, monitoring tools, or advisory services that raise awareness of consumption patterns and actively support reduction efforts. Examples include smart metering, digital dashboards, or efficiency consulting that guide users toward more sustainable behaviours. Value is captured through revenues from service provision, consultancy fees, or subscription models, while also enhancing the company's reputation as an enabler of resource efficiency.	• no examples were found in the case studies
		Encourage sufficiency	Value is delivered by supporting customers and consumers in adopting more sustainable consumption behaviour and extending the life of products they already own. Companies use information campaigns, educational initiatives, and responsible advertising to promote conscious purchasing, careful use, and longer product lifespans. Such practices can reduce overall demand for new goods while strengthening customer loyalty. Value is captured through enhanced brand image, long-term trust, and differentiation as a responsible market actor, even if short-term sales volumes are moderated.	• Customer education on garment care, repair, or alternative uses • Support conscious purchasing decisions (e.g., through digital product passport) • Awareness-raising on fast fashion and promotion of sustainable alternatives • Guidance and tutorials for conscious consumption, repair and care • Provision of instructions, spare parts, and services to extend product life
	Collaborative consumption	Sharing economy	Value is delivered by enabling individuals or communities to share access to products, assets, or services without direct monetary exchange. Companies facilitate this through platforms, networks, or services that organise and support peer-to-peer sharing, thereby reducing the need for each consumer to own products individually. This can decrease overall resource demand and promote more efficient use of existing goods. Value is captured through community growth, increased brand engagement, and potential indirect revenues from complementary services, while positioning the company as a facilitator of collaborative consumption.	• No examples were found in the case studies
		Sharing or pooling systems	Value is delivered by providing access to textiles or clothing owned by individuals or organisations through shared or pooled use rather than individual ownership. Companies establish platforms or infrastructures that enable multiple users to share, rent, or borrow textile or clothing products for a fee (the Uber principle). This model increases the utilisation rate of each product and reduces the overall demand for new production, while also giving customers flexible and affordable access to a wider variety of items. Value is captured through revenues from subscriptions, or platform transactions, alongside the benefits of higher customer engagement and differentiation.	• No examples were found in the case studies
	Product-service systems	Access model	Value is delivered by granting customers temporary access to products instead of transferring ownership. Companies offer leasing, renting, or subscription-based models that provide the functionality or experience of a product without requiring purchase. This approach enables more intensive use of products across multiple customers and reduces the need for new production, while giving users flexibility and lower upfront costs. Value is captured through recurring revenues from access fees, subscriptions, or leasing contracts, as well as stronger customer relationships and opportunities for service-based differentiation.	• Rental & leasing service e.g., for sports and outdoor clothing or work wear • Collaboration with textile and clothing rental platforms (e.g., Hirestreet)
		Performance or result model	Value is delivered by providing the performance or outcome of a product rather than the product itself. Customers pay for an agreed functionality or result, such as cleanliness, protection, or comfort, without taking ownership of the underlying textile. Companies retain responsibility for maintenance, repair, and replacement, which incentivises durability and resource efficiency. In the textile and clothing industry, this applies to workwear services or household textile services e.g. in hospitality, where customers contract for results such as hygienically clean uniforms, bed linens, or towels. Value is captured through continuous revenue streams linked to performance contracts, while also building long-term customer relationships and ensuring efficient product use.	• No examples were found in the case studies

Table 42: continued

BM Element	BM Category	BM Archetype	Description	T&C case examples
Value delivery	Long life	Lifetime Products	Value is delivered through textile or clothing products that are intentionally designed for exceptional durability and long-term use. Products are manufactured from high-quality materials, with robust construction and timeless design, and are supported by repair services or a warrenty that extend their lifespan well beyond conventional products. This reduces the frequency of replacement purchases and promotes more sustainable consumption patterns. Value is captured through premium pricing, brand positioning in the high-end market segment, and the loyalty of customers who associate durability with quality and responsibility.	• High-quality raw materials as a foundation for long-lasting products • Robust and durable materials designed to be recyclable at end of life • Durability as a core feature across entire workwear collections • Focus on timeless design and high-quality workmanship instead • Development of longer-lasting aesthetics in colours and cuts
		Products with life extension services	Value is delivered by offering durable and repairable textile or clothing products and/or high-quality services that extend their useful life. Companies complement product sales with through-life services such as repair, alterations, refurbishment, or upgrading. In some cases, procurement and stock-holding services are added to create a comprehensive 'full service' offer for customers. This approach reduces the need for premature replacement and promotes sustainable consumption. Value is captured through recurrent revenues from service provision, stronger customer loyalty, and differentiation as a provider of long-lasting, service-supported products.	• Repair & Care services to extend product lifespan • Repair workshops with experienced tailors and original materials • Partnerships with service providers (e.g.,iFixit or Repair Cafés) to provide accessible repair options for customers/consumers
		Hybrid model	Value is delivered by combining durable, long-lasting textile or clothing products with short-lived components or consumables that require regular replacement (aka Razor-and-Blade model). The durable core product provides reliability and sustained use, while the consumable elements ensure continued functionality or customisation. In the T&C context, this can include items such as reusable workwear with replaceable protective inserts, modular outdoor clothing or accessoires with exchangeable parts, or high-end textile equipment supported by consumable accessories. Value is captured through initial sales of the durable product combined with continuous revenues from the repeat purchase of consumables, creating an ongoing customer relationship.	• No examples were found in the case studies
	Next life	Direct reuse	Value is delivered by facilitating the continued use of textile or clothing through second-hand markets, redistribution, or exchange systems. Products are kept in circulation rather than discarded, thereby reducing waste to landfill and maximising the use of existing resources. Reuse can take place with or without prior repair or upgrading, and items may be supplied free of charge, resold at lower prices, or exchanged between consumers. Value is captured through revenues from resale activities, cost savings from reduced disposal, and enhanced reputation as a promoter of circular and responsible consumption.	• Support for private resale of used products (e.g., via platforms like eBay) • Cooperation with upcycling stores to provide second-hand functional materials for DIY projects • In-store collection of used clothes with donation to charity organisations (e.g., Oxfam)
		Next life sales	Value is delivered by taking back used or unwanted textiles or clothing through convenient return systems organised by the manufacturer or retailer. Returned items are refurbished, remanufactured, or otherwise prepared for resale, extending their value through subsequent use cycles. This approach reduces textile waste, conserves resources, and offers customers accessible pathways to return products responsibly. Value is captured through revenues from the resale of next-life products, cost savings from recovered materials, and strengthened customer loyalty through engagement in circular take-back initiatives.	• Resale of remnants/ returns as special items through dedicated channels • Sale of cleaned, refurbished, and repaired returns through secondhand channels
		Product transformation	Value is delivered by taking back used or unwanted textiles or clothing through convenient return systems and increasing their value by reusing components, reconditioning items, or repurposing them for new applications. Products may be disassembled to harvest valuable materials, repaired and upgraded for renewed use, or creatively transformed into new products with different functions. This approach reduces waste, conserves resources, and enables innovative second-life applications. Value can be captured through revenues from the sale of transformed products, savings from recovered materials, and brand differentiation as an innovator in circular textile solutions.	• No examples were found in the case studies
		Extending resource value	Value is delivered by collecting used or unwanted textile or clothing products through convenient take-back systems with the aim of recycling, reusing, or recovering materials. Products are diverted from landfill and processed to reclaim fibres, fabrics, or other resources that can be reintegrated into production cycles. This approach reduces raw material demand, minimises waste, and supports circular flows in the textile industry. Value is captured through cost savings from recovered resources, revenues from recycled-material products, and reputational gains from positioning as a sustainable and resource-efficient company.	• Free take-back schemes for used textile and clothing products in cooperation with recycling partners (e.g., Turns, SOEX/I:Collect) • Integration of textile recycling into retailer and end-customer service offers • Collaboration with recycling partners in processing returned textile and clothing into new raw materials • Production of regenerated wool by setting up a dedicated internal unit for collecting and repurposing textile waste from other wool producers
Value creation	Collaborative impact	Develop scale up solution	Value is delivered by facilitating the development and diffusion of sustainable innovations through cooperative or network-based approaches. Companies engage in practices such as open innovation, crowdsourcing, or incubator models to co-create solutions that can be scaled up for widespread impact. The focus lies on delivering sustainable outcomes at a large scale in order to maximise societal and environmental benefits beyond individual products or services. Value is captured through access to shared knowledge, accelerated innovation processes, strengthened partnerships, and reputational advantages as driver of systemic change.	• Innovation hubs to collaborate with designers, start-ups, manufacturers in experimenting and realising new ideas and technologies (e.g. Südwebs; Gucci Circular Hub) • Organisation of industry talks, dialogues, panel discussions, webinars, trainings, and events to foster collaborative initiatives and advance sustainability and circularity across the textile sector • Industry consulting in developing and implementing sustainability strategies • Training for designers on responsible and sustainable design
		Inclusive value creation	Value is delivered by explicitly integrating disadvantaged or marginalised groups into value creation processes or by developing offerings tailored to their needs. Companies prioritise social and environmental benefits over shareholder profit maximisation, often working in close collaboration with local communities and diverse stakeholder groups. In this model, the traditional notion of the customer as the sole beneficiary shifts toward a broader distribution of value, encompassing producers, workers, and communities along the textile and clothing value chain. Value is captured through strengthened stakeholder relationships, legitimacy, and reputation, while fostering long-term resilience and inclusivity in business practices.	• Engagement in initiatives to support farmers in growing regions, promoting the shift to organic farming (e.g., cotton, wool) • Collective funding programmes to support decarbonisation and climate action in textile production countries • Engagement in multi-stakeholder initiatives (e.g., Better Cotton Initiative, Partnership for sustainable textiles)

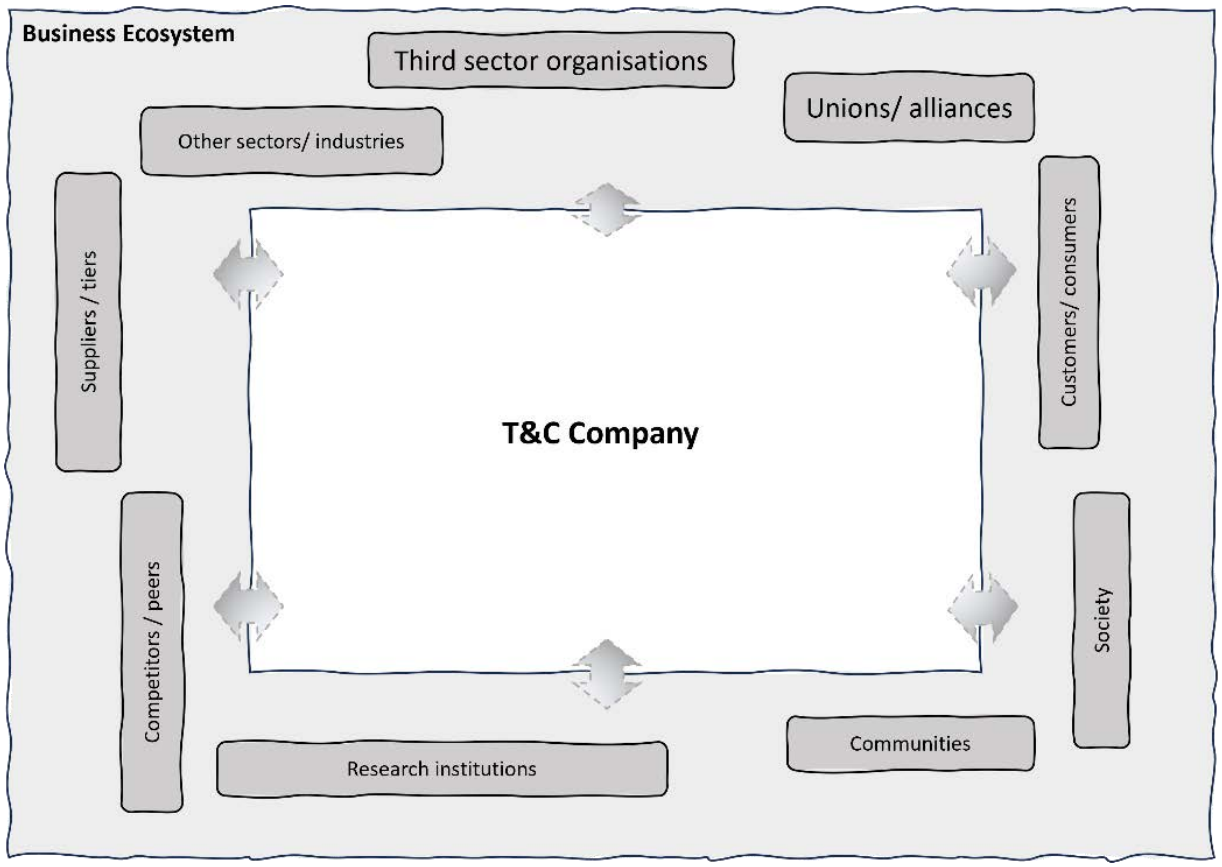
Table 42: continued

BM Element	BM Category	BM Archetype	Description	T&C case examples
Value creation	Circular sourcing	Asset management	Value is delivered by optimising the utilisation and lifespan of company-owned assets such as buildings, vehicles, equipment, or ICT infrastructure. This is achieved through practices like pooling, sharing, lending, reuse, refurbishment, or resale in order to reduce underutilisation and extend asset life. The focus lies on improving internal efficiency and sustainability in the upstream area of operations rather than on customer-facing activities. Value is captured primarily through operational cost savings, improved resource efficiency, and reduced capital expenditure, while also contributing to a lower environmental footprint.	• Transition of vehicle fleets to hybrid/ electric models and promotion of carpooling • Installation of in-house e-charging stations for company and private vehicles • Rebuilding and repairing defective machines or parts to extend asset life • Wastewater treatment plant used by several textile companies in a local district
		Industrial symbiosis	Value is delivered by transforming waste streams, by-products, or residual materials from production into valuable inputs for other processes or products. This process-oriented approach relies on collaboration between firms, often supported by geographical proximity, to exchange resources and optimise material flows. In the textile and clothing industry, this can include practices such as using fabric offcuts for insulation materials, repurposing dye sludge for pigments, or redirecting process heat into energy systems. Value is captured through cost savings on raw materials and supplies, reduced waste disposal expenses, and reputational benefits from contributing to closed-loop industrial ecosystems.	• Collection and reuse of production and cutting waste from partner companies • Collaboration with recycling plants to turn textile scraps into yarns or materials and reuse it in new materials/products • Direct resale of production offcuts and remnants to recycling companies (e.g., downcycling into automotive and cleaning products) • Processing of end-of-life textiles into nonwovens through regional partners
		Natural/ circular/ renewable material and energy	Value is delivered by sourcing and applying inputs that reduce environmental impacts, such as recycled or circular materials, renewable energy, or non-hazardous chemical substances. By integrating these inputs into production processes, companies lower their ecological footprint and align operations with sustainability standards. The focus of this archetype lies primarily on optimising resource efficiency and minimising environmental harm rather than generating new revenue streams. Value is captured through cost reductions from improved resource use, lower energy expenditures, compliance with environmental regulations, and reputational benefits as a sustainable operator.	• Substitution of synthetic by cellulose-based fibres • Exclusive use of recycled or regnerated fibres (e.g., REPREVE®, GRS-certified, TENCEL™ Modal) • Collections and portfolios featuring natural, biodegradable, or recycled fibre blends (e.g., wool, silk, Ecovero, recycled polyamide) • Transition to renewable energy sources (e.g., hydrogen, solar power) • Strict chemical approval processes and substitution with safer alternatives
	Circular production	On demand	Value is delivered by producing textile or clothing products only after customer demand has been confirmed, thereby avoiding overproduction, excess inventory, and waste. Companies may engage customers directly in the decision process, for example by allowing them to pre-order or vote on which designs should enter production. This approach aligns supply more closely with actual demand, ensuring resources are only used for products with a secured market. Value is captured through savings from reduced unsold stock, lower warehousing costs, and improved responsiveness to customer preferences, while strengthening brand image as a lean and sustainable producer.	• Production only on order (e.g. digital printing and knitting services, scalable batch sizes for yarn and fabric dyeing) • Accurate sales forecasts with customers, avoiding stock production
		Cleaner production and eco-efficiency	Value is delivered by improving production and distribution processes to increase material productivity and resource efficiency while reducing waste, emissions, and environmental pollution. Companies adopt practices such as energy-efficient technologies, process optimisation, or waste minimisation strategies to lower the environmental footprint of operations. The focus is on embedding sustainability into manufacturing without compromising output quality. Value is captured through cost savings from reduced energy and material use, lower waste management fees, and compliance with environmental regulations, alongside reputational benefits as a responsible producer.	• Wastewater treatment and reuse to save drinking water • Replacement of old equipment with new, energy-efficient technologies • Localised European production with certified environmental/ social standards • Optimisation of packaging and logistics (e.g., no air freight, card box circulation) • Maximising fabric use in production / minimize cut-waste • Energy recovery in heating processes • Reprocessing of selvedges and fabric waste for new textile applications • In-house upcycling and resale of residual materials
		Collection, take back,or reprocessing of used products, materials or energy	Value is delivered by establishing systems to collect, take back, and process end-of-life textiles in order to recover materials and generate new value. Companies organise convenient return channels for consumers and apply technologies such as sorting, shredding, fibre-to-fibre recycling, or chemical processing to turn discarded products into usable inputs for new production. This approach diverts textiles from landfill, reduces the need for virgin resources, and contributes to circular material flows. Value is captured through savings from recovered materials, revenues from products made with recycled content, and reputational benefits from demonstrating commitment to waste reduction and circularity.	• Collaborative R&D projects for textile waste recycling • In-house upcycling or resale of residual materials/ leftovers (e.g., processing advertising banners into handbags, turning old tent material into bicycle bags) • On-site energy generation from waste materials (low emission)

Ecosystem orientation

The findings from the case study demonstrated that the transition to sustainable and circular practices cannot be implemented in a company in isolation. Rather, companies operate within a multi-layered business ecosystem comprising diverse stakeholder groups, both internal (e.g., employees, owners) and external (e.g., suppliers, customers, other firms, NGOs, …) to the company, which both influence the company and are directly or indirectly influenced by it. Orientation towards this ecosystem, including a proactive involvement of stakeholders and the alignment of corporate strategy and activities with their interests, is therefore essential for the transition. Recent case studies from the T&C Industry in Italy and the Netherlands (Abbate et al. 2023; Hartley et al., 2022; Saccani et al., 2023) likewise underline the importance of collaboration with educational and research institutions, industry associations, NGOs, and political actors as such partnerships not only drive important innovations but also help to shape regulatory frameworks and market conditions. Figure 46 provides an overview of those actors in the business ecosystem of T&C companies based on the case study analysis.

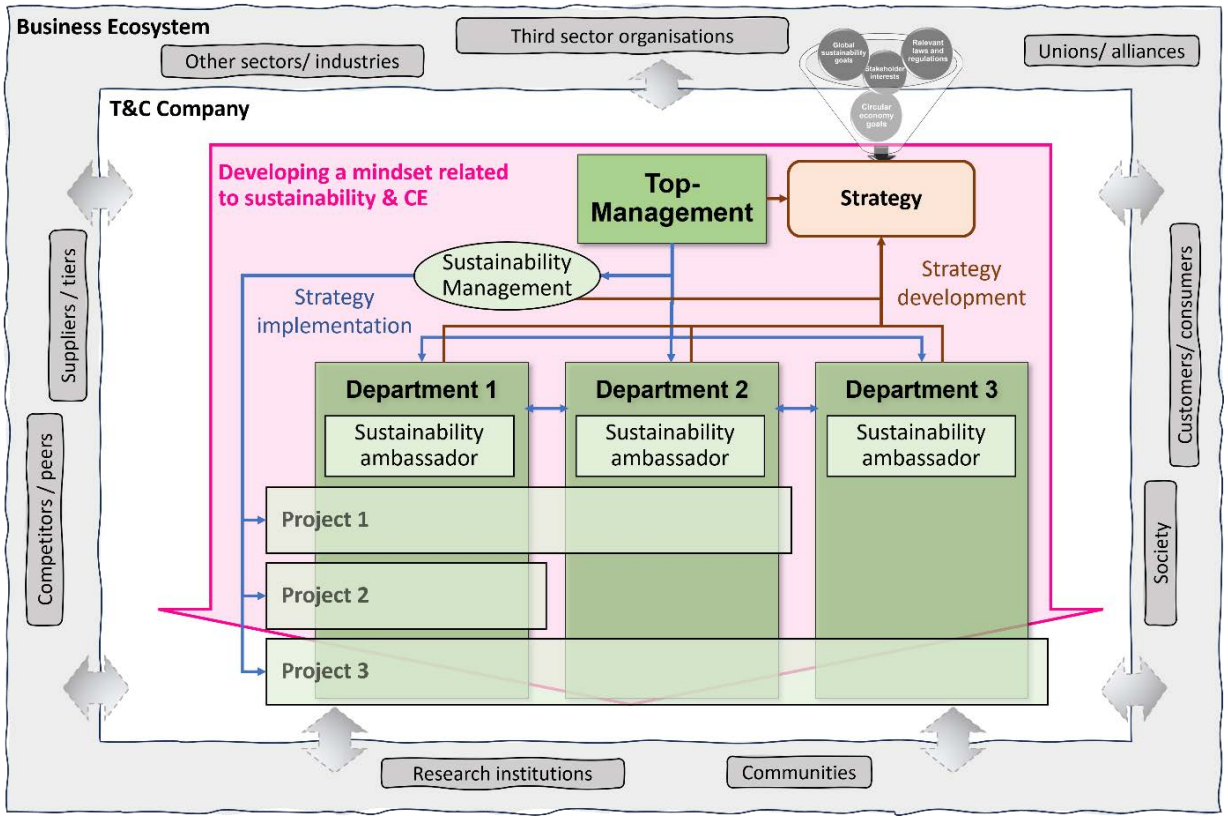
Figure 46
External ecosystem actors and stakeholders for the transition to sustainability and the CE



Structure and culture

The development of corporate strategies and objectives takes place at top management level, with consideration of and engagement with the relevant stakeholders. Implementing these strategies requires corresponding adjustments to organisational structures and cultures in line with strategic objectives and stakeholder interests (Figure 47). The development of organisational culture in this context involves fostering a mindset related to sustainability and the CE across the organisation. Embedding responsibility for sustainability and the CE structurally within corporate governance emerged as crucial.

Figure 47
Interrelations between internal and external ecosystem actors and stakeholders for the transition to sustainability and CE



The case study findings showed that the transition to sustainability and the CE is still at an early stage and is influenced by dynamic factors such as technological developments, material innovations, and customer acceptance, which affect all business areas. For this reason, a step-by-step approach that gradually permeates the organisation is recommended. The case study revealed that central departments or dedicated responsibilities for sustainability management have been established to initiate and

accompany the transition. These units should be equipped with the necessary expertise but understood less as specialised departments and more as coordinating functions. Acting as interfaces between top management, business units, and relevant stakeholders within the ecosystem, they support both strategy development and the coordination of operational implementation. In addition, to foster and embed a sustainability- and CE-oriented mindset throughout the organisation, teams or individuals from different business units may act as ambassadors, helping to build awareness, knowledge, and competences within their respective areas.

Given both limited resources and the need for continuous development and innovation, combined with a generally low level of prior experience, it seems advisable to implement strategy through selected pilot projects - for example, in relation to new products, materials, or business models. Such projects enable companies to gain experience, identify challenges, and learn and adapt quickly. A dynamic and agile project structure that involves the relevant departments is essential, not only to build skills and knowledge but also to foster acceptance and engagement (Pieroni et al., 2021). On this basis, successful approaches can be scaled up and transferred to other product lines or business units, thereby becoming progressively integrated into the organisation. A key objective should also be to gradually phase out special responsibilities for sustainability and CE during the transition and integrate them into regular operations. For instance, while the development of indicators and reporting mechanisms for internal and external purposes may initially be carried out within dedicated projects, responsibility for their ongoing collection and further development must ultimately shift to operational functions. Based on the case study findings a staff-line structure is recommended for sustainability management, systematically advancing strategy implementation across all operational levels through targeted diffusion into all business areas, while simultaneously building awareness, knowledge, skills, and competences at all levels. The development of a corporate mindset related to sustainability and the CE forms a core element of this unit. It involves creating a shared corporate understanding of sustainability, embedding corresponding values across the organisation, and integrating them into goal-setting systems and decision-making processes.

The limited progress made by the case study companies in implementing sustainability and CE practices and business models aligns with the findings of earlier studies (e.g., Cagno et al., 2025; Stumpf et al., 2021) which show that the transition is characterised

by incremental rather than radical innovations. The case study of German T&C companies revealed specific challenges that help explain this phenomenon and from which potential solutions and measures for overcoming them can be derived. These are discussed in detail below.

Challenges and influencing factors

Competing goals and priorities

Examples from the case study companies illustrate that the stepwise approach to the transition to sustainable and circular practices can lead to conflicts of objectives between different departments within an organisation. These conflicts arise from the necessity for organisations to pursue multiple strategies or goals simultaneously. As a result, existing solutions and business models are inevitably continued while, at the same time, being gradually complemented or replaced by new ones. The concurrent emphasis on both exploratory and exploitative strategies is commonly conceptualised in the literature as organisational “ambidexterity” (Santa-Maria et al., 2022, p. 880). Managing such an approach places particular demands on organisational capabilities, managerial competences, and resource allocation, as it involves maintaining parallel structures and processes. A potential solution, as suggested by the findings and already explained under the key activities, lies in the establishment of a dedicated sustainability management unit combined with comprehensive and transparent communication throughout the organisation. Targeted communication tools, training activities, and the active involvement of managers and employees - as ambassadors or through dedicated projects - in both strategy development and implementation processes can foster awareness and understanding across all organisational units. Furthermore, organisations need to strengthen awareness of environmental and social impacts, foster a mindset that supports circular thinking, and develop relevant skills and competences among internal and external stakeholders. This also involves managing potential resistance to change, which frequently arises in transformation processes of this kind. A supportive organisational culture that embeds and promotes sustainability objectives is interpreted to be a key condition for successful CE implementation. Targeted training and communication measures can help to build a shared understanding of CE principles and practices and to encourage the development of a workforce committed to sustainability and circularity.

Limited resources and capabilities

A key challenge identified through the case study analysis concerns the availability of sufficient financial and human resources to establish the organisational structures, capabilities, and competences required for implementing the aforementioned key activities. The case study companies provide some examples of promising approaches to addressing this challenge. Partnership-based approaches and collaborative initiatives offer opportunities to build systematic networks and alliances that enable the sharing of costs and expertise. These include, for example, multi-stakeholder initiatives such as the German Partnership for Sustainable Textiles, in which companies and a wide range of other actors pool resources, capacities, and competences to work jointly on solutions for sector-specific risks. Other examples include industry initiatives, research collaborations, innovation hubs, and regional clusters, where collective projects and solutions for sector-specific challenges can be developed. Another approach - though still underutilised - is the active acquisition of funding. The case study analysis revealed that companies often lack information and consultancy support and display a certain reluctance due to perceived bureaucratic hurdles. However, active participation in co-operative and collaborative initiatives with diverse ecosystem partners - particularly with research institutions and industry associations - offers companies valuable opportunities to access information about potential collaborative projects and funding programmes.

Lack of digital integration

The implementation of strategies for the transition to sustainability and the CE - such as the need for communication, cooperation, collaboration, and compliance with growing stakeholder and regulatory demands - requires the effective use of DTs. The case study companies showed, however, that many lack the necessary level of digital integration, both in terms of infrastructure and in terms of skills and competences. A combined approach could serve as a solution: the development of digital infrastructure and the associated competences must form an integral part of strategy formulation and implementation alongside organisational change and business model design. Addressing this gap requires a combined approach in which the development of digital infrastructure and related competences forms an integral part of strategy formulation and implementation, alongside organisational change and business model design.

Building on insights from the literature review (Section 2.5), this lack of integration should not be understood merely as a technical deficit, but as a manifestation of an underdeveloped socio-technical system. As Seidel et al. (2013) showed in a case study, DTs realised their potential to support sustainability related strategies through interconnectivity, that is, through the functional linkage of technologies, organisational units, data flows, and actors within and across organisational boundaries. Fragmented, ad hoc adoption of digital solutions without strategic embedding could result in isolated efficiency gains rather than systemic sustainability outcomes. In particular, insufficient interconnectivity between IT systems, data, and organisational competencies and responsibilities emerged as a key barrier to the strategic use of DTs for CE practices. A strategic and integrated approach would instead ensure that broader aspects are also considered. For example, instead of merely replacing analogue wet-printing methods with digital printing machines, the associated data and systems could be connected and utilised in the development of print designs that are as colour- and energy-efficient as possible. The organisational units responsible for sustainability management and IT/digitalisation thus form a crucial interface in strategy implementation. Raising awareness of digitalisation not only as an efficiency tool but also as a lever for sustainability and CE-practices is vital to exploit the potential of existing applications and identify promising new tools and technologies.

At the same time, the analysis suggested that cross-company development of digital solutions - such as supply chain grievance mechanisms, sector-specific digital platforms, and digital material libraries - constitutes an important lever for overcoming resource and competence limitations.

External challenges

A challenge for companies in implementing sustainable and circular business models lies in market uncertainties and contradictions. Case study examples showed that difficulties arise with initiatives that aim to close resource flows, such as circular packaging solutions or take-back systems, which failed due to the lack of participation by ecosystem partners. Similarly, product–service systems such as repair or rental models are particularly poorly received in the B2C sector, despite broader trends suggesting rising consumer expectations for sustainable products and services. As a result, these approaches are currently not economically viable for companies and therefore remain

unscaled. Individual case study examples suggested that combinations of different factors can provide promising solutions. To meet customer expectations, innovative solutions are needed that are developed from the consumer perspective, ideally involving them directly in the design of such offerings. The case study indicated, for example, that consumer participation in design decisions can help reduce overproduction. In similar vein, the involvement of consumers in the development of take-back schemes or repair services is likely to result in more practical and widely accepted solutions. The same applies to initiatives aimed not at end consumers but at other ecosystem partners such as suppliers or logistics providers. Active involvement of relevant partners and the joint development of solutions can both foster genuine innovation and distribute risks more broadly. DTs can further support such initiatives by improving the efficiency of implementation and enhancing the evaluation of outcomes. However, the case study findings highlighted that it is hardly feasible for individual companies to implement a fully circular business model, given the complexity of the textile value chain and its distribution across a wide range of actors. The resulting interdependencies between companies underline the critical importance of cooperation and collaboration within and beyond the core textile ecosystem. A stepwise approach - building on small-scale initiatives, learning from early experiences, and subsequently scaling successful solutions - emerges as a pragmatic pathway. Active communication and the integration of stakeholders throughout this process are essential to ensure both the viability and acceptance of new business model approaches.

Technology deployment

To enable an effective transition to sustainability and the CE, companies should systematically deploy DTs that strengthen communication, stakeholder engagement, and sustainability management. While a wide range of DTs can be applied, their use and implementation should be systematic, aligned with the company's strategic orientation, and designed with the involvement of relevant stakeholders and users in order to efficiently support the strategy and business model. Social media platforms are already in use by most companies today; however, in the context of organisational change they should not be regarded primarily as marketing instruments, but also as tools for transparent communication of sustainability activities, stakeholder integration, and consumer education. Previous research indicates that many consumers do not possess the necessary skills and knowledge to repair products (Fachbach et al., 2022; Laitala

et al., 2018), suggesting an area where companies could provide targeted support. Nevertheless, the case study findings indicate that social media is rarely used as a channel for direct interaction with consumers or for communicating knowledge related to product repair and therefore contributes only marginally to fostering a repair-oriented culture. Mobile applications, which are already standard in most firms and across society, should be consistently and systematically utilised to support decentralised working and communication processes, thereby reducing travel and associated emissions, replacing physical product presentations with virtual formats where possible (e.g. at trade fairs or in sales meetings), and enabling the exchange of data and information with stakeholders across the entire value chain. Information and enterprise software systems such as ERP and PDM/PLM complemented by cloud services should build the core of the organisational infrastructure to enable the interconnection of actors and objects as well as the exchange and integration of data. These systems enable the structured collection, analysis, and reporting of environmental and social data for ensuring compliance with standards and facilitate transparent reporting. A critical factor in this regard is compatibility and interoperability with other systems and platforms, to automate the collection and use of data from a wide variety of sources. This requires sufficient storage capacity, functional interfaces, and robust security systems. Equally important is the development of digital competences across the organisation.

Summary and action list

At the organisational level, the transition to sustainability, the CE and digitalisation requires a clear strategic alignment that goes beyond legal compliance, embedding global goals and stakeholder interests into corporate strategy and objectives. Business model innovation, while currently incremental, must evolve towards holistic configurations that integrate value creation, delivery, and capture to unlock their full potential. The active involvement of diverse ecosystem partners is essential, as companies cannot achieve circularity in isolation, and pilot projects should serve as catalysts for gradual but scalable change. Organisational structure and culture must be reshaped to diffuse responsibility for sustainability across all units, supported by strong communication, training and coordination mechanisms. The consolidated action list (Table 43) highlights the key activities, challenges, and technology deployment that companies must address to operationalise this transition effectively.

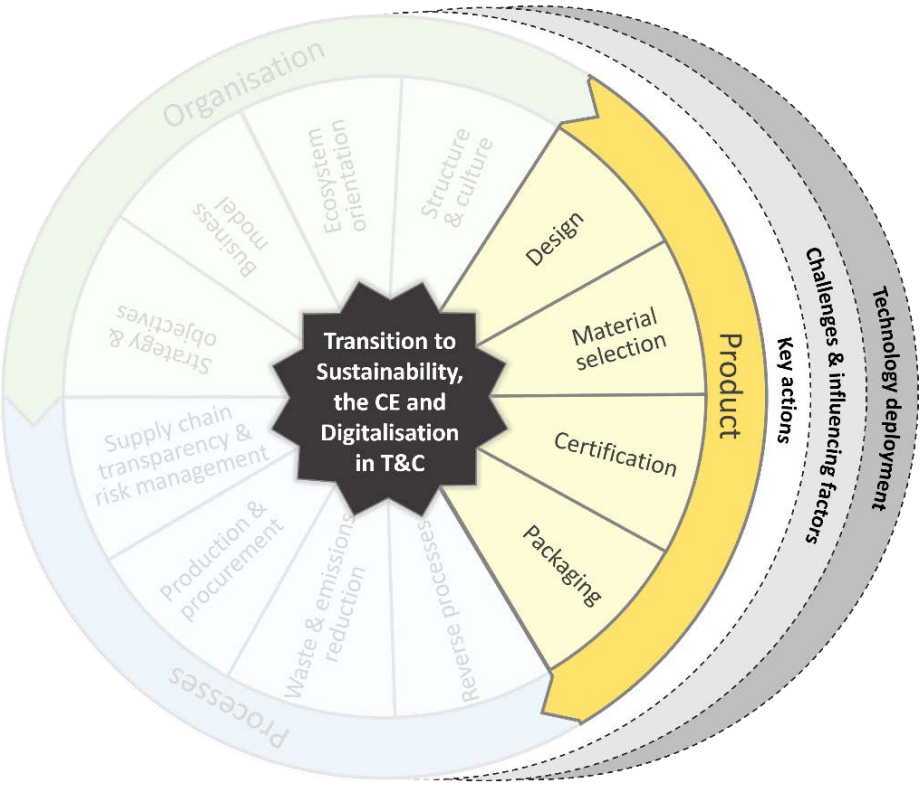
Table 43:
Action list for the change dimension organisation

<table>
<tr><th colspan="3">Organisation</th></tr>
<tr><th>Activities & key actions</th><th>Challenges</th><th>Influencing factors</th></tr>
<tr><td rowspan="3">Strategy & objectives
• Align corporate strategy with global sustainability goals (SDGs, Paris Agreement), CE objectives, stakeholder interests, and legislation
→ Holistic approaches over isolated adjustments
• Define clear financial, environmental, and social indicators
Business model adaptation
• Experiment with alternative business models to narrow, slow and close resource flows (e.g., repair, rental, collaborative recycling)
• Combine different business model archetypes to holistically rethink value proposition, creation, delivery, and capture
Ecosystem orientation
• Proactively involve internal and external stakeholders
• Strengthen collaboration with ecosystem partners
Structure & culture
• Ensure top management commitment and embed responsibility structurally for strategy implementation (e.g., sustainability management unit).
• Foster a sustainability- and CE-oriented mindset across the organisation e.g., through ambassadors to build awareness and competences
• Implement pilot projects for gradual integration</td><td>• Conflicting objectives across departments
• Market uncertainties
• Lack of digital integration
• Limited financial/human resources</td><td>• Active and transparent communication and decision making across the organisation
→ Awareness, skills, knowledge are present across the organisation
→ Clear and measurable objectives and reporting mechanisms established
→ All relevant stakeholders (e.g., employees, suppliers, customers) are involved in strategy implementation / pilot projects
• Active engagement in cross-company collaborations (clusters, partnerships, innovation hubs)
• Access to sector-specific information events, projects and funding opportunities (e.g. through research collaborations or industry associations)</td></tr>
<tr><th colspan="2">Technology deployment</th></tr>
<tr><td colspan="2">• Derive IT/digitalisation strategy from corporate strategy
→ Align sustainability management and IT management structurally and strategically
→ Align digital infrastructure with strategy implementation and business model adaptation (storage capacity, interface functionality, security)
→ Empower employees to develop digital skills and competences
• Set a robust and scalable digital infrastructure forming the foundation for the seamless integration of different (and future) technologies and deploy them in an integrated and interconnected manner
→ State of the art ERP, PDM/PLM, and ESG management systems
→ Digital platforms and applications (e.g. social media, traceability and collaboration platforms)
→ Mobile devices and mobile applications
• Ensure integrated communication and data collection, analysis, and sharing across organisational and inter-organisational levels</td></tr>
</table>

6.2.3 Change Dimension: Product

Products constitute the primary carriers of value and environmental impact in the T&C industry and therefore represent a crucial lever for change. At the product level, the transition to sustainability and the CE requires the integration of environmental and social considerations into product development and design. The framework for this dimension focuses on four interrelated fields of activity: design, material selection, certification, and packaging. The following section outlines the key actions, associated challenges, and potential DTs that may support the transition to sustainability and the CE (Figure 48).

Figure 48
Change dimension product and associated fields of activity



Fields of activity and key actions

Design

Design decisions fundamentally determine the impacts associated with a product, including its ecological footprint, durability, and the recyclability of its components. To foster sustainability and circularity in textile products, companies must embed design principles that prioritise safety and non-toxicity for humans and the environment, as

well as durability, reparability, modularity, and recyclability (Aguiar & Jugend, 2022). Depending on its strategic orientation and business model decisions, a company's products and services should be aligned with the objectives of sustainable development and the principles of the CE. For example, if the introduction of product–service systems is envisaged, this must be considered in product development so that processes are efficient and customer value is maximised. The case study companies are still at an early stage in this respect, focusing primarily on the development of viable business models while product adaptation to support these offerings remains limited. However, examples from the literature show that holistic approaches hold significant potential for cost-efficient models. For instance, modular product designs can support cost-effective services such as maintenance in rental models for outdoor clothing (Fuchs & Hovemann, 2022). While the integration of RFID tags in garments can optimise service-related inventory and logistics processes (Alves et al., 2022; De Felice et al., 2025) or provide consumers with accessible product information and services (Carvalho et al., 2025). Based on the case study findings, two aspects related to the product dimension are of particular importance.

Firstly, the empowerment of designers and product developers. Without adequate knowledge and competences regarding sustainability and the CE, the development of new solutions is limited. This includes not only material and manufacturing knowledge but also the ability to assess potential product impacts across the lifecycle, with a focus on extended use, use cascades, and environmentally sound recycling. Designers and product developers thus represent a central stakeholder group for the transition, acting as a lever in translating strategic objectives into product development and design (Dan & Østergaard, 2021). Second, the definition of specific product requirements and indicators is crucial for continuously advancing and improving product design. Standardised LCA analyses can, for example, provide designers and developers with information on resource use or carbon footprints, while durability, repair, or recycling indices enable comparisons and thereby support optimal design decisions. Key requirements and goals for sustainable and circular product design include ensuring high quality and durability, reducing the complexity of material composition, and enabling disassembly for reuse and recycling. The literature review further identified a wide range of sustainable and circular design concepts and strategies that may be applied

depending on a company's strategic orientation and potential business model adaptations (Table 44). These provide a starting point for systematically aligning products with CE principles — narrowing, slowing, and closing resource flows.

Table 44
Examples of product design strategies for the CE

CE-principle	Design strategy
Narrowing	- Design for light weighting - Design for resource efficient production - Design for standardisation
Slowing	- Design for reliability and durability - Design for ease of maintenance & repair - Design for upgradability & adaptability - Design for standardisation & compatibility - Design for refurbishment and remanufacturing
Closing/ regenerating	- Design for dis-/re-assembly - Design for recycling - Design with non-toxic materials - Design with recycled materials

Source: Based on Aguiar & Jugend, 2022; Bocken et al., 2016; Den Hollander et al., 2017

It should be noted that most of the practices identified stem from companies in the clothing industry (NACE 14), while companies in the textile industry (NACE 13) reported very few design-related changes. For textile companies, two approaches appear to be of particular importance. First, the development of product innovations is crucial, for example through the creation of sustainable, functional, and high-quality yarns or fabrics that enable the development of downstream sustainable and circular products or services. This may also include the design of particularly robust, durable, or biodegradable (intermediate) products. Second, targeted and active collaboration with downstream customers, as well as with other ecosystem partners such as recyclers, is essential to foster sustainable and circular solutions. Such collaborations should also be leveraged to jointly establish best practices and industry standards, for instance regarding the requirements for recyclable products and materials.

The case study findings further indicate that a selective approach is advisable when adapting product design. This means that the transition should begin with individual products, product lines, or collections. These may either be existing items that are adapted or newly developed offerings complementing the existing portfolio. In this process, integration and collaboration with relevant stakeholders along the value chain are vital to enable rapid learning and to ensure that solutions are tailored to market potential. It is therefore essential that companies adopt a life cycle perspective, seeking to preserve the value of products, components, and materials for as long as possible while minimising waste from the outset.

Material selection

The choice of materials represents a crucial decision for product development and has a significant impact on the overall sustainability performance of products. Renewable, recycled, and certified sustainable fibres and materials should be prioritised, as they are associated with minimal negative ecological and social impacts across their entire material life cycle. Evidence from the case study companies highlights that openness and willingness to experiment on the part of product developers and designers play a central role in material selection. For instance, by-products from the food industry may serve as promising raw materials for sustainable and circular alternatives. Unlocking and scaling such potential requires objective evaluation of the sustainability performance of candidate materials, considering ecological, economic, and social dimensions. At the same time, material choices must carefully balance aesthetic requirements and practical considerations such as durability, reparability, and cost factors, while also ensuring end-of-life valorisation based on material composition. Challenges arise from the use of composite materials, for example when combining synthetic and natural fibres or applying finishes and coatings, as these limit recyclability. One promising approach in this context is the use of mono-materials, i.e., single-material compositions, which allow for more efficient recovery and recycling at the product's end of life.

Certification

Based on the findings of the case study analysis, credible product and material certifications, alongside transparent and comprehensible product labelling, are indispensable for communicating the sustainability performance of products and materials to stakeholders and for strengthening consumer trust. Over time, a wide range of certifications and standards for textile products has emerged. From the perspective of customers and consumers, this can be problematic, as it may lead to confusion, overload, and consequently low acceptance (Diekel et al., 2021). Companies should therefore align with internationally recognised and independently verified material and product standards and incorporate compliance with such requirements into their decision-making processes. The relevance of specific labels will vary depending on the product type; however, comprehensive certifications that account for the entire product life cycle and cover a broad spectrum of ecological and social aspects are preferable to more fragmented labels that address only individual dimensions. Table 45 provides an overview

of key sustainability certifications for textile products, which may serve as a starting point for defining requirements and conditions for material selection and product design.

Table 45

Overview of textile-specific sustainability certificates and associated product requirements

Certificate	Description and requirements
Güner Knopf/ Green Button	- German governmental seal for textile products - Sets binding requirements to protect people and the environment - Certifies products produced in compliance with at least 46 social and environmental standards
Global Organic Textile Standard (GOTS)	- Certifies textile products that consist of at least 70% certified organically produced natural fibres, excludes harmful chemicals and guarantees minimum social standards from the raw material to the finished product
Oeko-Tex	- Certifies textiles tested for harmful substances - Standard 100 certifies that a product is free of harmful substances - Made in Green = Standard 100 + traceable product supply chain
bluesign®	- Certifies textiles produced with safe chemicals, resource efficiency, and minimal environmental impact across the production process
Fairtrade	- Certifies goods produced under fair trade principles, ensuring improved working conditions, fair wages, and environmental responsibility across the supply chain. - Offers two certifications for textiles: - Fairtrade Cotton: product is made from fairly produced and traded raw cotton that is traceable through all production stages and was separated from non-fairly traded cotton during processing. - Fairtrade Textile Production: textile product has been produced and traded sustainably and fairly along the entire supply chain
Global Recycled Standard (GRS)	- Certifies products that contain at least 20% recycled material - Each stage of production is required to be certified, beginning at the recycling stage and ending at the last seller in the final business-to-business transaction.
Cradle to Cradle Certified ™	- Assesses the safety, recyclability and responsibility of materials and products against five categories of sustainability performance: material health, product circular economy, air and climate protection, water and soil conservation, and social fairness

Source: The author based on information provided on the websites of the certifying organisations

Packaging

Although often overlooked, packaging makes a significant contribution to waste generation and environmental impacts. Companies should therefore integrate packaging into their sustainability activities and pursue dedicated strategies by critically reviewing existing product packaging, reducing it wherever possible, switching to recyclable or compostable options, and exploring reusable systems. The case study analysis revealed that collaborative approaches are particularly important in this context, involving relevant ecosystem partners such as logistics partners, suppliers, packaging manufacturers, and customers to jointly develop and implement more effective and innovative solutions, such as reusable and circular systems.

Challenges and influencing factors

Balancing conflicting goals

Product-related changes are associated with several challenges, one of the most prominent being trade-offs between specific practices and CE principles. This applies to the tension between using more sustainable or recycled materials and optimising products in terms of durability, functionality, and recyclability. For example, the durability of a product may be reduced by using recycled materials, while the combination of different fibres can enhance performance and longevity but simultaneously hinder recyclability. A potential solution lies in strengthening research and innovation to develop materials and products that combine durability with recyclability. Targeted collaboration with value chain partners, as well as with research institutions and recycling companies, can further support companies in identifying and testing novel materials and processes that help to mitigate such trade-offs.

Aligning cost pressure and market acceptance

Another major challenge concerns cost pressures and market acceptance. Sustainable and circular materials, products, or packaging are often associated with higher costs as well as quantitative and qualitative fluctuations in sourcing and processing. This can result in higher prices and reduced acceptance among customers and consumers. Addressing this challenge requires holistic approaches. While the mere substitution of conventional materials with, for example, recycled alternatives may drive up costs and, consequently, product prices, a more comprehensive rethinking of products - in combination with business model adaptations in line with CE principles - could enhance customer and consumer acceptance. This may include the integration of additional functions or services, accompanying communication and awareness campaigns, and innovative product-as-a-service business. A stepwise approach is recommended, beginning with selected products or pilot lines and involving relevant stakeholders, to enable rapid learning and gradually build acceptance.

Technology deployment

The findings from the case study analysis suggested that DTs play a central role in implementing sustainable and circular product design strategies. At the product level, digital manufacturing tools – including 3D design and prototyping software – were used to enable virtual product development and to largely eliminate the need for physical

samples. This can significantly reduce the material, energy, water, and chemical consumption associated with product development, while simultaneously lowering transport-related emissions and reducing costs. Although these applications are still at a very early stage of development in the case study companies, evidence suggests that AI-based applications in combination with digital twins hold considerable potential for optimising product designs regarding reduced resource and energy consumption during manufacturing. For example, in the development of print designs for fabrics and garments, digital simulations could provide insights into ink and energy consumption during production and generate suggestions for resource-optimised adjustments. Similarly, digital colour management systems and virtual material libraries can help to minimise waste by providing relevant data for design related decision-making but also improve coordination processes and accelerate decision-making in collaborative product development. These applications highlight the potential of DTs to support product design, while also helping to offset material- or processing-related cost increases through savings in product development.

Beyond digital manufacturing, IoT-based solutions such as QR codes, RFID tags, and tracer systems embedded in fibres, fabrics, clothing products or packaging enhance the traceability of products and materials across their entire life cycle. In combination with blockchain and cloud technologies, these tools provide secure and transparent means of collecting, analysing, and sharing data, thereby enabling systematic product optimisation and compliance with emerging regulatory requirements, such as the EU Ecodesign Regulation and the upcoming Digital Product Passport. Integrated approaches of this kind strengthen transparency and can also facilitate recycling and take-back systems and contribute to closing resource loops.

The integration of such technologies, however, also poses challenges. Companies may remain in the pilot phase, where fragmented systems and limited connectivity restrict the full potential of data-driven decision-making. In addition, the absence of harmonised standards, high investment requirements, and gaps in digital competences represent further barriers. A stepwise approach is therefore essential, integrating sustainability, CE, and DTs within strategic planning and the associated implementation measures. Pilot projects should serve as starting points, with successful solutions gradually scaled up across product lines. Partnerships with technology providers, research institutions, and value chain partners seem to be central in developing feasible

solutions and creating shared digital infrastructures that can help reduce costs and strengthen acceptance across the value chain.

Overall, DTs should not be regarded solely as efficiency tools but strategically positioned as enablers of innovation and sustainability. By embedding them in product design, material selection, certification, and packaging processes, companies can both narrow and close resource flows while simultaneously enhancing transparency and fostering stakeholder trust.

Summary and action list

Products are a key driver of both value creation and environmental impact in T&C companies and are therefore central to the transition to sustainability and the CE. The main requirements include durable, repairable and recyclable products, the use of renewable or recycled materials, credible certification systems, and collaborative approaches to sustainable packaging. However, companies must balance trade-offs between durability, functionality and recyclability, while facing challenges associated with higher costs and limited market acceptance. Addressing these issues requires not only awareness and expertise among designers and product developers regarding the requirements for sustainable and circular products and materials, but also innovation, cross-value chain collaboration, and gradual implementation through pilot projects. DTs play a central role and should be systematically employed to dematerialise the design process, provide designers and developers with relevant and comprehensive data - such as resource consumption and environmental impacts – related to product design decisions, and enable the exchange of product-related data and information with key stakeholders, such as customers and consumers, for instance through tracers, tags or digital product passports.

The consolidated action list (Table 46) highlights the key activities, challenges and DTs that companies need to address in order to effectively advance the transition at the product level.

Table 46

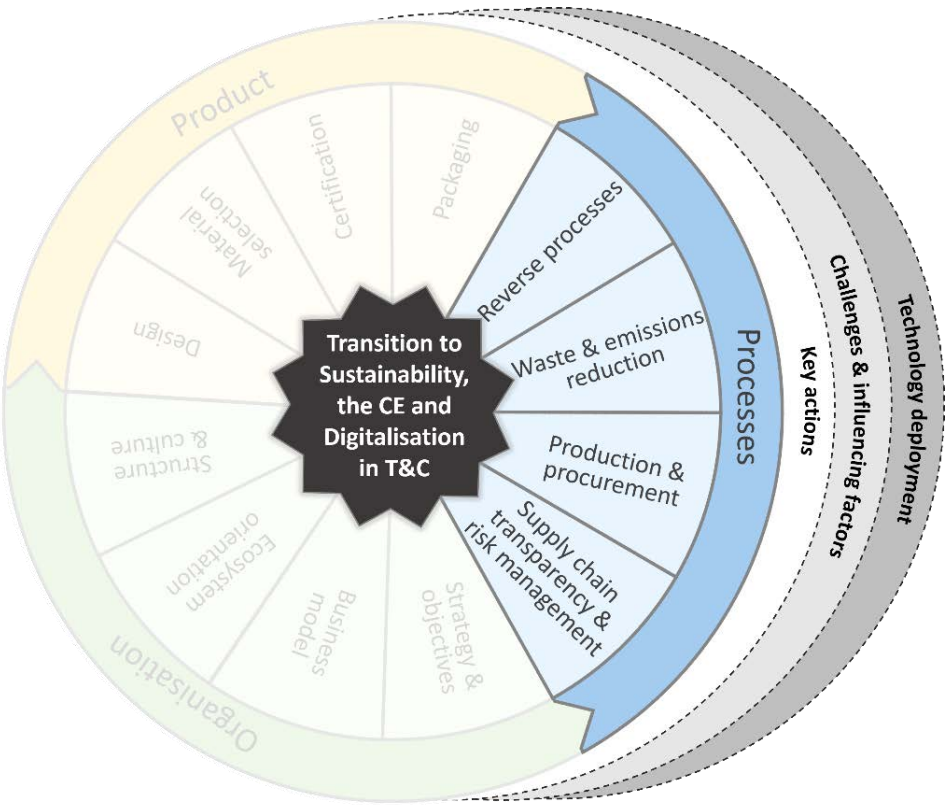
Action list for the change dimension product

Product		
Activities & key actions	**Challenges**	**Influencing factors**
Design • Develop and embed sustainable and circular product design strategies (e.g., safety, durability, reusability, reparability, modularity, recyclability) • Empower designers with CE knowledge and life cycle perspective and collaborate with downstream partners and recyclers • Define specific indicators and targets (e.g., carbon-footprint, durability, repair indices) **Material selection** • Prioritise renewable, recycled, and certified sustainable fibres and materials • Evaluate ecological, economic, and social impacts of candidate materials through the life cycle • Use mono-materials to facilitate recycling **Certification** • Adopt credible, internationally recognised standards • Use comprehensive certifications covering full product life cycle • Provide transparent and comprehensive labelling **Packaging** • Critically review and minimise packaging • Increase use of recyclable/compostable options • Explore reusable packaging systems	• Limited CE competences among designers • Trade-offs between durability, functionality, and recyclability • Lack of standards in design processes • Cost, availability, and quality fluctuations in sustainable and circular materials • Cost and market acceptance of alternative materials and products	• Training and capacity-building for designers and product managers • Research and innovation on materials and packaging solutions → Experimentation with alternative raw materials and packaging solutions (e.g., food-industry by-products) started → Active network with research institutions, recycling companies, logistics partners, suppliers and packaging manufacturers in place • Holistic product (re-)design combined with business model adaptation (e.g., product-as-a-service) started → Value added through extra functions, services, or awareness campaigns to increase acceptance → Step-by-step approach applied with pilot products or product lines and involving relevant stakeholders
	Technology deployment	
	• Deploy digital technologies to enhance traceability, sustainable design and dematerialisation → 3D design and prototyping software /plat-forms for virtual and collaborative product development instead of physical sampling → Digital colour management systems and virtual material libraries to dematerialiese product development → Digital twins and AI simulations to support sustainable design decisions → IoT-based tools (QR codes, RFID, tracers) combined with blockchain/cloud to enhance traceability, transparency, and compliance	

6.2.4 Change Dimension: Processes

Shifts in corporate strategy towards overarching sustainability objectives and CE-principles should be accompanied by corresponding changes in operational processes, both within companies and across value chain networks. These processes encompass the manufacturing, delivery, and end-of-life management of products and materials. At the process level, four fields of activity emerged as central to the transition: supply chain transparency and risk management, procurement and production, waste and emissions reduction and reverse processes (Figure 49). The following section outlines the key actions, associated challenges, and digital technology deployment that may support the transition to sustainability and the CE on the process level.

Figure 49
Change dimension processes and associated fields of activity



Fields of activity and key actions

Supply chain transparency and risk management

The case study analysis highlighted the complexity of the T&C value chain, involving diverse actors distributed across the globe. This complexity creates significant risks of

adverse social and environmental impacts that hinder sustainable development. Transparency regarding supply chain processes and the impacts associated with the origin and production of materials and products is therefore a fundamental prerequisite for both effective risk mitigation and the development of solutions for narrowing, slowing, and closing resource flows. Therefore, companies should adopt systematic approaches to map their supply chains transparently. This extends beyond Tier 1 partners and should include both upstream and downstream processes. Key actions include establishing structured data collection processes (such as questionnaires and social and environmental audits) and ensuring secure and standardised data exchange. For globalised supply chains, professional risk management systems and due diligence frameworks (e.g. OECD due diligence guidance) provide structured approaches for identifying and mitigating risks, as well as for demonstrating and documenting sustainability performance to various stakeholders. Examples from the case study companies demonstrated the importance of direct collaboration with supply chain actors. These include participation in initiatives supporting cotton farmers – representing the very beginning of the supply chain – in transitioning to organic cultivation, or initiatives aimed at safeguarding occupational health and safety, human rights, and living wages in global T&C production. The findings further showed that company activities in terms of risks - both in the textile and the clothing industry – have so far focused primarily on the upstream supply chain, while downstream processes have largely been overlooked. To address this gap, companies should systematically collect and analyse information on downstream processes, including actual material and product lifetimes, disposal practices, and recycling rates, and derive targeted measures from these insights.

Procurement and production

Decisions on procurement and production are central levers for addressing sustainability impacts both upstream and downstream in the supply chain. Procurement principles should be closely aligned with corporate strategy and business model development, extending beyond price and quality to include clear ecological and social criteria. Supplier selection and evaluation should systematically consider the potential for narrowing, slowing, and closing resource flows. Contractual instruments such as codes of conduct, combined with credible and regular auditing, can provide a foundation for

change, but the emphasis should be placed on building long-term, trust-based supplier relationships that foster innovation and continuous sustainability improvement.

Thus, procurement should be understood as a strategic function that makes a critical contribution to implementing sustainability and CE strategies. The case study revealed that the potential of short supply chains and local networks within Germany or Europe is not yet fully exploited. Greater use of regional and European sourcing can both reduce supply chain risks and mitigate negative environmental and social impacts. Furthermore, as firms move towards more circular business models such as on-demand production, product-service systems or next life approaches, collaboration with new types of partners (e.g., repair providers, recycling industry) in regional clusters becomes increasingly important for developing competitive circular solutions.

Companies with their own production facilities must also focus on continuously optimising cost, energy, and resource efficiency, minimising waste and emissions, and adopting flexible yet efficient manufacturing processes. These include specifically adapting manufacturing processes to recycled materials, which are often characterised by inconsistent quality.

Waste and emissions reduction

Waste and ghg emissions are among the primary drivers of negative environmental and social impacts in the T&C industry. In transitioning to sustainability and circularity, companies should systematically address both the direct impacts (Scope 1 and 2) and indirect impacts (Scope 3) across their supply chains. This requires a holistic approach that integrates waste prevention, resource efficiency, and emission reductions into production, logistics, and supply chain management. Measuring relevant waste streams and emissions represents the first and most important step in this regard. Beyond greenhouse gases, this includes water and soil pollution, for example from chemical discharges. Data collection provides the foundation for analysis, the setting of reduction targets, and the development of effective measures. The case study findings intend that companies already collect extensive data on internal waste and emissions and have implemented a range of reduction measures. These include renewable energy use, energy and resource management systems, energy-efficient office and factory equipment, resource-efficient production techniques such as digital printing, quality assurance measures to reduce defective goods, and packaging reduction thereby contributing to both waste and emission reduction as well as cost savings.

However, the findings also showed that initiatives largely remain limited to internal processes. Waste and emissions generated upstream and downstream in the supply chain are often not fully accounted for, largely because they fall outside a company's immediate sphere of control. Expanding activities to include Scope 3 emissions and waste is therefore essential. This requires systematic collaboration with supply chain partners to collect data, define reduction targets, and jointly implement measures. Promising approaches identified in the case study companies include participation in industry initiatives, the use of shared data platforms, and collective investment in reduction projects. To ensure alignment with international sustainability objectives (e.g., Paris Agreement) corporate goals should be linked to global frameworks (e.g., via the Science Based Targets initiative) and integrated into transparent company and product-level indicator calculation and reporting (e.g., corporate and product carbon footprints).

Reverse processes

Reverse flows constitute a central element of the CE, enabling the closing and slowing of resource flows. The case study companies provided extensive examples of the direct reuse and recovery of materials generated during manufacturing processes. These include the reuse of process water and chemicals in closed-loop systems, the reintegration of fibre and yarn waste from production into yarn or nonwoven manufacturing, the sale of production waste to other industries, and approaches to take-back used sportswear and workwear for reprocessing into secondary materials.

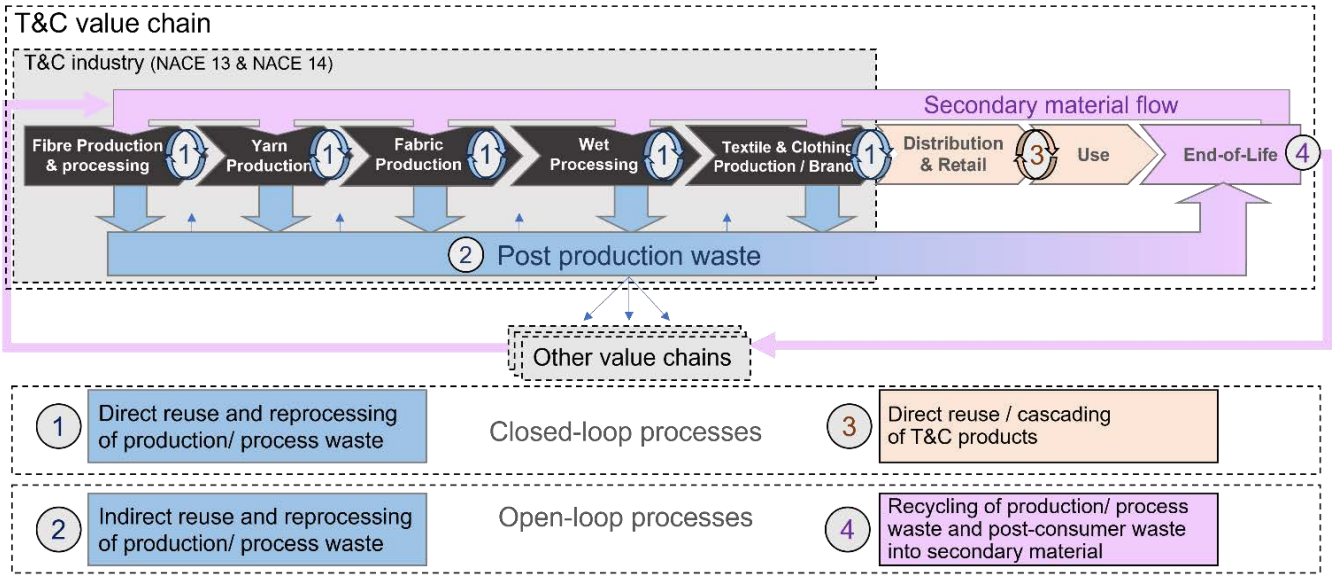
Drawing on these examples, four types of reverse flows can be distinguished (Figure 50). Firstly, the direct reuse or reprocessing of production- and process-related waste streams in closed loops within the company itself (e.g. process water, chemicals, material offcuts). Secondly, the indirect reuse, further processing, or recycling of production- and process-related waste streams in open loops by other companies within or outside the T&C value chain. Examples include circular packaging systems, the sale of spinning waste from wool processing to other industries, or the sale of yarn residues from fabric production for recovery in the nonwoven industry. Such practices represent applied solutions that are relevant and transferable to all T&C companies and should be systematically exploited. Therefore, companies must assess, which (unavoidable) waste streams occur and which types of reuse or recycling are most viable from a sustainability perspective.

Thirdly, companies that operate directly in consumer markets should establish closed loop processes for the direct reuse of textiles and clothing. Examples include product–service systems such as rental models, repair services with regional partners (e.g. Ifixit), collaborations with resale platforms (e.g. eBay) for private reuse, in-house take-back and resale schemes (e.g. 'Second Life Stores').

Fourthly, all remaining waste that cannot be reused in any other way should be directed into appropriate open-loop recycling processes, where it is converted into secondary raw materials that can be reintegrated into the T&C or other value chains.

Figure 50

Four types of potential reverse flows in the T&C value chain



Building robust reverse flows requires collaboration and partnerships both within and beyond the T&C value chain. Collaboration with logistics providers, recyclers and peers is crucial to developing collection systems, improving sorting infrastructure, and developing industry standards for recyclable products. At the same time, participation in research projects can accelerate innovation in fibre-to-fibre recycling, regeneration technologies and reprocessing in production, thereby contributing to more consistent output in terms of volume and quality of recycled materials.

Challenges and influencing factors

Reduced process efficiency and increased costs

Compared with virgin fibres, recycled materials often display greater inconsistency in quality and availability. This creates additional complexity to procurement and production processes in the textile industry, resulting in longer lead times, increased manual effort, and the need for expertise in adapting production processes to achieve consistent, high-quality production output. To address this, companies should drive joint innovation with supply chain partners, research institutions, and recycling operators to enhance quality and consistency of secondary materials and processing techniques, ensuring comparable quality to virgin materials. Greater automation in other processes, such as quality control using AI systems, can help to ensure consistent output quality and partially offset higher costs related to more complex production processes. In procurement, building strategic, long-term partnerships - particularly within regional clusters for alternative or recycled material sourcing combined with active engagement in secondary raw material platforms can strengthen security of supply while reducing ecological and social impacts. Adjustments to sourcing strategies, such as maintaining higher stock levels, may also be required. Based on the findings from the case study, a stepwise approach is recommended, starting with selected products or materials in pilot projects, enabling rapid learning, process optimisation and scaling.

Information and data collection along supply chains

Achieving transparency and data availability across global supply chains emerged as another major challenge. While Tier 1 suppliers are relatively straightforward to monitor, obtaining information from deeper tiers, particularly regarding social and environmental risks (e.g., Scope 3 emissions), remains difficult. Low levels of digitalisation and reliance on manual, company-specific workflows complicate sustainability monitoring, hinder comparability and lead to high administrative burdens for the actors involved. Solutions include greater standardisation and the use of and collaboration with sector-wide databases where supply chain and sustainability related information, certifications, and audit results can be centrally stored and accessed by all supply chain actors. Coordinated action by multiple buyers working with the same suppliers can further increase leverage in enforcing requirements and improvements.

Building and improving circular supply chains

The development of reverse supply chains represents a third group of process-related challenges. Closing material loops is still at an early stage, as take-back, reuse, and recycling systems remain fragmented, and consumer participation is relatively limited. For many firms, particularly those with production outsourced, unavoidable process and production waste streams may not be reprocessed or recycled (e.g., due to inadequate local recycling infrastructure). Addressing these challenges requires collective efforts to build harmonised collection infrastructures and foster cross-sectoral platforms for secondary raw materials, also in production countries. Companies should systematically separate and measure waste streams, reintegrate them into internal processes where possible, and direct unavoidable volumes into other industries. Clear product labelling and the use of mono-materials in product development can further facilitate recycling. At the consumer level, awareness-raising campaigns, interactive labelling systems, and incentives for participation in take-back programmes could help to increase stakeholder engagement. Companies should also take an active role in multi-stakeholder initiatives and industry associations to harmonise standards and processes for reverse flows, reducing fragmentation and fostering broader participation across the value chain.

Technology deployment

At the process level, a wide range of DTs – particularly in combination – can contribute to reducing resource consumption, minimising waste and emissions, and strengthening transparency and traceability along the T&C supply chain. The case study analysis revealed that while many applications are already in use or being piloted, they are often applied individually and in a fragmented context rather than through industry-wide solutions and common standards. Moving forward, greater collaboration and coordination are required to establish such standards and avoid a proliferation of disparate tools that generate more effort than value for companies and stakeholders. The findings also highlighted that the systematic and targeted deployment of DTs can significantly support and facilitate the transition to sustainability and the CE by increasing transparency and efficiency along the supply chain and enabling to narrow, slow and close resource flows. The central task for companies is therefore to integrate these technologies systematically and strategically into existing and new process structures to ensure they

generate both ecological and economic value. Digital applications and platforms that support data collection and end-to-end information sharing across companies in the T&C supply chain should replace manual data exchange, thereby reducing the associated burden for all actors. These tools make it possible to track and verify key aspects such as fibre and material origins, the results of certifications and audits, and compliance with environmental and social standards. Typically, such systems combine multiple technologies – including cloud solutions, blockchain, and process automation – to meet complex requirements while remaining user-friendly. To ensure efficiency and comparability, companies should actively engage in and adopt industry-wide solutions. Examples from the case study companies demonstrated that industry platforms (e.g. Retraced, TextileGenesis) offer advantages through standardised data collection and reporting, whereas company-specific approaches may result in fragmentation, manual work, and increased costs. Well-designed platforms reduce the reporting burden and enable companies to embed sustainability requirements more effectively into procurement and supplier management. Companies with in-house production facilities can additionally benefit from technologies that enable the systematic collection and analysis of process data. IoT-based solutions and sensors, for example, allow real-time monitoring of detailed process parameters, thereby improving resource efficiency (e.g. water, heat, chemicals, material waste), reducing errors, and minimising production waste. Automated processes such as cutting and packaging further increase efficiency and conserve resources. AI-based applications, such as image recognition, can support quality control and waste sorting, thereby reducing waste generation while improving recycling and reuse. Resource-intensive wet processes – such as dyeing and printing – which are associated with high levels of water, chemical, and energy use, should increasingly be replaced or supplemented by DTs that reduce consumption, such as digital printing. Reverse flows should be facilitated by digital take-back systems, customer-oriented mobile applications, and online platforms that make participation fast and simple for both companies and consumers. Tracer technologies embedded into products can support sorting, recycling, and reuse, while shared industry platforms for secondary raw materials allow companies to reintegrate pre- and post-consumer waste into production processes. These tools help to scale circular practices by enabling more efficient collection, sorting, and reprocessing systems. Ultimately, DTs should not be regarded merely as instruments for efficiency but as enablers of systemic

change. By embedding them into operational processes and linking them with enterprise software, management, and reporting systems, companies can create the transparency and efficiency required to advance circular strategies and strengthen collaboration with stakeholders across the value chain.

Summary and action list

Operational processes represent a key lever for the transition to sustainability and the CE in the German T&C industry. Four main fields of activity characterise this dimension: supply chain transparency and risk management, procurement and production, waste and emission reduction, and reverse processes. Companies must establish transparent supply chain mapping beyond Tier 1, integrate structured data collection and due diligence frameworks, build trust-based supplier partnerships, and align procurement decisions with environmental and social criteria. Production processes require continuous optimisation in terms of resource and energy efficiency and should be adapted to the processing of recycled materials of inconsistent quality. The reduction of waste and emissions must be extended beyond internal processes to include Scope 3 impacts, which requires collaborative data platforms and industry-wide initiatives. Reverse processes are central to closing resource flows and include open and closed loops for direct and indirect product and material recovery processes. Building robust reverse processes requires partnerships with actors inside and outside the value chain. DTs play a cross-cutting role across all four fields of activity, enabling transparency, efficiency, and circularity through the interconnected use of cloud-based platforms, IoT, AI, and blockchain applications. Ultimately, change at the process level requires coordinated collaboration and the systematic integration of technologies to ensure both environmental and economic value creation. The consolidated action list (Table 47) highlights the key activities, challenges, and digital enablers that companies must address on process level to operationalise transition to sustainability, the CE and digitalisation effectively

Table 47

Action list for the change dimension processes

Processes		
Activities & key actions	**Challenges**	**Influencing factors**
Supply chain transparency and risk management • Adopt systematic approaches for end-to-end supply chain mapping • Implement systematic supply chain risk assessment to identify potential negative social and environmental impacts • Cooperate directly with actors at all supply chain stages **Procurement and production** • Align supplier selection and evaluation with environmental and social criteria, as well as the potential to narrow, slow and close resource flows • Foster long-term supply chain partnerships and expand regional/European sourcing • Adapt production processes to handle recycled and alternative materials **Waste and emissions reduction** • Implement measuring and reduction programmes for waste and emissions (Scopes 1–3), including greenhouse gases, water, chemicals, etc. **Reverse processes** • Systematically separate and measure waste streams • Establish and implement open and closed loop reverse processes for products and materials • Foster resue and recycling of textile products and materials through active participation in research and development projects	• High bureaucratic burden for sustainability data collection and reporting due to insufficient industry-wide standards • Reduced process efficiency and increased costs related to alternative materials processing • Limited influence over social and environmental risks in the supply chain • Fragmented take-back and recycling systems	• Advanced digitalisation and standardisation → Sector-wide databases for certifications, audits, and supply chain data applied → Industry-wide standardisation for sustainability information and reporting established • Active collaboration aross supply chain → Engagement in projects and initiatives with peers and NGOs to increase sustainability performance in upstream supply chain processes → Research and experimentation on secondary and alternative material processing in procurement and production started → Regional initiatives and cross-sector platforms for the exchange of secondary materials established • Customers and consumers are aware and actively participating in take-back programmes
	Technology deployment	
	• Deploy digital technologies to enhance supply chain transparency → Cloudbased supply chain platforms and blockchain solutions for traceability → Participate in the development of industry standards for data collection and reporting and avoid company-specific solutions • Deploy digital technologies to enhance process automation and efficiency → Replace manual processes for collecting, processing and exchanging data with digital solutions → IoT-based solutions for the systematic collection and analysis of process data for real-time decision making → Automation of processes (e.g., cutting, packaging) to reduce costs and waste → AI-based applications such as image recognition in quality control and waste sorting to reduce waste generation and improve recycling processes → Digital fabrication processes such as digital printing to replace resource-intensive processes (such as dyeing and rotary printing). → Mobile applications and online platforms to build simple and customer-oriented reverse flows	

6.3 Assessment of the Operational Framework

As the outcomes of this research are intended to be applicable in practice, the value and practical relevance of the developed operational framework by industry practitioners is of particular importance – in line with Pettigrew`s (2011) emphasis on linking scholarly rigour with practical relevance. To assess the operational framework, an online questionnaire was conducted. The sustainability experts and managers of the 29 case study companies were invited to participate.

The questionnaire provided a detailed introduction to the operational framework and consisted of eleven statements (Nos. 1 – 11) presented as five-point Likert items ('strongly agree' to 'strongly disagree'), two multiple-choice questions (Nos. 12 – 13), and three open-ended questions (Nos. 14 – 16) (see Appendix D). In cases of disagreement or strong disagreement with a statement, participants were asked to provide a brief explanation.

In total, eight responses were received from experts: four from the textile industry and four from the clothing industry (Tables 48 - 50).

The alignment of corporate sustainability objectives with overarching global goals such as the SDGs and the Paris Climate Agreement (Statement 1) was (strongly) agreed by six respondents. Two participants – one from the textile and one from the clothing industry – remained neutral. This suggests that global frameworks act as contextual factors influencing corporate change processes. The two participants who responded neutrally both referred, in their responses to open questions concerning missing aspects (No.14) and weaknesses of the framework (No.16), to constantly changing, inconsistent, and frequently unclear laws and regulations, as well as to the multitude of sustainability certificates and related requirements. Another respondent from the textile industry, who agreed with Statement 1, also highlighted the need for harmonised regulations and requirements at European level when asked about missing aspects (No.14). As these comments are directly related to the present statement, they are discussed in this context.

These comments can be interpreted as indicating that legal and regulatory requirements represent a central issue companies (must) align with. This aspect is addressed in the operational framework, where it is explicitly stated that legal and regulatory requirements should be incorporated into strategic objectives and decision-making processes (change dimension: Organisation; field of action: Strategy and objectives).

However, such requirements should not constitute the sole point of reference. A purely compliance-based orientation may result in only marginal adjustments designed merely to meet minimum standards. This, however, would contradict the objective of comprehensive changes in line with sustainable development.
To maintain conciseness, detailed explanations that are provided within this thesis were not included in the questionnaire. This may explain why some participants perceived legal and regulatory conditions as insufficiently represented. Figure 44 in Section 6.2.1 illustrated the full range of factors that should guide strategic corporate decision-making, which also includes legal and regulatory requirements.

Regarding Statement 2, that the CE and related practices represent an approach to operationalising sustainability within corporate activities and actions, seven participants expressed agreement, while one remained neutral. Since this person did not provide any comments on the open questions, at least no negative attitude can be assumed here.

Statement 3, which posits that DTs serve as important enablers and facilitators for companies in implementing sustainable and circular practices, received two responses of ‘strongly agree’, five of ‘agree’, and one neutral response. The respondent who selected ‘neutral’ works in the textile industry and provided a comment in response to open question No.15 – *In your view, what are the main strengths of the framework?* – in which he or she referred to the consideration of social aspects. According to this respondent, changes take time, and employees must be engaged and supported to drive change from within the company. This comment may be interpreted as reflecting the view that the human component of the transition to sustainability and circularity is regarded as important as the technological component.
As the statement itself was not disagreed with and the human component was not perceived as missing but rather highlighted as a strength of the framework, the statement can be considered to have been agreed upon overall. This underlines the importance of digitalisation for companies in the transition to sustainability and the CE.
Overall, the operational framework and the action list were assessed by all participants as clear and comprehensible (Statement 4), and the three dimensions – organisation, products, and processes – were agreed upon as an appropriate structure for guiding change (Statement 5).

Statement 6, which posits that organisational change constitutes the central starting point and prerequisite for progress in the product and process dimensions, received three responses of ‘strongly agree’, three of ‘agree’, and one ‘neutral’ response from a participant in the clothing industry. The statement was not rejected, and no relevant free-text comment was provided. Overall, this can therefore be interpreted as agreement with the statement.
Regarding Statement 7, all participants agreed without exception that the fields of activity and actions described in the framework appropriately reflect the approaches required in practice for the transition to sustainability and the CE.

Statement 8, which suggests that the challenges presented in the framework represent the main barriers companies must overcome in the transition, is viewed more critically in the clothing industry than in the textile industry. In total, six participants agreed with the statement, while two – both from the clothing industry – responded neutrally. The statement, however, was not rejected. This indicates that while the challenges presented are considered relevant, additional challenges may also be associated with the transition. One of the participants who responded neutrally was again the individual who referred to complex legal requirements in question No. 14. In relation to Statement 8, this comment can be interpreted as suggesting that unclear or inconsistent requirements create challenges and additional effort for companies. This is understandable and is addressed in the operational framework within the organisational change dimension, which acknowledges that companies operate with limited financial and human resources that are increasingly occupied with bureaucratic demands. However, the challenge of legal and political uncertainty, as mentioned by the respondent, can only be influenced to a limited extent, even with greater financial or personnel resources. The political framework conditions were discussed as influencing factors in Section 5.4.2, as they were repeatedly mentioned in both the interviews and the document analysis. From a corporate perspective, there are only two conceivable ways to influence this factor: through active political engagement – for example, via participation in industry associations, multi-stakeholder initiatives, or direct political advocacy – or by relocating business operations to regions with more favourable political and legal conditions. Active participation and cooperation in associations and initiatives are emphasised as essential in the operational framework and are therefore covered. The relocation of business operations, however, was not identified as a relevant action in either the case study analysis or the

literature review. Considering the historical globalisation trends in the T&C industry (see Section 1.2.2) and global developments concerning climate change, environmental pollution, and social inequality, such an approach cannot be regarded as viable. Nevertheless, the concerns expressed by companies in this regard are understandable and present an interesting avenue for further research into the political and legal shaping of the transition to sustainability and the CE at the interface between business and policy.

Statement 9, which posits that the influencing factors presented in the framework have a positive impact on the transition when present, was supported by seven participants, while one participant from the textile industry responded neutrally. No explanatory comment related to this response could be identified. As the statement was not rejected, it can be assumed that the influencing factors are relevant for a successful transition.

The appropriateness of the digital technology use cases presented in the framework to support circularity and sustainability (Statement 10) was supported by five participants. Again, three participants – all from the clothing industry – responded neutrally. These findings may be interpreted as indicating that the overall level of digitalisation among the case study companies remains relatively low. Although numerous use cases were identified, many are still in the development or testing phase. Consequently, it is possible that company representatives were unable to fully assess the use cases presented in the framework, as they have thus far gained only limited experience with them in their own organisations. Moreover, the value-creation processes of clothing manufacturers tend to focus on design and administrative activities, while production is frequently outsourced. As a result, companies in this sector may inherently have a narrower field of application for various technologies than those in the textile sector. Since the statements were not rejected, it can be assumed that the use cases presented in the framework are generally relevant. However, there remains an urgent need for further research in the T&C industry to investigate and establish best practices and standards for digital technology deployment in this field.

Overall, the framework is perceived as useful for companies in their transition to sustainability and the CE. Seven of eight respondents agreed with Statement 11, while one participant from a clothing company responded neutrally. No explanatory comment related to this response was provided, nor were any additional free-text comments identified that could be associated with this assessment. As the statement was not rejected

and a total of 88% of respondents expressed agreement, it may be inferred that the framework provides value for companies in the T&C industry and is perceived as potentially supporting them in their transition to sustainability, circularity, and digitalisation.

Regarding the multiple-choice questions (No. 12 - 13; see Table 49), further insights emerged concerning perceived gaps and progress across the three change dimensions. Regarding the greatest gaps and challenges (Question 12), a contrasting pattern emerges between the two subsectors. 3 of 4 respondents from textile companies primarily identified the organisational dimension as the one perceived as most challenging, while only one respondent perceived processes as the main challenge. Whereas 3 of 4 respondents from clothing companies perceived processes as the most critical challenge and only one perceived the organisational dimension as the most challenging. This difference may be explained by structural characteristics: textile firms often operate their own production facilities in Germany and thus retain stronger process control, while clothing companies frequently outsource production to global suppliers, making process-related transformation more complex and less directly controllable.

Concerning Question 13, all respondents from textile companies reported that the greatest progress was made within the product dimension, whereas only two respondents from clothing companies indicated the same. The remaining two respondents from the clothing industry considered the greatest progress in their companies to have been made in the areas of organisation and processes. This finding is consistent with the findings of the case study, which revealed that most companies are engaged in measures relating to material selection (e.g., the use of natural or sustainable alternatives and recycled materials) as well as product-related sustainability certifications. However, these activities largely take place within existing linear business models and should therefore be interpreted more as marketing arguments directed at customers and consumers than as components of a comprehensive sustainability strategy. As a result, the impact of such measures is limited and the transition to a sustainable and circular T&C industry is hindered. This underlines once again both the urgency and the practical relevance of the operational framework in supporting companies during the transition and enhancing their sustainable and digital maturity.

Finally, questions No.14 - 16 invited participants to provide open-ended responses, which are discussed below (Table 50). Question No.14 asked respondents to identify any aspects, practices, challenges, or influencing factors that they considered missing from the framework. A total of four comments were provided, two of which simply indicated that no aspects were missing. The other two comments have already been discussed in relation to Statement 1; both refer to the political and legal framework conditions and the associated uncertainty and administrative burden for companies in the sector. As previously outlined, this is an area in which companies can exert only limited direct influence. Given the high relevance of this topic in the overall context of the transition to a sustainable and circular T&C industry, it will be revisited and discussed in detail in Chapter Seven, supported by a discussion in the light of the extant literature.

For question No.15, which asked about the strengths of the framework, four open-ended responses were provided. One response highlighted the clear and comprehensible structure of the framework, while the remaining three referred to the organisational change dimension. One respondent noted that considering the business model constitutes a strength, as many companies would not typically consider this aspect. This observation aligns with the findings of the case study analysis and underscores the relevance of the detailed business model concepts and examples developed in connection with the operational framework. Another comment referred to the consideration of a gradual, iterative approach and emphasised the importance of corporate culture and employee mindset in driving innovation from within the organisation. This aligns with framework's intended logic: to define a starting point – the organisational level – where the prerequisites and control for change are established, and to ensure that it subsequently diffuses throughout the company through iterative processes, pilot projects, and rapid learning cycles. Internal and external stakeholders are to be involved throughout to foster acceptance and engagement. The final comment on this question essentially relates to the same aspect. It stresses the importance of active involvement and accountability of top management in driving change, as well as the need for transparent communication and decision-making. This, like the previous comment, indicates that socio-economic aspects should receive greater attention in the transition.

Regarding the final question (No. 16), which asked about the weaknesses of the framework, only one comment was received. Similar to the responses to question No.14, it

referred to the political and legal framework conditions. This aspect has already been discussed in detail above.

In summary, the practitioners broadly supported two key aspects. Firstly, the operational framework was perceived as comprehensive in addressing the changes required for the planned transition of the German T&C industry towards sustainability, the CE and digitalisation, including the associated challenges, influencing factors, and supporting technologies. Second, the practical relevance of the action lists was emphasised, as they can support and guide companies in their transition by helping them to identify existing gaps or areas for further progress and to develop specific solutions.

The next chapter critically discusses the framework in light of the broader academic literature and compares it with other relevant frameworks. It also addresses two aspects that emerged from the practitioner's feedback.

Table 48
Practitioner responses – Likert-scale statements

No	Statement	Textile					Clothing				
		SA	A	N	D	SD	SA	A	N	D	SD
1	Global sustainability goals such as the Sustainable Development Goals (SDGs) and the Paris Climate Agreement provide guidance for corporate initiatives, and for aligning corporate sustainability goals.	1	2	1			1	2	1		
2	The circular economy is regarded as an approach to operationalise sustainability within corporate activities and actions.		4					3	1		
3	Digital technologies serve as enablers and supporters for companies in the implementation of sustainable and circular economy practices.		3	1			2	2			
4	Overall, the operational framework and action lists are clear and comprehensible	1	3				1	3			
5	The three dimensions – organisation, products, and processes – provide a clear and suitable structure for the transition to sustainability and the circular economy in textile and clothing companies	3	1				2	2			
6	The framework assumes that organisational change is the central starting point and prerequisite for progress in the product and process dimensions. To what extent do you agree with this assumption?	2	2				1	2	1		
7	The activities and key actions outlined in the framework appropriately represent the approaches necessary for companies' transition in practice		4					4			
8	The challenges outlined in the framework correspond to the main barriers companies face in the transition to sustainability and the circular economy.		4					2	2		
9	The influencing factors outlined in the framework have a positive effect on the transition when present.		3	1				4			
10	The framework contains appropriate use cases for digital technologies to support the circular economy and sustainability.		4					1	3		
11	Overall, the framework would be valuable for guiding our company in its transition to sustainability and circularity		4					3	1		

SA - Strongly agree; A - Agree;
N - Neutral ; D – Disagree;
SD - Strongly disagree

Table 49
Practitioner responses – multiple choice questions

No	Question	Textile				Clothing			
		Organisation	Products	Processes	Others	Organisation	Products	Processes	Others
12	In which of the three change dimensions do you see the *biggest gaps or challenges* in your company's current transition towards sustainability and the CE?	3		1		1		3	
13	In which of the change dimensions (organisation, product, processes) has your company made the *most progress* so far?		4			1	2	1	

Table 50
Practitioner responses – open ended questions

No	Question	Textile	Clothing
14	In your opinion, are there any important aspects of the transition to sustainability, circular economy and digitalisation that are missing from the framework? (e.g. actions, challenges, influencing factors or technologies)	• Can't think of anything • No	• Is not directly related to the framework, but it is massively disturbing that politicians are constantly issuing new directives and laws, both nationally and throughout the EU, which are changed again based on factors. This becomes unbelievable at some point. In addition, there are various certificates that are implemented more or less successfully. A comprehensive overview is almost no longer possible. Some requirements are also unrealistic to implement • Reliable and standardised regulations and requirements throughout Europe. Without these, a company that prioritises sustainability is not competitive
15	In your view, what are the main strengths of the framework?	• Comprehensible, business models taken into account - most companies do not think about this • A step-by-step approach and communication are so important, you can't tackle a transformation like this with a crowbar, we have to take our employees with us and develop the necessary mindset so that innovation and change come from within the company, that takes time, you overwhelm people with too many changes at the same time • Top-management support and responsibility and transparent communication and decisions!!!	• Clear and comprehensible structure
16	In your view, what are the main weaknesses of the framework?	• None from a business perspective, but the legal framework must be standardised for all market participants. Those who are not sustainable should have disadvantages on the market, not vice versa	

6.4 Summary

This chapter addressed RO3 – to develop an operational framework for the transition to sustainability and the CE, leveraging the potential of digital technologies for the German T&C industry. Two guiding questions were derived from this objective, which are summarised below together with the main findings:

Question 1: Based on the PCF and the case study findings can an operational framework and an associated action list be developed to support and advance the transition to sustainability and the CE in the German T&C industry?

Question 2: What digital technologies can most effectively support these actions?

The case study analysis revealed that the transition to sustainability, circularity, and digitalisation in the German T&C industry has largely begun but remains fragmented, inconsistent, and shaped by multiple challenges and influencing factors. Based on these findings, this chapter developed an operational framework that illustrates how companies can systematically manage this transition and use DTs to support it. The framework, derived from the PCF, comprises three change dimensions – organisation, products,

and processes. For each dimension, relevant fields of activity, key actions, challenges and influencing factors, and technology use cases were presented.

The organisation forms the starting point and anchor of change. At this level, companies define long-term strategies, structures, and values relating to sustainability, circularity and digitalisation, as well as the necessary resources and measures for implementation. A key element is the evaluation and (re-)design of the business model. Organisational changes require a clear strategic orientation that goes beyond regulatory compliance and integrates global goals and stakeholder interests into corporate strategy and objectives. Business model innovation should shift from incremental adjustments to holistic, sustainable approaches that integrate value creation, delivery, and capture. Collaboration across the ecosystem is essential, as sustainable and circular practices cannot be achieved in isolation. Pilot projects serve as catalysts for gradual yet scalable change. Organisational structures and cultures must also be adapted so that responsibility for sustainability is shared across all units. DTs – such as ERP, PDM/PLM, and cloud systems – form the backbone for collecting, analysing, and reporting environmental and social data, ensuring interoperability and secure data exchange. Social media and mobile applications should not only serve marketing purposes but also enable stakeholder engagement, consumer education, and flexible working. To realise these potentials, companies must invest in digital infrastructure, skills development, communication, and coordination mechanisms.

The product dimension highlights the importance of product design and the competencies of designers and product developers. Products developed with the appropriate knowledge base and mindset are assumed to be better positioned to meet sustainability and circularity requirements. However, companies often face trade-offs between durability, functionality, recyclability, cost, and market acceptance. Addressing these challenges requires not only awareness and expertise but also innovation and cross-value-chain collaboration. DTs play a central role in this process, enabling the dematerialisation of design through 3D and virtual development tools. Combined with cloud, IoT, and blockchain applications, designers and developers gain access to comprehensive data on resource use and environmental impacts, facilitating transparent information exchange with stakeholders such as customers and regulators. This supports compliance with emerging legal requirements, while improving transparency, traceability, and acceptance.

The process dimension covers operational activities related to production and logistics, including the management of material and resource flows across companies' supply chains. Four key fields of activity are central: supply chain transparency and risk management; sustainable sourcing and production; waste and emissions reduction; and reverse logistics. Companies should establish transparent supply chains beyond Tier 1, integrate environmental and social criteria into procurement, and optimise production processes for energy and resource efficiency, including the use of recycled materials. Furthermore, collaboration with logistics and recycling partners is essential to establish efficient reverse flows. DTs such as cloud computing, IoT, AI, and blockchain enhance transparency and efficiency and should be systematically integrated to deliver both environmental and economic benefits. Data standardisation and cross-industry collaboration platforms will be crucial to overcoming existing challenges in this dimension.

The practical relevance of the framework was assessed through an online questionnaire with sustainability managers and experts from the case study companies. Respondents largely expressed agreement regarding the framework's clarity, completeness, and applicability, as well as the suitability of the change dimensions, fields of action, and technological measures. Although regulatory and political complexity were highlighted as ongoing challenges, the findings overall suggest that the framework is perceived as comprehensive, useful, and practically relevant. The responses further indicated that companies have made the greatest progress in the product dimension, while substantial gaps remain at the organisational and process levels - highlighting the framework's potential as a practical tool to guide companies in their transition.

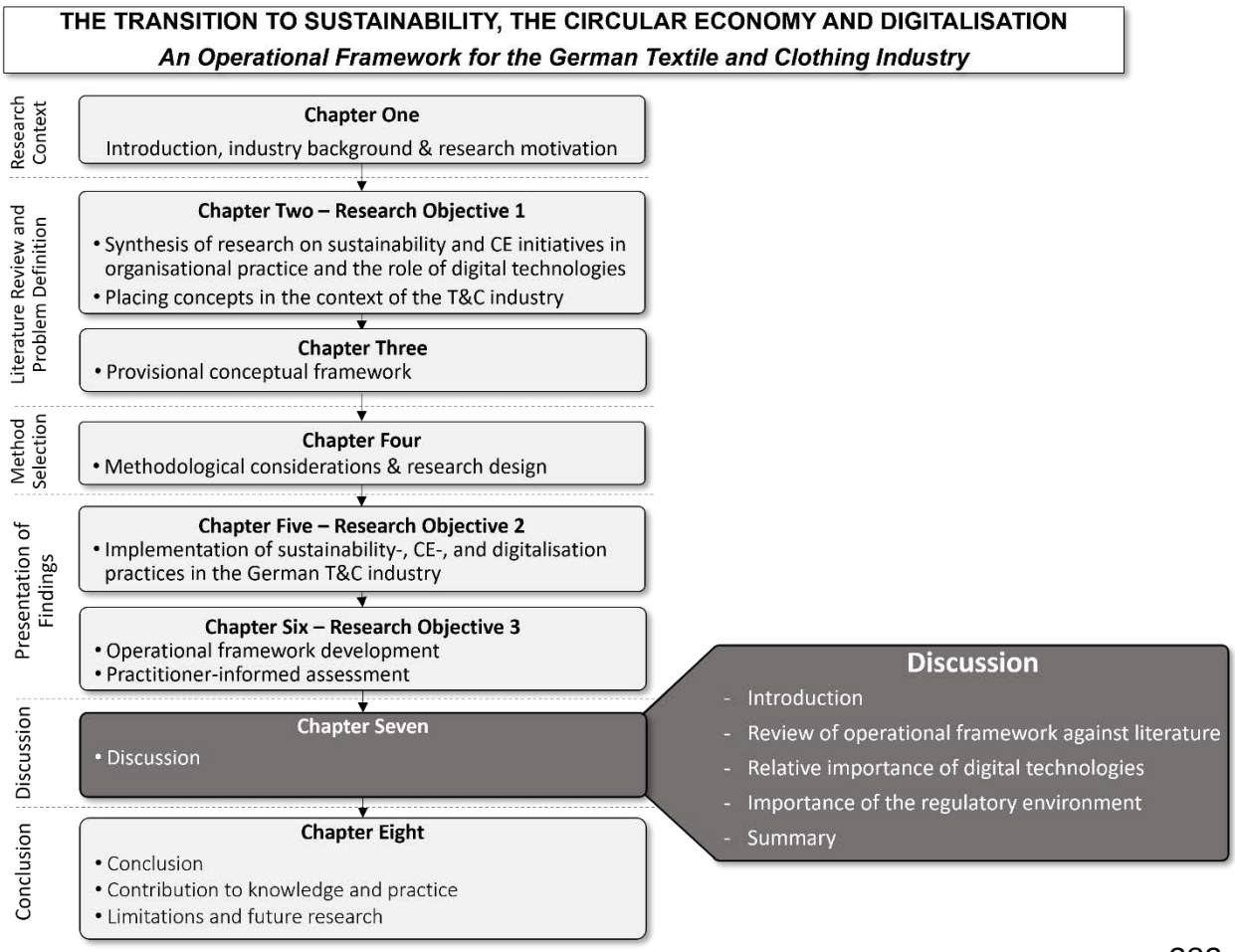
In conclusion, this chapter addressed RO3 by developing and presenting an operational framework and associated action list. Together, these provide a structured, empirically grounded, and practice-oriented instrument to assist companies in the German T&C industry in their transition to sustainability, the CE and digitalisation. The next chapter builds on these findings, situates the framework within the broader literature, and discusses key developments and challenges identified through the case study analysis and assessment.

7 DISCUSSION

7.1 Introduction

In the preceding chapter, RO3 was addressed. An operational framework and associated action lists for the transition to sustainability, the CE and digitalisation were developed and validated. This chapter discusses the operational framework in light of the existing literature and, in particular, in comparison with other models and frameworks. It further addresses issues arising from the analysis in Chapter 5 and from the practitioner feedback, specifically concerning the relative importance of DTs as well as relevant legislation, policy, and the role of customers and consumers. Following this introduction, the remainder of the chapter is structured as follows: Section 7.2 discusses the operational framework in relation to existing literature. Section 7.3 examines individual DTs and their relative importance in the context of sustainability and circularity, while Section 7.4 broadens the perspective by discussing the role of regulatory aspects and of customers and consumers, against the backdrop of current developments. Finally, Section 7.5 provides a summary for the chapter (Figure 51).

Figure 51
Structure of Chapter Seven in context of the thesis



7.2 Review of Operational Framework Against Other Models and Frameworks

Driven by a range of trends and dynamics – particularly those relating to sustainability, circularity, and digitalisation – the German T&C industry is undergoing significant changes. The initial assumption of this study was therefore that companies are actively adapting to these developments to maintain their competitiveness. Accordingly, this study aimed to examine, from a corporate perspective, how the transition to sustainability and circularity can be effectively organised and operationalised, and how DTs can support this process.

The theoretical foundation of this study lies in the concept of organisational change and follows the analytical framework proposed by Pettigrew (1987) which conceptualises organisational change as comprising three interrelated dimensions: context, content, and process. These dimensions must be viewed holistically. Against this theoretical background, only a limited number of studies have so far examined the transition to sustainability and circularity from an organisational change perspective – a gap also recently found by Graessler et al.(2024). Based on this overarching model and the findings of the literature review, a provisional conceptual framework was developed to guide empirical investigation. This framework aimed to provide insights into the state of the transition to sustainability, circularity, and digitalisation in the German T&C industry.

The broad theoretical foundation adopted in this study enabled a holistic examination of change from the perspective of individual organisations and facilitated the development of a comprehensive, sector-specific operational framework for the German T&C industry. To the author's knowledge, existing studies have not yet provided a similarly integrated framework at the company level that combines the dimensions of organisation, products, and processes in the context of sustainability, the CE and digitalisation. The framework and its constituent elements are discussed below in relation to existing literature and, in particular, in comparison with related frameworks addressing the transition to sustainability, the CE and digitalisation.

External context factors for organisational change

The concepts of sustainability and the CE represent important external contextual factors and drivers for organisational change that guide companies in aligning their strategic objectives to maintain competitiveness. The findings, however, indicate that these factors should not be pursued separately but rather viewed in an integrated manner.

The concept of sustainability is broad and often abstract, providing overarching direction for corporate activities through global political goals such as the SDGs and the Paris Climate Agreement. It therefore constitutes the desired outcome of organisational change. Santa-Maria et al. (2022) refer to this as a “north star” (p. 1317), describing it as a guiding vision that steers a company’s long-term orientation.
In contrast, the CE offers specific strategies for reducing resource use and waste generation, which can be directly embedded into business operations to promote sustainable development. Furthermore, specific legislative requirements and guidelines for protecting stakeholder interests - such as Human Rights and Environmental Due Diligence (HREDD) - serve as additional external contextual factors. Notably, the need to integrate both CE-related and social factors - particularly with regard to supply chain risks - into strategic development is highlighted almost exclusively in frameworks with a T&C focus (Abdelmeguid et al., 2024b; Franco, 2017). More general frameworks without a sectoral focus, such as those from Chen et al. (2020), Graessler et al. (2024) or Lopes de Sousa Jabbour et al. (2018) tend not to address these aspects explicitly. This reflects a sector-specific characteristic of T&C companies, whose complex global supply chains entail particular risks. It also confirms the value of sector-specific studies and the derivation of corresponding best practices over the use of universal frameworks (Santa-Maria et al., 2021).

Digital technologies, in turn, act as enabling factors for the successful implementation of these strategies. Their effective use depends on, and should be derived from, a company’s specific strategy, which aligns with the model by Lopes de Sousa Jabbour et al. (2018, 2022). The findings suggest that DTs are primarily deployed to enhance efficiency and reduce costs, whereas their integration into sustainability and CE strategies remains limited. This indicates that digitalisation and sustainability are still frequently treated as separate transformation processes rather than as closely interrelated developments. Similar patterns have been observed in previous research. For instance, a global CEO survey by Software AG (2023), reported that “84% of companies see digital and sustainability transformation as separate initiatives” (p.4). Arnold et al. (2023), showed that, although digitalisation opportunities are recognised within the German textile industry, structured approaches to their implementation are still lacking. In addition, recent survey evidence indicates that T&C SMEs lag behind other European industries in terms of digitalisation (Izsak & Moreno, 2024). These findings underline the value of

the framework presented in this study, which provides concrete guidance for the targeted use and combination of DTs to effectively support sustainability- and CE-related initiatives.

Structure and culture as organisational preconditions for change

Arnold et al. (2023) argue that “circularity does not have a starting point as there are ongoing changes in circularity – either stepwise or volatile – in all areas, technological, social, and organisational” (p. 14). If this statement were taken literally, there would be no reason for companies to engage actively with the transition to sustainability and circularity. The findings of this study, however, indicate that external contextual factors provide the initial impetus for such a transition by offering overarching sustainability goals, strategic and practical approaches, and potential technologies that companies need to make sense of and strategically integrate in order to remain competitive. Nevertheless, the distinctive feature of this transition – and in this respect Arnold et al. aptly observe – is that it is not finite but iterative in nature, requiring companies to evolve continuously through pilot projects and rapid learning processes, which is in line with the iterative model presented by Graessler et al. (2024). At the outset, the focus of change does not lie on individual products or processes; rather, change begins at the organisational level and subsequently extended across all business areas (Chen et al., 2020). Organisational change thus entails decisions not only regarding corporate strategy and business model design but also the active development of structural and cultural conditions, including a clear allocation of responsibilities (Seles et al., 2022; Werning & Spinler, 2020) and an iterative approach that fosters continuous learning and improvement, which integrates elements form former findings by Graessler et al. (2024), Santa-Maria et al. (2022), and Sarja et al. (2021).

Werning and Spinler (2020), for instance, identified correlations between organisational units and CE-related challenges and derived task packages, priorities, and responsibilities designed to ensure a smooth and effective transition. Although such assignments cannot be universally generalised, their findings suggest that change efforts linked to the CE should be accompanied by clearly defined actions and responsibilities. Seles et al. (2022) further emphasise that the allocation of responsibilities should not be confined to the managerial level but must also extend to employees, who “need to understand and commit to the transition towards the circular economy” (p. 1827). Accordingly, coordinated action and transparent communication – involving both internal stakeholders

(employees, management) and external stakeholders (customers, suppliers, and ecosystem partners) – are essential to ensure an efficient and effective transition process and are therefore critical to the success of CE implementation efforts.

The operational framework presented in this study reflects these findings by proposing to establish a sustainability management unit and decentralised ambassadors to foster knowledge building, awareness, and skills development, as well as stakeholder communication and engagement within change initiatives. The significance of these internal factors as a distinct dimension of change has received limited attention in existing frameworks. Graessler et al. (2024) emphasise the importance of integratively addressing multidimensional changes across technological, organisational, and human levels. However, their recent and comprehensive literature review on organisational change for the CE found no study that treats all these dimensions in a holistic manner. The framework presented in this study provides such a multidimensional approach by integrating changes at the organisational, product, and process levels, and by offering fields of activity, key actions, and potential use cases for DTS.

Business model innovation

Business models represent a central lever for driving change towards sustainability and circularity (Chen et al., 2020; Sarja et al., 2021; Seles et al., 2022; Werning & Spinler, 2020). However, they also constitute one of the greatest challenges: the transition to the CE is often associated with significant uncertainty and contextual complexity. The absence of standards, guidelines, and best-practice examples makes it difficult for companies in the T&C industry to assess the opportunities and potential success of new or alternative business models. The case study companies revealed that existing business models remain largely linear and dependent on the sale of physical products. Business model innovation is primarily driven by efficiency improvements. Notably, business model elements that enable the slowing and closing of resource flows have so far been implemented only to a very limited extent, and where attempts have been made, companies have faced considerable market-related challenges. Consequently, business model transformation is understood to require a high degree of innovation, experimentation (Kirchherr et al., 2018; Werning & Spinler, 2020) and rapid learning (Santa-Maria et al., 2021).

These aspects are reflected in the operational framework presented in this study. Furthermore, the reluctance of the case study companies highlights the need for practical, workable solutions and functioning examples. The operational framework presented here therefore provides an overview of sustainable and circular business model archetypes, accompanied by real-world examples from the T&C industry. To the author's knowledge, existing studies have not yet provided a comparable overview of sustainable and circular business model archetypes tailored specifically to companies in the T&C sector. In this respect, the framework offers a structured contribution to industry practice.

Cooperation und collaboration

The case study findings highlighted the critical importance of intensive cooperation and collaboration as a key factor for the transition to sustainability, circularity and digitalisation. Recent literature refers to this growing interconnectedness as 'hyperconnectivity' (Wu et al., 2025). The case study companies demonstrated a wide range of approaches in this regard, encompassing both internal collaboration across departments and divisions – for example, in pilot projects, sustainable and circular product development, or in adapting procurement and production processes – as well as external collaboration with ecosystem partners, particularly in innovation hubs or to close material loops.
These insights align with the findings of earlier studies. Dziubaniuk et al. (2024), for instance, emphasise that interactions – both interpersonal and interorganisational – play a crucial role in shaping corporate CE transition strategies. The insights and experiences gained through collaborative projects enable companies to build and share knowledge rapidly, reduce risks, and minimise investment burdens. Partnerships and cooperation can also contribute to the development of new business models and foster competitive advantages for all actors involved. In this context, Fischer and Pascucci (2017) present several examples from Dutch fashion brands that have developed and implemented circular business models through partnerships. They observe that "fashion companies are willing to cooperate in order to improve material production processes" as long as their specific designs and know-how are protected (p.23). Their findings further show that typical challenges in collaborative initiatives – such as a lack of trust – can be successfully addressed through well-designed agreements and contractual frameworks. At the same time, cross-border value chain configurations may complicate progress. Evidence from Italy, for example, highlights the importance of locally embedded ecosystems for fostering circular and innovative products and business models (Abbate et al.,

2023)Such regional ecosystems were not identified in this case study, indicating the need for further research to determine whether comparable ecosystems exist in Germany or could be successfully established.

The case studies by Abbate et al. (2023), Hartley et al. (2022) and Saccani et al. (2023) likewise underline the importance of collaboration with educational and research institutions, industry associations, NGOs, and policymakers. Such partnerships not only drive innovation but also contribute to shaping regulatory and market conditions, which have proven challenging for companies in this study. Graessler et al. (2024) further note that the necessity of external collaboration distinguishes CE-related initiatives from other sustainability-oriented changes, which have traditionally focused more on internal structures and processes.

The operational framework presented in this study reflects this finding by emphasising active collaboration with partners across all dimensions of change as a key influencing factor. It also provides specific guidance and examples that companies can use to develop networks and partnerships. In this context, firms are encouraged to engage with diverse network and ecosystem initiatives that address different aspects of the CE, facilitating resource pooling and coordinated efforts towards systemic change in the German T&C industry.

7.3 Relative Importance of Digital Technologies

This study is among the first to focus specifically on German T&C companies and their use of DTs in the context of the transition to sustainability and the CE. The literature review identified a set of nine technologies that potentially play a pivotal role in this transition. The case study findings indicated that all SMAC and BRAID technologies are potentially relevant for advancing sustainability and circularity in the German T&C industry and further highlighted the role of management and information systems, as well as digital platforms. However, in the practitioner assessment, the statement '*the framework contains appropriate use cases for digital technologies to support the circular economy and sustainability*', was rated neutrally by 50% of the respondents, from the clothing sector. These findings raise several points warranting further discussion.

Information systems as the backbone of digitalisation

Firstly, management systems and platforms such as ERP, PDM, SCM, and other information systems were identified as core technologies relevant to sustainability- and CE-related initiatives in the case study companies. This is notable, as such systems are seldomly discussed in the extant literature on sustainability and the CE. These systems primarily enable and support transparency and the integration of product, business, and supply chain data within companies, aiming to enhance time and cost efficiency (Al-Mashari et al., 2003; Tony Liu & William Xu, 2001). Their relevance thus extends beyond their inherent functionalities and is rooted in their role as a central infrastructural element that enables the interconnection of different technologies, organisational units, and other stakeholders. From a socio-technical systems perspective, these information systems constitute a central coordination layer in which technological components, organisational structures, and decision- and communication processes can be linked and aligned.

However, research on digitalisation and sustainability or CE tends to focus on the application of specific technologies and their potential to enable or support sustainable and circular practices but rarely addresses how these technologies should be integrated into existing information systems. ERP systems, for example, can serve as platforms through which data from multiple sources – such as IoT sensors, production, or supply chain processes – are collected, automatically processed, and made available for sustainability assessment and decision-making (De Soete, 2016; Ferrari et al., 2021). Information systems therefore play a central role for the implementation and integration of DTs in companies, as the successful implementation of new technologies strongly depends on the readiness of existing systems. When ERP, PDM, and other systems are not open, compatible, and secure, they can hinder – or at least limit – the effective deployment of new technologies (Tabim et al., 2024; Yurtay, 2025).

This highlights the need for a clear strategy and well-defined objectives when using DTs to support sustainability and CE practices. Such a strategy needs to take into account the existing information system infrastructure and, where necessary, expand it to provide the required functionalities, reporting capabilities, and connectivity for integrating DTs (Wynn, 2022; Yurtay, 2025). The current focus of the case study companies on the development of fundamental information systems appears to underline this need. As

long as these systems do not provide the necessary functionalities, interfaces, and – crucially - security standards (Tabim et al., 2024) to enable seamless data flows and real-time information exchange, more advanced analytics and reporting functions aimed at supporting sustainability, the CE, and compliance processes are unlikely to be fully realised (Dumitru et al., 2023; Kristoffersen et al., 2020).

The operational framework presented in this study explicitly recognises this dependency by positioning the alignment between IT strategy and corporate strategy as a prerequisite for organisational change and by emphasising the importance of information systems as the core of the organisation's digital infrastructure. Moreover, corporate information systems themselves are subject to continuous evolution. Mannan et al. (2025) examined the integration of AI applications into ERP systems and predict that ERP will increasingly evolve into a strategic platform for sustainable business management. According to Mannan et al. (2025), AI-enabled modules, for instance, could allow for the automated calculation, continuous monitoring, and predictive management of emissions (Scope 1–3). In addition, material flow analysis and product life cycle optimisation could enhance the implementation of CE principles by integrating recycling, reuse, and take-back processes more efficiently. In the field of reporting, AI could facilitate automated ESG data collection and validation, substantially reducing manual effort.

Ultimately, the effective utilisation of these emerging features depends on the integration and interconnection with other technologies, as well as with relevant stakeholders and decision-makers, since even the most advanced systems rely on appropriate and reliable data collection, processing, and management, as well as on the competent translation of the presented information into decision-making.

Emerging and future digital technologies

Secondly, while DTs are playing an increasingly important role in the German T&C industry, the sector still lags significantly behind other industries in terms of digitalisation (Arnold et al., 2023; Schöggl et al., 2023). This raises the question of how technologies may evolve in the medium term – especially those that may become key to the industry's competitive position. The findings of this study show that social media, cloud computing, mobile applications, and IoT technologies are currently the most widely adopted in the industry, although their potential remains far from fully realised. Wynn (2025) expects little in the way of novel applications from these technologies, arguing that they no longer

represent emerging innovations but are now firmly established across business and society. By contrast, greater potential is further anticipated from AI, robotics, analytics, and blockchain applications, as well as from emerging technologies such as the metaverse, quantum computing, and nanotechnologies.

In this context, it appears increasingly important to combine DTs in meaningful ways to address specific use cases - both to achieve economic benefits and to reduce resource consumption and waste generation, thereby advancing sustainable development, as proposed under the international paradigm of “new quality productivity” (Yue et al., 2024, p. 3). Through the objectives of the European Green Deal and the EU Circular Economy Action Plan (European Commission, 2020a), transparency is emerging as a key requirement for businesses. The EU strategy foresees, among other measures, the introduction of a DPP to be implemented across all goods traded within the EU. The DPP serves as a central instrument for promoting transparency, traceability, and circularity. Its primary aim for textiles is to provide comprehensive product-related data - covering material composition, production processes, environmental impacts, and end-of-life options - to enable more sustainable production and consumption decisions along the entire value chain (Legardeur et al., 2024). The DPP relies on several DTs, including unique product identifiers (e.g., QR codes, RFID), cloud infrastructures, and blockchain and IoT systems, to ensure secure, interoperable, and real-time data exchange (Carvalho et al., 2025; Langley et al., 2023). Additionally, AI applications can help verify and enhance data quality within DPP systems, reducing inconsistencies and improving reliability (Cruz et al., 2025). Although DPPs were not explicitly discussed by the case study companies, traceability and transparency were identified as key areas of activity. These are, however, currently characterised by low levels of digitalisation, high manual effort, and limited standardisation and cooperation across the value chain. Legardeur et al. (2024) identify several challenges likely to arise from the mandatory implementation of the DPP for T&C companies, including the need for harmonised data standards across all participating firms, associated implementation costs, and ensuring data access control and privacy. The introduction of the DPP could therefore entail significant effort and cost for companies that fail to align their processes, IT systems, and data infrastructures early and consistently. Consequently, these developments point towards a growing relevance of DTs in this context - particularly blockchain, cloud, and IoT solutions for standardised and secure data collection and exchange - within the industry.

Moreover, the concept of the metaverse has recently attracted increasing attention in both research and practice. It represents an immersive and interactive space that merges physical and virtual worlds, enabling users to create and interact with digital objects and environments through avatars (Di Paolo et al., 2025; Luong et al., 2024; Piñeiro-Chousa et al., 2025). In the T&C sector, the metaverse could offer potential in areas such as digital fashion, virtual showrooms, avatar-based customer interactions, and virtual product development (Textilwirtschaft, 2023a, 2023b). The industrial metaverse, in turn, refers to the application of immersive environments in manufacturing contexts - such as digital production or smart factories - aimed at enhancing efficiency and sustainability through virtual twins, simulations, and real-time data (Leutheuser et al., 2025; Ren et al., 2024). The Boston Consulting Group (BCG, 2025) describes the potential of the industry metaverse as follows:

"*By embracing this paradigm, factories of the future will no longer be constrained by physical prototyping or incremental improvements. Instead, they will be 'born in simulation' - designed, tested, and optimised in virtual environments before operating in reality*" *(p. 3).*

While the metaverse primarily focuses on consumer interaction through virtual goods and business models, the industrial metaverse targets industrial value creation and process optimisation. Both developments are likely to become highly relevant for the German T&C industry in the medium term. In this context, 3D-design applications emerge as highly relevant technologies, capable of accelerating product design processes, reducing material waste, and fostering closer integration between design, production, and consumption - such as through consumer participation in design processes within metaverse environments (Liang et al., 2025; Zang et al., 2025).

Key technologies for the industrial metaverse include AI and digital twins for generating and simulating digital objects, inspection, and defect detection; blockchain for ensuring ownership and sustainability credentials; and 3D-design software and digital twins for optimising product development and manufacturing processes (BCG, 2025; Leutheuser et al., 2025; Nisa et al., 2025; Ren et al., 2024). For companies that have lagged behind in digitalisation, these developments underscore the necessity of adaptation - aligning systems and strategies with emerging technologies such as the metaverse while maintaining openness and flexibility to capture competitive advantages without losing sight of sustainability objectives.

The 'dark side' of digital technologies

Thirdly, it seems necessary to address a strand of research that has recently gained increasing attention. While DTs are widely recognised as key enablers for the transition to sustainability and the CE, recent studies have also begun to highlight their 'dark side'. Alongside benefits such as efficiency gains, transparency, resource savings, and waste reduction, unintended and undesirable consequences may also arise, creating new environmental, social, and ethical challenges (Bohnsack et al., 2022; Chung et al., 2025; Dieste et al., 2024).

For instance, digital technology deployment can lead to higher energy consumption, dependence on large technology providers and platforms, and consequently increased costs and skill requirements - particularly challenging for SMEs (Alves et al., 2022; Chung et al., 2025). Glogar et al. (2025) and Hassan et al. (2024) emphasise the substantial investment costs associated with software systems for digital product development, intelligent manufacturing systems, and AI-based applications - barriers that can impede rapid adoption, especially among SMEs, and create competitive disadvantages. Dieste et al. (2024) further note that while Industry 4.0 technologies may help to save resources, they can also increase energy use and electronic waste, and through automation and data-driven control, contribute to stress, surveillance, and social inequality. Consequently, these authors advocate for a transition towards "Industry 5.0" (p. 926), centred on human-centricity, resilience, and sustainability. Conversely, Neri et al. (2023, 2024) demonstrate that DTs can also have positive effects on human factors, for instance by improving working conditions and supporting collaboration. Accordingly, organisations need to assume responsibility for the ethical and sustainable management of DTs, ensuring that their deployment is guided by principles of transparency, trust, data protection, and competence development (Dieste et al., 2024; Wynn & Jones, 2023). In the context of the T&C industry, Luoma et al. (2023) identify specific tensions related to the use of blockchain technologies, which "can trace life cycles but consume energy" (p.1406); while transparency in life cycle data can strengthen corporate sustainability narratives and consumer trust, it may simultaneously undermine competitive advantage. Vieira & Jones (2025) likewise highlight that data centres required to operate online platforms and retail systems generate high energy demand and dependence, thereby contributing to global warming.

Overall, these findings suggest that digitalisation can only make a meaningful contribution to sustainability and circularity if it is designed and governed consciously, ethically, and with careful consideration of resource efficiency. From a socio-technical systems perspective, DTs cannot be understood as standalone tools; rather, their sustainability effects emerge from the interplay between technological infrastructures, organisational structures, governance mechanisms, and the active involvement of internal and external stakeholders. The operational framework developed in this study addresses this interdependence to some extent by recommending, firstly, a close structural and strategic alignment between sustainability management and IT management and, secondly, by explicitly emphasising the need to build digital literacy and skills among employees as an integral part of organisational change. Nevertheless, this highlights the need for further research to ensure that the increasing use of digital technologies DTs in the transition towards sustainability and the CE does not merely result in a displacement of sustainability challenges from one sector (e.g., T&C) to another (e.g., the electronics industry). In particular, questions concerning the environmental impacts of hardware production, the high energy consumption of data centres, the generation of electronic waste, as well as the social and ethical implications of digitalisation, should be critically examined and weighed against their positive effects in order to identify and promote the most sustainable solutions. Such research is essential to ensure that digitalisation contributes holistically to the objectives of sustainability rather than shifting ecological and social burdens along global value chains.

7.4 Importance of the Regulatory Environment

In the assessment of the operational framework by practitioners, three open-text comments were provided, each referring to the political and regulatory conditions under which the corporate transition to sustainability and the CE takes place and which affect companies in the German T&C industry. The practitioners highlighted to changing and increasingly complex national and EU regulations and certification systems related to sustainability and circularity, which, in their view, create uncertainty and unfair competitive conditions and hinder effective implementation. Similar challenges were also identified in the case study analysis, but were only partially integrated into the operational framework, as changes to political and regulatory frameworks were assumed to be influenced to a very limited extent at the company level and affect all firms in Germany to

a similar degree. This study explicitly focuses on the micro level – that is, individual companies – while acknowledging that the transition towards a CE also involves regional (meso) and global (macro) actors (see Section 2.3.2). Nevertheless, the comments from industry representatives provide an important basis for discussing the significance of political and regulatory developments that drive the transition towards sustainability and circularity in the German T&C industry. The proliferation of environmental and social standards at national and European levels has not only been raised by practitioners but is also increasingly discussed in academic research. A comprehensive review of this phenomenon would exceed the scope of this section. Therefore, the discussion focuses on the most relevant developments in the German T&C industry context – namely, the increasing complexity, fragmentation, and bureaucratic burden related to the European regulatory landscape. This landscape is characterised by a multitude of diverse and, in some cases, overlapping legislative frameworks addressing various dimensions of sustainability and the CE. At the European level, the European Green Deal (European Commission, 2019) serves as the overarching political framework. Introduced in 2019 as a growth strategy, it aims to create a fair, resource-efficient, and competitive economy that achieves net-zero ghg emissions by 2050. Within this strategy, comprehensive legislative packages have been advanced to drive the ecological, social, and digital transformation of the European economy and society. Based on the works by Hörner Bussolo et al. (2024) and Wiegand & Wynn (2025), Table 51 provides an overview of key EU regulations relevant to the German T&C industry. Additionally, national legislation by the EU Member States - some of which overlap with the European law, such as the German Supply Chain Act - and international legislative initiatives - further contribute to the increasing complexity of the regulatory environment (Siliņa et al., 2024). This multitude of regulations illustrates the density of requirements and the resulting legal and administrative complexity. German Companies must operate within this framework while simultaneously understanding and complying with a range of reporting obligations, environmental targets, and monitoring mechanisms. Siliņa et al. (2024) highlight the absence of a central global legislative body and the lack of international coordination, which has led to a proliferation of unaligned and, to some degree, contradictory legal initiatives for sustainability in the global textile sector.

This fragmentation particularly affects companies with globalised supply chains, as they must account for a variety of national and regional requirements. Especially for SMEs

the implementation of statutory due diligence obligations entails increased costs and administrative burdens, particularly as many are indirectly affected through their suppliers or customers, even if they are not directly subject to the regulations themselves (Kolev-Schaefer & Neligan, 2024). A lack of harmonisation between different regulations and clear guidance also means that compliance with the rules becomes an obstacle rather than a catalyst for positive change, leading to uncertainty and confusion for companies when implementing different national regulations and shifting the focus to bureaucracy rather than efforts to identify, prevent, and eliminate adverse effects, which may result in competitive disadvantage compared to non-European companies (Espínola et al., 2024; Kolev-Schaefer & Neligan, 2024). These findings are consistent with the views expressed by industry representatives during the assessment of the operational framework developed in this study: companies perceive themselves to be at a disadvantage compared to non-European market actors due to the significantly higher regulatory burden in Europe. Consequently, recent research increasingly points to the need for harmonised and internationally coordinated regulatory frameworks and governance systems (Beyers, 2024; Stadler et al., 2025). Hörner Bussolo et al. (2024) note that academic research has so far focused too narrowly on the interface between businesses and consumers, highlighting the need for stronger engagement at the intersection of science, industry, and policy to design political instruments – such as the DPP – in ways that ensure their practical feasibility and real-world effectiveness. Addressing this requires close collaboration among policymakers, NGOs, businesses, and consumers to build mutual understanding and promote joint development of innovative solutions (Beyers, 2024; Hörner Bussolo et al., 2024). These insights point to further research opportunities at the interface of business, policy, and society – particularly regarding how awareness and collaboration can be effectively fostered, what barriers persist, and which strategies best help to overcome them.

Table 51
Overview of European regulations relating to the T&C industry (not exhaustive)

Regulation	Description / Purpose	Relation to Textiles	Source
EU Strategy for Sustainable and Circular Textiles	Aims for durable, repairable, recyclable and recycled textile products by 2030	Central policy framework guiding all EU textile-related sustainability measures	European Commission, 2022b
Revised Waste Framework Directive	Requires member states to introduce separate waste collection and develop recycling and reuse infrastructure. Establishes the legal basis for textile waste management and national EPR systems.	Makes textile producers financially responsible under Extended Producer Responsibility (EPR) schemes for the collection, sorting and recycling of textile waste to incentivise more durable, repairable and recyclable products	European Commission, 2023d
Ecodesign for Sustainable Products Regulation (ESPR)	Sets eco-design requirements to improve product recyclability, energy efficiency, and durability - introduces the DPP.	Expands eco-design principles to textiles, encouraging resource-efficient and circular product design	European Commission, 2024b
Green Claims Directive	Stil under proposal Requires that voluntary "green" claims be substantiated, verified and comparable. Aims to prevent greenwashing and to ensure consumers receive trustworthy environmental information.	companies must provide verified, evidence-based environmental claims for their products, ensuring transparency and avoiding misleading "greenwashing" practices in marketing	European Commission, 2023b
EU Taxonomy Regulation	Aims to define which economic activities are environmentally sustainable to guide investments.	Encourages financial flows into sustainable textile manufacturing and innovation.	European Commission, 2025
EU Deforestration Regulation (EUDR)	Aims to ensure that products placed on the EU market are not associated with deforestation or forest degradation.	Affects textile companies using materials like leather, rubber, or wood-based fibres, requiring proof that these are sourced from deforestation-free supply chains	European Commission, 2023c
REACH Regulation	Aims to ensure protection for human health and environment from risks posed by chemicals used in products.	Requires companies to manage and disclose chemicals in production, substituting hazardous substances and ensuring compliance with restricted substances lists	European Commission, 2020c
Corporate Sustainability Reporting Directive (CSRD)	Requires mandatory sustainability reporting from ensuring transparent ESG disclosures.	Requires large companies to publish regular reports on the social and environmental risks and impacts	European Commission, 2022a
Corporate Sustainability Due Diligence Directive (CSDDD)	Aims to foster businesses to behave responsibly and sustainably across global value chains.	Obliges companies to trace their supply chains and ensure compliance with human rights, environmental and labour standards	European Commission, 2024a

7.5 Summary

This chapter critically discussed the developed operational framework in light of the broader literature. It highlighted that the operational framework developed in this study may be regarded as a comprehensive and sector-specific approach to structuring and operationalising the transition to sustainability, the CE, and digitalisation in German T&C companies by integrating the dimensions of organisation, products, and processes. The discussion further indicated that the transition to sustainability and the CE requires an integrated and iterative approach to organisational change, supported by structural and cultural alignment, business model innovation, and strengthened stakeholder collaboration.

The framework provides practical guidance for companies and emphasises sustainability management structures, employee empowerment, and cross-sectoral cooperation as central elements that may facilitate the transition. Furthermore, the findings demonstrated that information systems, as the backbone of digitalisation, represent a crucial factor to be considered and should function as the connecting element between sustainability and IT strategies. In addition to established DTs, emerging approaches such as the Metaverse and their influence on market and competitive dynamics – as well as their potential to reduce resource consumption and waste generation in the German T&C industry – should be observed and integrated. At the same time, the ‘dark side’ of digitalisation – including increased energy consumption, electronic waste, and ethical challenges – should be acknowledged and incorporated into the strategic and operational considerations of digitalisation efforts. The regulatory discussion highlighted the growing complexity and fragmentation of the European and national policy landscape, which creates uncertainty and administrative burdens, particularly for SMEs. Although regulation is a key driver for implementing sustainability- and CE-related initiatives, the findings underscore the urgent need for harmonised and internationally coordinated frameworks, clear guidelines, and multi-stakeholder collaboration to ensure that political instruments can be implemented in a practical and effective manner.

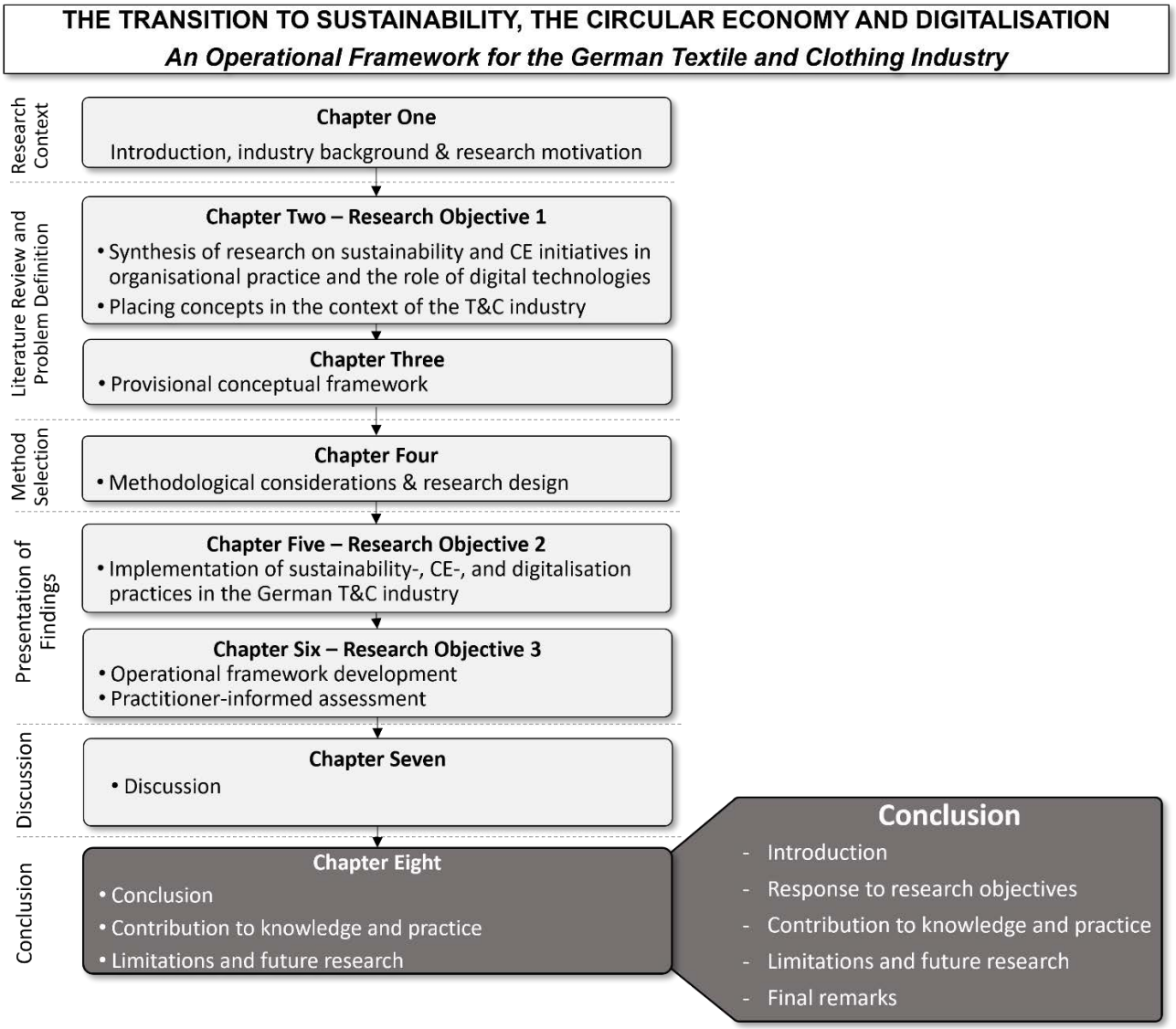
Overall, the discussion showed that the transition of the German T&C industry to sustainability, the CE and digitalisation requires an integrated strategy that combines technological innovation, organisational change, collaborative governance, and regulatory alignment – while also offering significant potential for further research. Finally, this chapter serves as a bridge to the concluding chapter, where the findings are synthesised in relation to the study’s central research objectives.

8 CONCLUSION

8.1 Introduction

The global T&C industry is undergoing profound changes driven by global, technological, and societal change. As one of the world's most resource-intensive and globalised sectors, the global T&C industry faces growing pressure from consumers, policymakers, and international organisations. This study explored the German T&C industry's transition from a resource-intensive, linear, and analogue to a more sustainable, circular, and digital industry. The overarching aim was to investigate the significance of sustainability, the CE and digitalisation from an organisational change perspective and to provide operational guidance for managing this transition in the German T&C industry. Figure 52 shows this chapter´s structure.

Figure 52
Structure of Chapter Eight in context of the thesis



This chapter summarises the main findings, outlines the study's contributions to knowledge and practice, and discusses its limitations and potential directions for future research. It is structured as follows: Section 8.2 revisits the research objectives and synthesises the key findings; Section 8.3 presents the study's contributions to knowledge and practice; Section 8.4 discusses limitations and future research opportunities; and Section 8.5 concludes the thesis with final remarks and a personal reflection on the research process.

8.2 Response to Research Objectives

The author's professional experience in the German T&C industry, combined with the sector's central role in the EU's sustainability agenda, formed the starting point for a personal motivation to understand the complex changes occurring in the transition to sustainability, the CE and digitalisation, and to support practitioners in addressing these changes. Previous studies from other countries have shown that T&C companies face institutional pressure – both coercive and normative – prompting them to adapt accordingly. Despite the growing political and societal relevance of these developments, there remains limited knowledge about how German T&C companies are actually managing this transition. A review of the academic literature further revealed that, despite the German T&C industry's significant role in Europe and its relevance to the EU's sustainability goals, it has received little scholarly attention. There is a notable lack of empirical, sector-specific insights into how the transition to sustainability, the CE and digitalisation unfolds from an organisational perspective.

From this research gap, three research objectives were derived and corresponding findings are summarised here.

RO1: To critically explore and analyse the interrelation and implementation of sustainability, the CE and digitalisation in an organisational context based on existing literature.

RO1 was addressed through a semi-structured literature review. The aim was threefold: first, to identify and analyse the key themes and challenges related to implementing sustainability and circularity from an organisational perspective; second, to examine the role of DTs in supporting this transition; and third, to identify existing models and frameworks addressing the transition to sustainability, the CE and digitalisation.

To enable a systematic analysis, the concepts of sustainability and the CE were first defined for the context of this study. Corporate sustainability is understood as a holistic, strategy-integrated concept that goes beyond profit maximisation and, in line with the TBL approach, seeks to minimise negative social and environmental impacts while contributing positively to societal, ecological, and economic well-being, guided by the UN SDGs. The CE is viewed as an approach to fostering sustainability by minimising resource use and waste generation through narrowing, slowing, and closing resource flows. Three key change dimensions emerged as central for the transition to sustainability and circularity: products, production and supply chain processes, and organisational structures and business models. Products represent a primary leverage point in this transition, as design decisions largely determine sustainability and circularity outcomes. Product development therefore needs to integrate CE and sustainability considerations alongside functionality and aesthetics, aiming to reduce lifecycle impacts while retaining product, component, and material value for as long as possible. Existing studies provide extensive insights into sustainable and circular design strategies for fashion products, while other textile product categories remain underexplored. Furthermore, the literature highlighted various industry-specific challenges for T&C companies – including complex product structures and trade-offs between availability, price, and quality of conventional versus alternative materials – but offers few practical solutions or guidelines.

Business model innovation plays an equally crucial role. The literature review revealed that the interplay between sustainable and circular products and suitable mechanisms and services for their successful market implementation can ensure long-term competitiveness. Sustainable and circular business models aim to create lasting economic value by integrating ecological and social aspects into value creation, delivery, and capture, while narrowing, slowing, and closing resource flows. Although research on sustainable and circular business models has grown significantly in recent years, there remains a lack of industry-specific studies and practical guidance for applying such models in the T&C sector.

Further, the findings suggest that adjustments to products and business models typically involve corresponding changes in production and supply chain processes. Sustainable and circular supply chain management involves coordinating forward and reverse material and information flows in a way that minimises negative environmental and social impacts while enabling resource recovery, regeneration, and waste and emission reduction. However, the literature on sustainable and circular supply chains in the T&C industry is

fragmented and largely focused on the fashion segment. The main challenges identified are insufficient transparency and limited collaboration along supply chains, both of which hinder the implementation of circular and sustainable practices. German companies are particularly underrepresented in this field, with only one study by Arnold et al. (2023) addressing CE practices among German textile manufacturers. Overall, the fragmented state of the literature hindered to derive clear, actionable recommendations for companies in the German T&C industry.

DTs play an increasingly important role in literature on the transition to sustainability and the CE. The nine technologies commonly subsumed under the SMAC and BRAID acronyms were found to be particularly relevant to the transition towards sustainability and the CE, as they support or enable change at the organisational, business-model, product, and process levels. However, recent studies comparing different industries (such as Orisadare et al., 2025; Schöggl et al., 2023) indicate that the T&C sector generally exhibits a comparatively low level of digitalisation. Similarly, existing research on the transition to sustainability and the CE often addresses technologies and their roles in this process only marginally. To date, only one study by Hassan et al. (2024) has been identified that provides a comprehensive review of DTs in connection to CE practices from a product lifecycle perspective.

While a range of technological applications has been discussed – including those contributing to resource savings in production processes, the virtualisation of product development, platform-based business models, and the creation of transparent and traceable forward and reverse supply chains and information flows – the literature on sector specific digital technology deployment remains highly fragmented. Empirical studies further suggested that the implementation of DTs is still predominantly driven by cost-reduction motives rather than sustainability strategies, indicating that the two areas are not yet strategically integrated but pursued separately. Consequently, existing research offers little sector-specific insight into actionable pathways for leveraging DTs to advance sustainability and the CE. This highlights the need for further industry-specific research on technologies and their functions in relation to the identified change dimensions.

Existing frameworks and models addressing the transition towards sustainability, the CE and digitalisation – whether general or sector-specific – are scarce and fragmented. Some focus primarily on sustainability and the CE, while DTs play no explicit role; others concentrate on technologies but neglect products, processes, and other key aspects of the

transition. As a result, current frameworks appear to provide only a limited foundation for developing a practical guide to support German T&C companies in their transition towards sustainability, the CE and digitalisation. They offer useful conceptual foundations but lack depth, specificity, and an integrative perspective. The literature thus reveals a lack of robust frameworks or models that effectively integrate practices and DTs and that are adequately tailored to the particular characteristics and challenges of the German T&C industry. This clearly demonstrated the need for further research. The conceptual framework developed in Chapter Three (see Figure 17) was derived from the findings of the literature review and served as the starting point for an in-depth study of the state of transition in the German T&C industry (RO2). Building on these insights, the study aimed to develop an operational framework to support practitioners in guiding companies successfully through the transition to sustainability, the CE and digitalisation.

RO2: To research and analyse the status of the transition to sustainability, the CE and digitalisation in the German T&C industry

A qualitative case study methodology was selected as the most suitable approach to research the current status of the transition to sustainability, the CE and digitalisation in the German T&C industry. The study included 29 SMEs. Of these, 21 were selected through purposive sampling from among the members of the German Partnership for Sustainable Textiles. As voluntary members of a multi-stakeholder initiative aiming to promote a sustainable and circular textile industry (PST, 2025), it was assumed that these companies are already engaged in the transition and are implementing corresponding strategies and measures.

Since most of these companies belonged to the clothing sector (NACE 14), an additional eight companies from the textile sector (NACE 13) with a strong commitment to sustainable development were included to ensure broader sectoral representation. The study followed an inductive research design, combining various methods of data collection. Publicly available documents were analysed, including sustainability-related company websites and reports, as well as articles published in the two leading industry trade journals Textilwirtschaft and Melliand Textilberichte. In addition, semi-structured interviews were conducted with CEOs or sustainability managers from 10 of the case study companies. The resulting ten interview transcripts and 430 documentary sources were examined using thematic analysis. This study represents an initial step in developing a more comprehensive understanding of sustainability-, CE- and digitalisation-related activities in German T&C companies.

The analysis revealed that sustainability is firmly embedded in the corporate strategies of the case study companies. It is guided by global frameworks such as the SDGs and the Paris Climate Agreement and operationalised through organisational, product, and process-level activities. However, sustainability efforts emerged as primarily focusing on risk management, compliance, and incremental improvements in products and processes consistent with CE principles. However, a fundamental transformation of business models could not be observed.
Similarly, CE practices form an integral part of the sustainability strategies of German T&C companies. Implementation takes place at both product and process levels, although it remains in an early stage of development. Practices associated with the narrowing strategy were found to be most advanced, whereas slowing and closing strategies are pursued more selectively and inconsistently.

The findings further revealed that implementing sustainability and CE practices is associated with considerable challenges, which explains the fragmented and uneven progress observed. These challenges can be grouped into four categories: product-related, process-related, organisational, and market-related. In contrast, four key enabling factors were identified that shape and can help overcome these challenges: (1) collaboration and cooperation within and beyond the value chain; (2) the active development and use of innovative approaches and technologies, particularly for slowing and closing resource flows; (3) the targeted and strategic use of DTs and the development of relevant knowledge and competencies; and (4) harmonised regulations, standards, and financial incentives that motivate companies to implement change and mitigate associated risks.

With regard to the current and planned use of DTs, the findings indicate a fragmented picture. Use cases were identified for all SMAC and BRAID technologies previously introduced in the context of digitalisation, suggesting that these technologies are perceived to play both a supporting and, in some cases, an enabling role in the transition to sustainability and the CE. However, most companies are still in the early stages of implementation. Core systems such as ERP, PLM, and SCM, as well as specialised supply chain platforms, emerged as particularly important in this context, as they provide the infrastructural basis for data integration, transparency, and compliance with due diligence requirements in sustainability management. Accordingly, several companies are currently restructuring their IT infrastructures to establish a foundation for more advanced digitalisation initiatives.

The analysis also showed that the isolated use of individual technologies is perceived to create only limited added value, whereas the combined deployment of technologies - including cloud computing, blockchain, mobile applications, and AI - hold potential to address specific challenges in the transition towards sustainability and the CE.

In summary, the state of transition in the German T&C industry can be characterised as advancing but uneven. While sustainability is increasingly anchored at the strategic level and initial measures to implement circular principles are visible, the transition towards a genuinely sustainable, circular, and digital industry remains at an early stage. CE principles are being applied selectively and inconsistently, and large scale business model innovations are still the exception. Similarly, although companies recognise the relevance of DTs, these are not yet systematically deployed to support sustainability and CE objectives.

Building on these findings, an operational framework was developed in this study, addressing RO3, to support companies in the German T&C industry in systematically managing the transition to sustainability and the CE, while harnessing the potential of DTs more effectively.

RO3: To develop an operational framework for the transition to sustainability and the CE, leveraging the potential of digital technologies for the German T&C industry

The literature review (RO1) revealed that existing models and frameworks for the transition to sustainability, the CE and digitalisation provide valuable conceptual foundations but are only partially suitable as practical guidance for German T&C companies. The case study in the German T&C Industry (RO2) indicated that while sustainability and CE principles are embedded in companies and initial measures have been established at product, process, and organisational levels, implementation remains fragmented, inconsistent, and often focused on incremental improvements and cost optimisation.

Building on these findings, RO3 aimed to translate these conceptual and empirical insights into an operational framework designed to assist companies in the German T&C industry through the transition to sustainability and the CE, while strategically leveraging digital technology deployment to support and accelerate the transition. The PCF proposed in Chapter Three (Figure 17) was refined based on the case study findings and further developed into a new operational framework, including associated action lists for

the transition to sustainability, the CE and digitalisation in the German T&C industry. The operational framework developed in Chapter Six (Figure 42) seeks to contribute to practice by offering a structured orientation and assistance for T&C companies navigating this transition. It comprises three interrelated change dimensions - organisation, products, and processes - each encompassing specific fields of activity, key actions, challenges and enabling factors, as well as digital technology use cases. These dimensions are conceptually interconnected and mutually reinforcing. While all three dimensions are relevant to the transition, the organisational level emerges from the analysis as a critical starting point shaping the conditions under which product- and process-related changes can be initiated and sustained.

Clear strategic (re-)alignment that goes beyond legal compliance by aligning with global sustainability goals, CE principles, and the interests of relevant stakeholders forms the basis for a structured and targeted transition. Business model innovation represents a central lever in this context. Currently, business model innovation in the sector tends to be incremental, addressing individual elements within the linear model. A shift is required towards a holistic reconfiguration of the value proposition and the corresponding alignment and integration of value creation, delivery, and capture. This study provides, for the first time, a comprehensive overview of sustainable and circular business model archetypes, including detailed descriptions and real-world examples from the T&C industry (Figure 45 and Table 42).

The active involvement of ecosystem partners is essential, as individual companies often lack the resources, knowledge, and capabilities to establish sustainable and circular systems independently due to complex and fragmented value chains. Implementation should therefore begin with pilot projects that facilitate rapid learning, adaptation, and continuous improvement.

A robust IT infrastructure forms a strategic prerequisite for this process. The requirements for such infrastructure should be derived from the company’s strategic and sustainability objectives and designed to support planned changes in business models, products, and processes. Information systems thereby act as a bridge between sustainability and digitalisation strategies by enabling data integration, transparency, and communication across all organisational levels. This allows companies to use DTs strategically as enablers of sustainable innovation, efficiency gains, and circularity.

Organisational structure and culture must also undergo an active shaping and alignment. Firstly, by integrating sustainability and IT responsibilities more closely, and secondly, by building awareness and accountability for sustainability and CE across all departments and stakeholders. This should be supported through strong communication, training, and coordination mechanisms.

Furthermore, strategies and objectives should be operationalised through targeted changes at the product and process levels. Key product-related fields of activity include product design, material selection, the use of credible certification systems, and sustainable packaging. Durable, repairable, and recyclable products, as well as renewable or recycled materials, should become the standard. However, companies currently face trade-offs between durability, functionality, and recyclability, while sustainable and circular product or material alternatives are often associated with higher costs and limited market acceptance. Addressing these challenges requires awareness and competence among designers and product developers regarding sustainable and circular design principles, alongside technical and structural innovation - most effectively achieved through cross-value-chain collaboration and continuous improvement.

DTs are intended to play a crucial role in supporting these efforts by enabling dematerialised design processes, providing designers and developers with relevant data (e.g., resource consumption and environmental impact), enabling collaborative development, and facilitating data exchange with key stakeholders such as customers and consumers - for instance, through tracers, tags, or digital product passports.

Operational processes need to be aligned with strategic goals and product requirements. Four key fields of activity emerged from the analysis:

1. Supply chain management – Companies are expected to identify and manage social and environmental risks by building direct partnerships and appropriate control mechanisms, incorporating sustainability and CE criteria into procurement decisions, and ensuring compliance through active monitoring and governance.
2. Production efficiency – Production processes tend to require continuous optimisation with regard to resource and energy efficiency. The processing of alternative, particularly recycled, materials often involves additional costs and operational adjustments, which may necessitate process adaptations, new machinery, or partnerships to develop the required capacities and competencies.

3. Emission management – The current focus on direct (Scope 1 and 2) waste and emissions is to be expanded to include indirect (Scope 3) impacts, necessitating shared data platforms and industry-wide initiatives.
4. Reverse logistics – The development of robust reverse processes for product and material recovery is widely regarded as central to closing resource loops and typically involves new forms of collaboration within and beyond the value chain.

DTs are intended to play a cross-cutting role in all four areas, enabling transparency, efficiency, and circularity through cloud-based platforms, IoT, AI, and blockchain applications. Ultimately, process-level changes require coordinated collaboration and the systematic integration of technologies to ensure both ecological and economic value creation.

The operational framework developed in this study is tailored specifically to the characteristics of the German T&C industry, particularly to SMEs, their complex and fragmented value chains, and the resulting need for collaborative solutions. While the sector currently shows a relatively low degree of digitalisation, it holds significant potential for leveraging digital tools in support of sustainability-related activities. This twin transition - digital and sustainable - offers companies a unique opportunity to integrate both pathways to drive innovation in business models, products, and processes and to strengthen their competitiveness in an increasingly digital and sustainability-oriented world.

The practical relevance and usefulness of the framework were assessed through an online questionnaire among experts from the German T&C industry. Respondents indicated that the operational framework and action lists - including the change dimensions, fields of activity, key actions, and technology use cases - are suitable for supporting and potentially accelerating the transition towards sustainability and the CE within German T&C companies.

8.3 Contribution to Knowledge and Practice

Contribution to Knowledge

The existing literature on the transition to sustainability and the CE is extensive, and the number of studies integrating the potential of DTs in this context is recently increasing. However, as this remains a relatively young research field, the body of research is still highly fragmented. It provides only limited insights into the managerial and organisational

implications of the transition and lacks sector-specific contributions that offer guidance to companies undergoing such change processes (Graessler et al., 2024; Jia et al., 2020; Ki et al., 2020).

This study contributes to the body of knowledge on the transition to sustainability, the CE and digitalisation by taking a sector-specific and practice-oriented focus on the German T&C industry. While only very few existing studies have examined this regional and sectoral context, this study provides a qualitative analysis of the current state of transition within the German T&C industry. By investigating companies from both subsectors (textile and clothing), it complements previous findings with deeper insights into organisational structures, practices, and industry-specific challenges.

A further theoretical contribution lies in the explicit integration of DTs into the analysis of organisational change in the context of sustainability and the CE. Previous sector-specific studies have tended to treat digitalisation and circularity as separate topics, or have focused on isolated technological applications, specific circular business models, or the fashion segment alone (see Table 8 for an overview of existing research and its focus). This study empirically examines both German T&C companies and digital technology deployment in relation to the transition to sustainability and the CE. The study focused on the cluster of emerging DTs commonly grouped under the acronyms SMAC and BRAID, which the case study companies perceived as particularly relevant to their transition processes. The study did not assess the performance or comparative effectiveness of individual technologies. Rather, it analysed how the companies interpret and utilise these technologies in their transition processes. These technologies should therefore be understood as those considered relevant within the investigated companies, rather than as universally effective solutions.
Although these technologies do not represent an exhaustive set, they capture central current trends shaping digitalisation initiatives.

Rather than establishing causal effects, the empirical findings illustrate how these technologies are strategically used to support sustainability- and circularity-related objectives in the German T&C industry. In particular, management and information systems as well as digital platforms emerged as important coordination and transparency mechanisms that facilitate data-driven decision-making. This integrative perspective on digital infra-

structures contributes to a more systemic understanding of their role as enablers of coordination, transparency and data-driven decision- making – an area that has received little attention in prior research.

With the development of the operational framework, this study presents an integrative framework for the transition to sustainability, the CE and digitalisation in the German T&C industry. The framework outlines actions, challenges, influencing factors, and technology use cases for each change dimension, thereby reflecting socio-technical interdependencies, including the alignment of DTs with organisational capabilities, and stakeholder engagement.

A major contribution of this work lies in its systemic perspective on the German T&C industry. Whereas earlier studies mainly focused on individual products or companies (typically fashion brands), this study examined the transition from the perspective of various German companies operating at different stages of the T&C value chain, each making autonomous strategic decisions within the broader ecosystem. This approach enables a more nuanced understanding of the internal dynamics and practices shaping organisational change processes.

Another contribution lies in the conceptual differentiation between sustainability and the CE. The study clearly distinguishes among sustainable, circular, and sustainable-circular products, business models, and supply chains, providing a level of conceptual clarity largely absent from prior work. This analytical distinction establishes a basis for further exploration of the interrelations and boundaries between the two concepts. Moreover, by introducing “change dimensions” and “fields of activity”, the study establishes a theoretical structure that could support future research on the transition of the T&C industry - both in Germany and internationally.

Finally, the study contributes an overview of sustainable and circular business model archetypes, supported by real-world T&C examples. To the author’s knowledge, this is one of the first such overview for the T&C sector. It offers value for future research, particularly for action research projects aiming to explore and expand the practical applicability of these classifications and archetypes.

Overall, this study provides an integrative framework that conceptualises the transition to sustainability, the CE and digitalisation from a practical and sector-specific perspective. It contributes to addressing an identified research gap and advances understanding of organisational change processes within this context. While the operational framework of-

fers a structured and integrative representation of change dimensions, challenges, influencing factors and technology deployment as they currently manifest in the German T&C industry, it does not constitute a predictive or universally applicable model. Rather, it should be understood as a structured set of elements that can inform practical implementation, rather than a detailed implementation plan. In this sense, it offers a conceptual starting point for action-oriented and practice-based research aimed at further exploring the implementation and practical refinement of its individual elements.

Contribution to Practice

Additionally, the operational framework contributes to practice by providing a structured orientation for companies in the German T&C industry that are engaging with sustainability, the CE and digitalisation. The empirical study primarily examined SMEs. The framework therefore reflects the conditions, constraints, and decision-making structures that typically characterise SMEs in this sector. Furthermore, the framework is not intended as a ready-to-use implementation tool or checklist. Rather, it should be understood as a set of elements that were identified as relevant in the context of transitioning to sustainability, the CE and digitalisation. It can support reflection and internal discussion, while practical implementation requires contextual adaptation, organisational learning, and iterative development. This is particularly relevant for SMEs, where limited financial and human resources may influence the scope and pace of the transition. The framework therefore highlights relevant activities without prescribing uniform solutions.

The study also points to the importance of developing knowledge and competencies across functional areas. Several companies reported limited expertise in circular design principles, sustainable materials, and digital tools. Strengthening competencies in ecodesign, life-cycle thinking, and digital product development may support the integration of sustainability considerations. At the same time, the ability to build such competencies depends on available resources and external support. The study further showed that many companies face similar structural challenges. Cooperation within networks and along the value chain can support knowledge exchange and reduce uncertainty. Collaboration with suppliers, customers, technology providers, and research institutions may facilitate access to expertise and shared infrastructures, for example in recycling or digital traceability.

Overall, the framework offers a structured overview of transition-relevant elements within the investigated sector. It may assist companies in reflecting on their current position and

identifying possible areas for development. However, it does not eliminate trade-offs between environmental ambition, economic viability, and organisational capacity. Its practical relevance ultimately depends on context-specific application and continued organisational learning.

In addition, the findings indicate that incremental efficiency improvements alone are unlikely to be sufficient for a broader transition. Some companies explored alternative value creation approaches such as product–service systems, resale models, repair services, or take-back schemes. The framework provides structured examples of such approaches but does not assume that they are suitable or economically viable for all companies.

While the framework provides a structured overview of transition pathways, its practical value ultimately depends on application and learning in real organisational settings. Future research should therefore focus on applying and refining the framework through longitudinal case studies or action research designs, allowing for the observation of implementation processes, organisational learning, and unintended consequences over time. Such studies could also support the development of more differentiated maturity models or decision-support tools tailored to specific organisational contexts.

8.4 Limitations and Future Research

Despite the scope of this study, several limitations must be acknowledged which at the same time offer valuable opportunities for future research.

Firstly, the analysis is based on a qualitative case study including only 29 companies, primarily SMEs, from the German T&C industry. The findings therefore reflect context-specific organisational realities and cannot be generalised or transferred to the wider national or international sector. Rather than aiming at representativeness, the study provides in-depth insights into practices, interpretations, and organisational approaches within the investigated setting. With regard to the operational framework, its development was based on qualitative empirical data and interpretive abstraction. While it is designed to be adaptable to different organisational contexts, its practical applicability and impact have not yet been systematically assessed. Future research could examine its use in real organisational settings, for example, through action-oriented or intervention-based studies. Such research may support the further refinement of its components and, where appropriate, the development of more structured assessment tools or maturity levels.

Future research could also build on this study's findings through larger-scale quantitative studies to examine the distribution and relative importance of identified change dimensions, actions, and influencing factors across a broader population of firms.

Secondly, the study also indicates that strategic alignment, organisational structures, and inter-organisational collaboration play an important role in shaping transition processes. However, the specific mechanisms through which collaboration contributes to or constrains change initiatives remain insufficiently understood. Further research could therefore investigate coordination structures, power relations, and shared infrastructure development within industry networks in greater detail. These considerations also point to further research opportunities at the interface of business, policy, and society. In particular, future studies could explore how awareness and collaboration can be effectively fostered across stakeholder groups, which structural or cultural barriers persist, and which governance or incentive mechanisms may help to overcome them.

Thirdly, the case study provided a cross-sectional perspective. Change processes towards sustainability and the CE are dynamic and unfold over extended periods of time. The study therefore captures strategies and practices at a specific point in time. Longitudinal research designs would be valuable to examine how organisational priorities, capabilities, and technology deployment evolve and how intended and unintended effects emerge over time.

Fourthly, the study focused on DTs commonly grouped under the acronyms SMAC and BRAID. While these clusters capture prominent current trends in digitalisation, they do not represent an exhaustive set of technological developments. Emerging or future technologies, as well as more niche applications, were not systematically examined. Moreover, the study did not assess the performance or comparative effectiveness of individual technologies. Future research could therefore broaden the technological scope and investigate the interconnections and long-term implications of different DTs in greater detail. In addition, future studies may benefit from concentrating more specifically on individual aspects of digitalisation and exploring the interplay between selected technologies, as well as the design and governance of the socio-technical systems in which they are embedded. Moreover, future research should critically assess whether the increasing deployment of DTs in support of sustainability and the CE may lead to unintended displacement effects, shifting environmental and social burdens to other sectors, such as electronics manufacturing. In particular, the environmental impacts of hardware production,

data centre energy consumption, electronic waste generation, and the broader social and ethical implications of digitalisation warrant closer examination.

Furthermore, the research adopts a company-centred perspective. The views of consumers, policymakers, industry associations, and civil society actors were not systematically included. Incorporating these perspectives could contribute to a more comprehensive understanding of institutional pressures, market dynamics, and ecosystem-level coordination mechanisms. In addition, research from other national contexts suggests that regional innovation ecosystems may play a crucial role in fostering circular and innovative products and business models (e.g., Abbate et al., 2023). Such ecosystem structures were not clearly identifiable in the present case study. Future research could therefore examine whether comparable regional ecosystems exist in Germany, how they function, and under which conditions they may support or hinder transition processes.

Finally, the findings are embedded in the regulatory, economic, and institutional context of the German T&C industry. Comparative studies across countries or regions could help identify context-dependent and context-independent elements of transition processes. Similarly, examining other industrial sectors may reveal both transferable principles and sector-specific characteristics. Such research would contribute to a more differentiated understanding of sustainability, the CE and digitalisation across industries, rather than assuming the emergence of a single generalisable model.

8.5 Final Remarks and Personal Reflection

Conducting this study has been an intensive and rewarding learning journey that has significantly contributed to both my professional and personal development. Throughout the research process, I was able to deepen my methodological understanding, refine my academic writing style, and enhance my competences in applying scientific methods, literature, and analytical tools. Beyond these methodological aspects, my approach to work has evolved into a more structured and systematic process, and I have developed a stronger awareness of the importance of critical engagement with academic literature and continuous exchange with peers.

In addition to methodological and subject-specific knowledge, this research process has also enabled me to strengthen key personal skills that are essential for academic work. Perseverance, structured thinking, and clear communication of complex ideas proved essential to the project’s progress, while I also realised that research is rarely a solitary

pursuit. The exchange with fellow scholars has been invaluable - particularly through participation in a joint book project with authors from nine different countries, which not only broadened my academic perspective but also fostered valuable professional connections for future collaborations.

Through this work, I have built a solid expertise in sustainability, the CE and digitalisation in the T&C context. The publications arising from this research have already opened new professional networks and opportunities, including invitations to participate in initiatives of the German Partnership for Sustainable Textiles and in the stakeholder dialogue on the development of Germany's Circular Economy Strategy at the Federal Environment Agency (UBA). More recently, I have been able to initiate a collaborative research project on the implementation of the DPP together with a research colleague and partner companies from the German T&C industry.

These experiences have strengthened my confidence in my academic abilities and deepened my enthusiasm for research. The entire process - from conceptualisation to implementation and publication - has reinforced my aspiration to further professionalise my academic career and to contribute, through future research and teaching, to advancing the transition to sustainability, the CE and digitalisation in business and society.

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Appendix A Overview and Synthesis of CE Definitions

Autor	Title	Type	Source	Year	Definition
Ellen MacArthur Foundation	Towards the Circular Economy: Economic and business rationale for an accelerated transition	Report		2013	"The circular economy refers to an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design. " CE principles: 1) Design out waste 2) Build resilience through diversity 3) Rely on energy from renewable sources 4) Think in 'systems' 5) Waste is food
Patrizia Ghisellini, Catia Cialani, Sergio Ulgiati,	A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems*	Review	Journal of Cleaner Production	2015	"CE may rather be considered a way to design an economic pattern aimed at increased efficiency of production (and consumption), by means of appropriate use, reuse and exchange of resources, and do more with less" (p.18) --> Authors conclude that CE offers promising pathways for balancing environmental and economic systems. Its global implementation is still at an early stage and largely focused on recycling rather than on more comprehensive reuse and reduction strategies. The authors emphasize the need for: -Expanded CE Practices: Moving beyond recycling to incorporate reduction and reuse, which are often more sustainable and cost-effective. - Collaborative Efforts Across Society: Successful CE transitions require the involvement of all societal actors, including businesses, governments, and consumers, to foster collaborative relationships that support circular practices. - Policy and Economic Incentives: Effective CE implementation relies on stable, supportive policies and economic returns on investment to incentivise companies and investors. in summery: need for broader adoption of CE principles and increased collaboration for a systemic transition
European Commission	Closing the loop - An EU action plan for the Circular Economy	EU Communication Document	European Commission	2015	"economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized"
Michael Lieder, Amir Rashid	Towards circular economy implementation: a comprehensive review in context of manufacturing industry	Review	Journal of Cleaner Production	2016	"For this paper, the relevant CE definition is the one of "an industrial economy that is restorative or regenerative by intention and design" (Ellen Macarthur Foundation, 2013). This definition is more comprehensive as it considers both the environmental and economic advantages simultaneously under the notion of regenerative performance requiring high quality circulation of technical nutrients while ensuring safe entry of bio nutrients in the biological sphere" (p. 37)
Julian Kirchherr, Denise Reike, Marko Hekkert	Conceptualizing the circular economy: An analysis of 114 definitions	Review	Resources, Conservation & Recycling	2017	"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations."

Autor	Title	Type	Source	Year	Definition
Martin Geissdoerfer, Paulo Savaget, Nancy M.P. Bocken, Erik Jan Hultink	The Circular Economy-A new sustainability paradigm?	Review	Journal of Cleaner Production	2017	"a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" The authors also highlight potential trade-offs, noting that while CE enhances environmental and economic aspects, it may lack emphasis on social dimensions. Thus, CE alone might not address all sustainability pillars, and integrating it with other sustainable approaches could achieve more balanced outcomes
Alan Murray, Keith Skene,Kathryn Haynes	The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context	Review	Journal of Business Ethics	2017	"The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being"
Denise Reike, Walter J.V. Vermeulen, Sjors Witjes	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	Review	Resources, Conservation & Recycling	2018	The article does not provide a definition for CE developed by the authors themselves. Instead, they discuss existing definitions and conceptualisations in the literature, particularly noting the variations in understanding CE as an alternative model of production and consumption, a growth strategy enabling the 'decoupling' of resource use from economic growth, thereby contributing to sustainable development (p. 246). --> The authors emphasise CE's evolution across three historical phases, termed CE 1.0, CE 2.0, and CE 3.0, which highlight shifts in focus from simple waste management to a broader systems perspective on resource efficiency and value retention. This framing reflects their view on CE as an evolving concept, combining elements from various sustainability models rather than establishing a novel definition.
Tom Lahti, Joakim Wincent, Vinit Parida	A Definition and Theoretical Review of the CircularEconomy, Value Creation, and Sustainable BusinessModels: Where Are We Now and Where ShouldResearch Move in the Future?	Review	Sustainability	2018	"The CE is essentially an environmental change in response to the global need for an ecological economy, which requires human economic activities that are consistent with the three Rs principles: Reduce, reuse, and recycle""a circular business model is designed to create and capture value while helping achieve an ideal state of resource usage (e.g., finding a model that mostclosely resembles nature and comes close to achieving the complete cycling of materials). Accordingly, the goal of the business model shifts from making profits through the sale of products or artifacts to making profits through the flow of resources, materials, and products over time, including reusinggoods and recycling resources."The authors conclude, that successful implementation of CE principles within business models requires a fundamental shift in how companies create, capture, and deliver value. Key outcomes: 1) Need for Theory-Driven Research: importance of integrating established management theories (e.g., contingency theory, transaction cost theory, resource-based theory) to understand the unique challenges and potential of circular business models. This theory-based approach is essential for gaining insights into the practicalities of CE adoption and profitability.2) Challenges in Circular Business Models: The article identifies several obstacles companies face in transitioning to CE, such as high upfront investment costs, complex collaboration needs, and difficulties in aligning long-term sustainability goals with traditional short-term profit goals.3) Research Agenda for Future Studies: call for empirical work on CE to validate and expand theoretical insights. 4) They conclude that achieving CE goals often demands collaboration across industries and a systemic realignment, where businesses, policymakers, and other stakeholders work together to facilitate the transition.
Jouni Korhonen, Antero Honkasalo, Jyri Seppälä	Circular Economy: The Concept and its Limitations	Review	Ecological Economics	2018	"Circular economy is an economy constructed from societal production-consumption systems that maximizes the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical materials flows, renewable energy sources and cascading-type energy flows. Successful circular economy contributes to all the three dimensions of sustainable development. Circular economy limits the throughput flow to a level that nature tolerates and utilises ecosystem cycles in economic cycles by respecting their natural reproduction rates." Limits / challanges: 1) Thermodynamic Limits: Due to entropy, complete recycling is impossible, and each cycle still requires energy and generates waste. 2) System Boundary Limits: CE implementations often encounter spatial and temporal boundaries, potentially

Autor	Title	Type	Source	Year	Definition
					shifting problems rather than solving them globally. 3) Physical Growth Limits: The rebound effect and Jevon's paradox suggest that efficiency gains may lead to increased consumption, counteracting sustainability goals. 4) Path Dependency and Lock-in: Existing technologies and market structures may resist new circular models, making it hard for innovative CE practices to penetrate. 5) Governance and Management Challenges: CE requires coordinated inter-organizational and inter-sectoral collaboration, which is complex to manage. 6) Social and Cultural Perceptions of Waste: Cultural and societal views influence the treatment of materials as waste or resources, impacting CE implementation.
Gianmarco Bressanelli, Federico Adrodegari, Daniela C. A. Pigosso, Vinit Parida	Towards the Smart Circular Economy Paradigm: A Definition, Conceptualization, and Research Agenda	Review	Sustainability	2019	"The circular economy is recognized by industries, scholars, and policy makers as a promising approach to jointly advance the sustainability and competitiveness of value chains, given its ability to decouple economic growth from resource consumption and waste generation [1–3]. Moving companies towards the circular economy involves fundamental changes in industrial ecosystems and a systemic redesign of products, production processes, business models, value chains, and consumption patterns [4,5]. By doing so, several 'R' strategies (sometimes called R hierarchies or imperatives) may be pursued" "Given the scarcity of existing contributions and building on the studies listed in Table 1,we define the Smart Circular Economy paradigm as: an industrial system that uses digital technologies during the product life-cycle phases to implement circular strategies and practices, aiming at value creation through increased environmental, social, and economic performance." conceptualization takes the view that digitalization for the smart circular economy is much more than the mere introduction of digital technologies, and that digitalization alone will not automatically lead to a higher sustainability performance. We, therefore, propose to adapt the underlying principle of the classical circular economy, 'waste equals food', to an equation more fitted to the digital age we are living in, namely: waste + data = resource In other words, the disruptive potential of digital technologies should be unleashed to turn waste into a resource, leveraging data as an essential raw material from which information and knowledge can be derived to generate sustainable value [77]
Gustavo Cattelan Nobre, Elaine Tavares	The quest for a circular economy final definition: A scientific perspective	Article	Journal of Cleaner Production	2021	"Circular Economy is an economic system that targets zero waste and pollution throughout materials lifecycles, from environment extraction to industrial transformation, and to final consumers, applying to all involved ecosystems. Upon its lifetime end, materials return to either an industrial process or, in case of a treated organic residual, safely back to the environment as in a natural regenerating cycle. It operates creating value at the macro, meso and micro levels and exploits to the fullest the sustainability nested concept. Used energy sources are clean and renewable. Resources use and consumption are efficient. Government agencies and responsible consumers play an active role ensuring correct system longterm operation."
Omar Alhawari, Usama Awan, M. Khurrum S. Bhutta,M. Ali Ülkü	Insights from Circular Economy Literature: A Review of Extant Definitions and Unravelling Paths to Future Research	Review	Sustainability	2021	"CE is the set of organizational planning processes for creating, delivering products, components, and materials at their highest utility for customers and society through effective and efficient utilization of ecosystem, economic and product cycles by closing loops for all the related resource flows." The authors propose a detailed definition of CE that incorporates organizational processes focused on maximizing resource utility and closing loops in both ecological and economic systems. They emphasize the dual-loop concept of CE, which combines closed-loop systems and "take-back" mechanisms to enhance resource efficiency and effectiveness

Autor	Title	Type	Source	Year	Definition
Christina Vogiantzi, Konstantinos Tserpes	On the Definition, Assessment, and Enhancement of Circular Economy across Various Industrial Sectors: A Literature Review and Recent Findings	Review	Sustainability	2023	"The Circular Economy (CE) is a visionary economic model that focuses on closed cycles where, ideally, there is an endless regeneration of resources. CE should be shaped through supportive regulations and policies. This transformative concept emphasizes the integration of renewable energy and sustainable practices. CE prioritises circularity, minimizing waste and maximizing value creation, promoting a harmonious interaction between society, economy and environment, and reflecting a collaborative spirit of innovation and responsible resource management" --> "The definitions of the CE encompass different approaches, but they all agree on basic principles. CE is an economic system designed to maximize value from flows of materials and energy through life cycles. Its objectives are to minimize waste, recycle, maintain value, and contribute to ecological well-being, economic growth, and human well-being (social). Common to these definitions is the idea of reducing material and energy consumption. These changes include a shift to renewable energy sources and the elimination of toxic chemicals that inhibit recycling."
Julian Kirchherr, Nan-Hua Nadja Yang. Frederik Schulze-Spüntrup, Maarten J. Heerink, Kris Hartley	Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions	Review	Resources, Conservation & Recycling	2023	"The circular economy (CE) is a regenerative economic system which necessitates a paradigm schift to replace the 'end-of-life concept' with reducing, alternatively reusing, recycling and recovering materials trhoughout the supply chain, with the aim to promote value maintance and sustainable development, creating environmental quality, economic development, and social equity, to the benefit of current and future generations. It is enabled by an alliance of stakeholders (industry, consumer, policy makers, academia) and their technological innovations and capabilities."
Morteza Alizadeh, Amirarash Kashef, Yu Wang, Jun Wang, Gül E. Okudan Kremer , Junfeng Ma a,	Circular economy conceptualization using text mining analysis	Review	Sustainable Production and Consumption	2023	"CE an economic system based on nonlinear and cycle-form business models that adopts regenerative, restorative, and renewable design approaches to recycle, reuse, reduce, and recover (repair) goods. The aim is to reduce environmental pollution, energy, and material waste while maintaining sustainable resources and minimizing ecological impacts. This system ultimately seeks to promote ecosystem transition to a higher level, achieving efficiency and service improvements for both current and future generations" Authors categorise CE into 4 elements: activities, strategies, aims, and business models.
Stuart Danvers, Jonathan Robertson, Ambika Zutshi	Conceptualizing How Collaboration Advances Circularity	Review	Sustainability	2023	"The CE concept is commonly divided into two streams: biological cycles and technical cycles [14]. A biological cycle is about regenerating the biosphere by enabling the natural cycling of biological nutrients (e.g., food organics) [33]. Technical cycles are concerned with technical waste produced by industry (e.g., metals, polymers, textiles). Technical cycles are shaped by an organization's business model and the strategic choices involved in how new products and services propose, create, and capture value [34,35]. The value proposition of the new circular products will require new business models designed to both deliver value and capture any new forms of value [36]" --> Authors propose that collaboration requirements vary across product lifecycle stages. At the design stage, open innovation fosters circular design thinking. During the use phase, intensified collaboration supports product-service systems, and at the end-of-life stage, collaboration in resource recovery ensures circular flows.
E. Sardianou, V. Nikou, K. Evangelinos, · I. Nikolaou	What are the key dimensions that CE emphasizes on? A systematic analysis of circular economy definitions	Review	Environment Systems and Decisions	2024	" CE has been recognized as a recurring positive growth cycle that sustains and improves natural capital, optimizes resource allocation, and minimizes system risks through a combination of policies and tools, while considering environmental boundaries. This closed-loop system can operate efficiently at any scale, by emphasizing effective planning of operations and resource utilization to optimize flows and maintain physical and technical flows." --> Authors find that "waste" and "recycling" are the most frequent concepts in CE definitions, aligning with EU policies like the European Green Deal. Other common terms include "environment," "economy," "materials," and "energy."
Sugam Upadhayay, Omaima Alqassimi, Ed-	Development in the Circular Economy Concept: Systematic Review in Context of an Umbrella Framework	Review	Sustainability	2024	"The circular economy is a transdisciplinary realm based on an ethical and responsible regeneration and restoration of resources for the attainment of the common good through

Autor	Title	Type	Source	Year	Definition
mund Khashadourian, Alex Sherm, Dinesh Prajapati					an integrated approach across the micro, meso, and macro levels with the promises and possibilities of environmental, economic, cultural, and social gains for existing and future generations." (p. 13)
Yuliia Maksymiv, Valentyna Yakubiv, Iryna Hryhoruk, Iryna Boryshkevych, Finbarr Carter,Viktoriia Vostriakova	The Circular Economy: Conceptual Definition and Framing for Socially Responsible Stakeholders	Review	Economic Affairs	2024	" the circular economy is a concept that aims to create or develop economic relationships through the operation of sustainable business models based on business processes with an extended product life cycle, socially responsible behavior at the micro, macro, and meso levels within the framework of planetary boundaries." --> for businesses the authors conclude: Entities that seek to function within the circular economy must expand the lifecycle of products, improve supply chains, and implement the integrated use of raw materials, as well as the use and production of renewable energy sources. They should minimize waste generation and create prerequisites for easy reuse, recycling, or repair of products during the product design phase. This will minimize the negative impact on the environment and achieve the sustainable development goals. Within a circular economy, complex resource use is possible both within one enterprise and within different business entities, along with through the intermediate link - the consumer, who must be "included," that is, interested in participating in the circular economy

Appendix B Interview preparation

B.1 Interview Consent Form

UNIVERSITY OF GLOUCESTERSHIRE
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EINVERSTÄNDNISERKLÄRUNG
(Consent Form)

11.05.2024

Forschung zu:

Digitale Technologien und Kreislaufwirtschaft in der deutschen Textil- und Bekleidungsindustrie
(Research project: Digital Technologies and the Circular Economy in the German Textile & Clothing Industry

Bitte füllen Sie dieses Formular aus, um Ihre Zustimmung zur Teilnahme an der Forschung zu o.a. Thema zu geben und kreuzen Sie JA oder NEIN an. Das Forschungsinformationsblatt befindet sich in der Anlage zu diesem Formular. (Please complete this form to indicate your consent to participate in the above-mentioned research project by ticking YES or NO. research brief is attached to this form.)	**JA** (yes)	**NEIN** (no)
1. Das Forschungsinformationsblatt wurde mir zur Verfügung gestellt. (I have been provided with the research brief)	☐	☐
2. Ich habe das Forschungsinformationsblatt gelesen und verstanden. (I have read and understood the research brief)	☐	☐
3. Ich habe Fragen zum Forschungsprojekt gestellt (oder hatte die Gelegenheit dazu) (I have asked questions about the research project (or had the opportunity to do so)	☐	☐
4. Ich nehme freiwillig an dieser Forschung teil (I am participating in this research voluntarily)	☐	☐
5. Ich bin mir bewusst, dass meine Teilnahme an dieser Studie bedeuten könnte, dass meine Antworten in der Dissertation oder damit verbundenen Arbeiten / Veröffentlichungen der Forscherin zitiert werden könnten. (Hinweis: Alle Zitate werden anonymisiert). (I am aware that my participation in this study may mean that my responses could be quoted in the researcher's dissertation or related academic publications. (Note: All quotations will be anonymised.)	☐	☐
6. Ich stimme der Teilnahme an dem Projekt zu und verstehe, dass die Teilnahme am Projekt das Ausfüllen des beigefügten Fragebogens umfasst. (I agree to take part in the project and understand that participation includes completing the attached questionnaire.)	☐	☐
7. Ich bin mir bewusst, dass ich jederzeit vor der Analyse der Daten ohne Angabe von Gründen von der Studie zurücktreten kann. (I am aware that I can withdraw from the study at any time before the data is analysed without giving reasons)	☐	☐

Name (name) _____ Unterschrift (signature) _____ Datum (date) _____

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B.2 Interview Research Brief

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Forschungsinformationsblatt

Digitale Technologien und Kreislaufwirtschaft in der deutschen Textil- und Bekleidungsindustrie

Hintergrund und Zweck der Forschung

Die Europäische Union (EU) hat die Kreislaufwirtschaft als wesentlichen Bestandteil ihrer umfassenderen industriellen Transformation hin zu Klimaneutralität und langfristiger Wettbewerbsfähigkeit definiert. Die Textil- und Bekleidungsindustrie wurde aufgrund ihres hohen Verbrauchs an Primärrohstoffen und Wasser sowie der verursachten Treibhausgasemissionen als Schlüsselsektor für die Transformation zur Kreislaufwirtschaft identifiziert.

Das Ziel der Kreislaufwirtschaft ist es, den Wert von Produkten, Materialien und Ressourcen in der textilen Wertschöpfungskette so lange wie möglich zu erhalten und die Entstehung von Abfällen und Emissionen zu minimieren.

Diese Studie geht davon aus, dass die Einführung von Kreislaufwirtschaftsstrategien und -praktiken in der deutschen Textil- und Bekleidungsindustrie in naher Zukunft aufgrund europäischer und nationaler Vorschriften sowie sich wandelnder Kundenwahrnehmungen beschleunigen wird und dies durch den innovativen Einsatz digitaler Technologien erleichtert wird. Der Fokus liegt insbesondere auf den Herstellungsprozessen, die für die Textil- und Bekleidungsproduktion von zentraler Bedeutung sind.

Dieses Forschungsprojekt (ansässig an der University of Gloucestershire (UK), School of Business, Computing and Social Sciences) untersucht die Beziehung zwischen der Einführung digitaler Technologien und dem Übergang zur Kreislaufwirtschaft innerhalb der deutschen Textil- und Bekleidungsindustrie.

Ziel ist es, zu erforschen und zu verstehen, wie Organisationen in der deutschen Textil- und Bekleidungsindustrie sich an die zirkuläre Transformation, wie sie von der EU im Rahmen des Green Deals vorgesehen ist, anpassen und welche Rolle digitale Technologien bei dieser Transformation spielen.

Die Studie zielt darauf ab, die folgenden **Forschungsfragen** zu beantworten:

1) Welche Strategien und Aktivitäten im Zusammenhang mit der Kreislaufwirtschaft werden in Unternehmen der deutschen Textil- und Bekleidungsindustrie verfolgt?
2) Welche digitalen Technologien werden derzeit in den Herstellungsprozessen der deutschen Textil- und Bekleidungsindustrie eingesetzt?
3) Wie unterstützt die Digitalisierung in der deutschen Textil- und Bekleidungsindustrie
   a) Prozessveränderungen und Innovationen und b) die Förderung der Kreislaufwirtschaft?
4) Kann ein operatives Modell erstellt werden, das den Übergang zur Kreislaufwirtschaft in der deutschen Textil- und Bekleidungsindustrie leitet?

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Research Brief

Digital Technology and the Circular Economy in German Textile and Clothing Manufacturing Companies

Purpose of the research

The EU has defined the circular economy (CE) as an essential part of its broader industrial transformation towards climate neutrality and long-term competitiveness and has identified the textile and clothing industry as a key sector for the transformation to the CE due to its high consumption of primary raw materials and water and the greenhouse gas emissions it generates.

The underlying objective of the CE is to preserve the value of products, materials and resources in the textile value chain for as long as possible and to minimise the generation of waste and emissions.

This study assumes that the introduction of CE practices and activities in the German textile and clothing industry will accelerate in the near future due to European and national regulations and changing customer perceptions, which will be facilitated by the innovative use of digital technologies.

It is focussing in particular on the manufacturing processes that are of central importance for T&C production.

This research study (based at the University of Gloucestershire (UK), School of Business, Computing and Social Sciences) investigates the relationship between the adoption of digital technologies and the transition to the circular economy (CE) within the German textile and clothing (T&C) industry. It aims to explore and understand how organisations in the German textile and clothing industry are adapting to circular transformation, as envisaged by the EU within the context of the Green Deal, and what role digital technologies are playing in this transition. The interview study aims to answer the following research questions:

RQ 1: What strategies and activities related to the CE are being pursued in German T&C manufacturing companies?
RQ 2: What digital technologies are currently being deployed in the manufacturing processes in the German textile industry?
RQ 3: How is digitalisation in German textile manufacturing a) supporting process change and innovation and b) advancing the circular economy?
RQ 4: What operational model can guide the transition to circularity in the manufacturing process of the German textile industry?

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Methodischer Ansatz

Im Mittelpunkt dieser Studie steht der u.a. vorläufige konzeptionelle Rahmen, um die **Beziehung zwischen dem Einsatz digitaler Technologien entlang der Wertschöpfungsstufen und den verfolgten Kreislaufstrategien und -praktiken zu veranschaulichen.** Das übergeordnete Ziel der Ressourcenschonung und der Vermeidung von Abfällen und Verschmutzung erfordert einen Wandel zu Kreislaufpraktiken durch die konsequente Verfolgung sogenannter R-Strategien (z.B. Refuse, Reduce, Reuse, Repair, Remanufacture, Recycle). Ausgehend davon wird davon ausgegangen, dass der Übergang zu nachhaltigen und zirkulären Textilien Veränderungen in allen Prozessschritten entlang der Wertschöpfungskette erfordert.

Das Kernstück des Rahmens besteht aus einer dreidimensionalen Matrix. Die erste Dimension umfasst fünf **Hauptstufen der textilen Wertschöpfungskette (Y-Achse)**. Die zweite Dimension umfasst die drei **Unternehmensindividuellen Bereiche Organisation, Produkte und Prozesse (Z-Achse)**, in denen alle Akteure eigene Innovationen und Veränderungen vornehmen müssen, um zu einer Kreislaufwirtschaft überzugehen. Und die dritte Dimension umfasst neun **digitale Technologien (X-Achse)**, die als Katalysatoren und Treiber für die Einführung und Umsetzung von Kreislaufpraktiken innerhalb von Unternehmen und in unternehmensübergreifenden Prozessen entlang der Wertschöpfungskette angesehen werden.

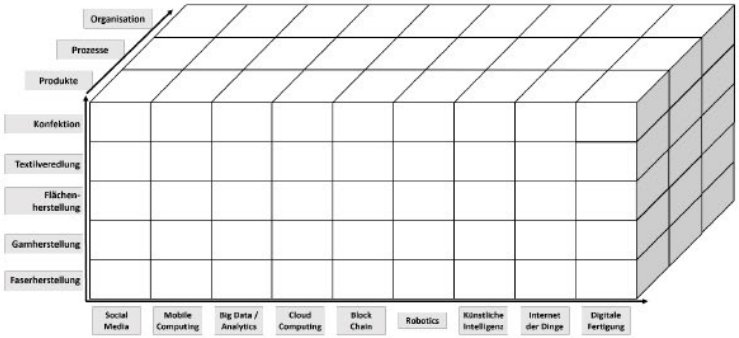

Abbildung 1: Vorläufiger konzeptioneller Rahmen

Der Wert und die Validierung dieses Rahmens hängen weitgehend davon ab, **sinnvolle Beziehungen zwischen digitalen Technologien und Kreislaufpraktiken** innerhalb der teilnehmenden Unternehmen entlang der textilen Wertschöpfungskette herzustellen. Diese Verbindungen und Beziehungen sollen in einer Reihe von **Experteninterviews mit Praktikern aus verschiedenen Stufen der Wertschöpfungskette** ergründet und validiert werden.

Ihre Beteiligung

Die Teilnahme an der Studie umfasst einen Fragebogen und ein persönliches Gespräch mit der Forscherin im Umfang von ca. einer Stunde, zu einer Zeit und an einem Ort, der Ihnen genehm ist.

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Methodological approach

Central to this interview study is the following conceptual framework, to illustrate the relationship between digital technology deployment along the manufacturing process steps and the circular strategies and practices pursued.

It assumes that the transition to sustainable and circular textiles requires changes in all process steps along the value chain. The overarching goal of conserving resources and avoiding waste and pollution requires a shift to circular practices through the consistent pursuit of so-called R-strategies (e.g. Refuse, Reduce, Reuse, Repair, Remanufacture, Recycle).

The core of the framework consists of a three-dimensional matrix. The first dimension comprises all value chain phases in textile and clothing production (Y-axis). The second dimension comprises the three company individual areas of organisation, product and processes, in which each individual player must make their own innovations and changes to transition to the CE (Z-axis). And the third dimension comprises nine digital technologies that are seen as catalysts and drivers for the introduction and implementation of circular practices within companies and in cross-company processes along the value chain (X-axis).

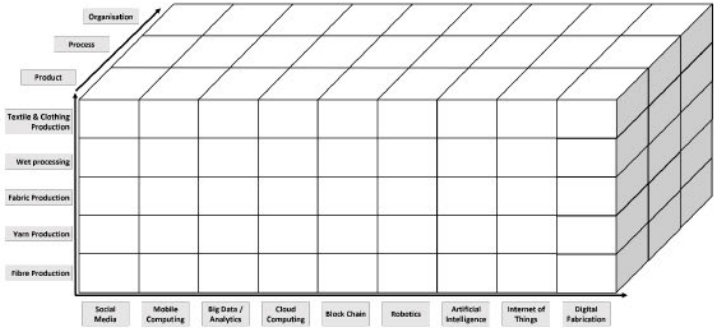

***Figure 1**: Provisional Conceptual Framework*

The value and validation of this framework will largely depend on establishing meaningful relationships between digital technologies and circular practices within the participating companies along the textile and clothing manufacturing processes. These connections and relationships need to be established and validated in a series of interviews with practitioners from five stages of the textile and clothing value chain.

Your Involvement

Taking part in the research will involve talking to the researcher from the University of Gloucestershire for up to an hour, at a time and location that is convenient to you. All information will remain strictly confidential, and all names will be anonymised.

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Erwarteter Nutzen für Teilnehmende

Diese Studie zielt darauf ab, Best-Practice-Anwendungen für die zirkuläre Transformation in der deutschen Textil- und Bekleidungsindustrie zu entwickeln. Es kann nicht versprochen werden, dass die Studie Ihnen persönlich hilft, aber die Ergebnisse können dazu beitragen, die Art und Weise zu verbessern, wie Unternehmen Kreislaufstrategien in Organisation, Produkten und Prozessen vorantreiben und wie der gezielte Einsatz digitaler Technologien dies unterstützen kann. **Bei Interesse erhalten Sie eine Präsentation der wichtigsten Ergebnisse und Erkenntnisse** der Studie, die Ihnen nach Abschluss des Forschungsprojektes zur Verfügung gestellt werden kann. Es sind keine bekannten Risiken mit der Teilnahme an der Studie verbunden.

Vertraulichkeit

Alle Informationen werden **streng vertraulich** behandelt, und sämtliche **Namen und Organisationen werden anonymisiert**. Die von Ihnen bereitgestellten Informationen werden mithilfe von Codes auf einem passwortgeschützten persönlichen Computer in einem verschlossenen Raum gespeichert. Ihr Name wird nicht zusammen mit Ihren Interviewdaten gespeichert. Es werden **keine Informationen über Einzelpersonen oder Unternehmen an Dritte weitergegeben**. In den Berichten der Studie werden nur Gruppeninformationen angegeben, **ohne Hinweise auf die Identität der Teilnehmer**. Nach Abschluss der Forschung und Berichterstattung werden alle Daten sicher für einen Zeitraum von 10 Jahren aufbewahrt, um bei Bedarf die Genauigkeit der Informationen während dieses Zeitraums überprüfen zu können.

Ergebnisse

Die Ergebnisse dieser Studie werden Teil einer Doktorarbeit sein und können auch in Form von wissenschaftlichen Artikeln in akademischen Zeitschriften veröffentlicht sowie auf akademischen Konferenzen präsentiert werden, um die Forschungsergebnisse zu verbreiten.

Forscherin und Betreuer

Dr. Martin Wynn (University of Gloucestershire, UK) and Professor Dr. Christine Brautsch (Hof University of Applied Sciences) sind die Hauptbetreuer der Studie, die die Arbeit der Forscherin beaufsichtigen. Tina Wiegand ist die Forscherin des Projekts und führt die Forschung für ihre Doktorarbeit durch.

Weitere Informationen

Wenn Sie Fragen zu dieser Forschung haben oder weitere Informationen benötigen, wenden Sie sich bitte an die Forscherin unter:

Tina Wiegand
Email:
Mobil:

Vielen Dank für Ihre Teilnahme und Ihre Unterstützung!

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Expected benefits

This study aims to develop best practice applications for the circular transition in German textile and apparel industry. It cannot be promised that the study will help you personally, but the results could contribute to improving the way companies drive circularity in organisation, products and processes and how the targeted use of digital technologies can support this. If you are interested, you will receive the results of the study first-hand in an executive summary presentation, which can be made available to you after the study has been completed. There are no known risks associated with participating in the study.

Confidentiality

The information that you provide is anonymous and will be stored using codes on a password-protected personal computer within a locked space. Your name will not be stored together with your interview data. No information about any single individual or company will be made available to any other person. Only group information will be given in any reports of the study with no indication of any participant's identity. When the research is completed and reported, all data will be stored securely for a period of 10 years to allow for checking the accuracy of the information if necessary during that period.

Results

The results of this research will be part of a doctoral thesis and will also be published in the form of academic papers in management journals and presented at academic conferences in order to disseminate the research findings.

Researcher and supervisors

Dr. Martin Wynn (University of Gloucestershire, UK) and Professor Dr. Christine Brautsch are the principal supervisors for the study who will oversee the work of the researcher. Tina Wiegand is the researcher on the project, and will be conducting the research for her doctoral thesis.

Further information

If you have any questions about this research, or require further information, please contact the study researcher at:

Tina Wiegand
Email:
Mobile:

Thank you for your interest and participation!

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Appendix C Deductive Coding Definition and Illustrative References for Adopted Sustainable and Circular Business Model Practices

BM Categories	BM Archetypes	Code definition	Exemplary references
Social and environmental profit	Adopt a stewardship role	Passages describing practices in which companies take on responsibilities beyond their core business to ensure the health and well-being of stakeholders, society or the environment. Examples include: transparent and/or certified supply chains, fair trade, active environmental/biodiversity protection.	C01: "Every step in the production process is traceable. This is all thanks to our long-standing partnerships that help us to monitor and certify our supply chains and products." C03: "We have fulfilled the Fairtrade criteria for using the Fairtrade Cotton seal since 2017" C04: "we as a company guarantee the safety of our products by making it our goal not only to meet the legal requirements, but to exceed them" C05: "Compliance with waste water limits according to ZDHC and OEKO-TEX STeP Detox to Zero" C06: "[C07] takes ecological and safety aspects into account in product development" C14: "The OEKO-Tex Standard 100, Made in Green and Green Button 2.0 certifications are basic requirements for us" C24: "Bluesign provides [C24] with a comprehensive and well-founded system, which provides the basis for the continuous development of the company's hazardous substance management to meet the needs of people and nature." C25: "As a current pioneer in the field of ecological functional textiles, we also want to be among the first in the industry to take the issue of microplastics seriously and move forward quickly."
	Re-purpose for society/ environment	Passages describing corporate practices that prioritise environmental and social aspects over profit maximisation or that are aimed at solving specific social or environmental problems, (e.g. B Corp certification, social enterpise, not for profit, orientation at economy of common good)	C02: "Many textile companies relocate their production to less developed countries in order to save costs. Sure, we can't compete with the low-cost suppliers in the industry. But that is not our aim either." C18: "we contribute to the common good by supporting projects through our company trust – the [C18]Foundation" C22: "We are very strongly orientated towards the economy for the common good. People are at the centre of our business activities, but not only people. [C22] protects mountaineers and mountains." C23: " [C23] Employees will once again be deployed on site at the 2024 Special Olympics National Games in Thuringia to become part of the movement as corporate volunteers." C25: "[C25] has been certified as a B Corp since 2019. For the third time in four years, [C25] received this award for its uncompromising strategic focus and consistent actions in favor of a sustainable and circular textile industry" C26: "Strenghtening the "lighthouse project" of dual training in the textile industry [in Uzbekistan], including the success of advertising this model to external companies" C28: "the [C28] Children's House, which is sponsored by the city and cares for up to 31 children. It celebrated its 20th anniversary in 2021. [C28] is operating as a tenant of a public outdoor pool"
Collaborative impact	Develop scale up solution	Passages describing practices aimed at facilitating sustainable innovations, e.g. through cooperative or network-based approaches such as open innovation, crowdsourcing models, or incubators.	C06: "[Name of hub] is the Innovation Hub of C06. Our mission is to inspire designers and producers in a B2B environment and present new ideas, new technologies, new collaboration possibilities and new products" C18: "Both as an organiser and as a participant, we encourage dialogue on sustainability topics and issues of the future with panel discussions, webinars, training sessions and other events. On this foundation, trust grows and sustainable business relationships are created." C28: "With our in-depth and long-standing expertise, we support companies in the diverse challenges of the transformation process towards a sustainable economy. We help to identify the areas of action relevant to the company in question, analyse the company's activities, develop a sustainability strategy and implement sustainability e ectively and long-term in the organisational structure." C25: "In cooperation with various renowned partners and change leaders, a regular industry talk is organised. Here, we jointly initiate and learn how circularity can work for the entire outdoor and textile industry. The goal is to create a library." C25: "The [C25] Sustainability Impact Programme is a training programme aimed at young designers in the outdoor industry. It designers a platform for knowledge exchange, workshops and lectures on the topic of responsible design."
	Inclusive value creation	Passages describing practices that explicitly aim to include disadvantaged or marginalised groups (e.g. the bottom of the pyramid) in value creation or to create appropriate offerings for them.	C01: "Our goal is to improve the living conditions of 450 cotton farmers and 1,000 children and adolescents in the growing regions. We promote sustainable agriculture by transitioning from conventional to organic cotton." C18: "we started a cooperation with Raddis® Cotton in 2023. It supports indigenous farmers in South India within switching from conventional to regenerative agriculture" C22: "The Impact Accelerator Fund for Climate (IAF), an initiative kickstarted by [C22], is a collaborative tool that is open to motivated outdoor companies, inviting them to contribute within their means. The funds raised through the initiative will be used to support decarbonization projects and climate mitigation action within supply chains." C23: "With our Empowering Farmers project, we support farmers in growing and converting to organic cotton" C27: "[C27] has been a member of the Better Cotton Initiative (BCI) since 2019, promoting the sustainable cultivation of cotton worldwide."

BM Categories	BM Archetypes	Code definition	Exemplary references
Demand and consumption reduction	Dematerialised services	Passages describing practices where physical infrastructure, assets, or products are replaced with digital or virtual ones.	C01: "We also use animations to replace photo shoots and customer presentations, saving additional resources." C02: "Our customers can now receive an electronic invoice. After some initial hesitation, around 99% of our customers now (2024) receive a paperless invoice." C29: "we are increasingly working on the topic of digitalisation, accompanied by the vision of a paperless office"
	Demand reduction services	Passages describing practices where companies provide solutions that moderate or reduce the use of energy and resources by individuals or organisations.	-
	Encourage sufficiency	Passages describing practices facilitating sustainable consumption and product life extension at customers and consumers	C02: "We would like to give you a few tips on how to care for our products to maximise their lifespan, how to darn and sew them after accidents and how to use them for other purposes." C05: "We offer our customers the transparency they need to make a conscious purchasing decision." C15: "We educate our customers about fast fashion and its effects and offer a more sustainable alternative." C17: "In this blog post, we would like to show you how to find your way to conscious fashion consumption step by step." C22: "REPAIR & CARE VIDEO TUTORIALS TO EXTEND THE LIFE OF YOUR PRODUCTS" C28: "For the care and repair of our products, we offer instructions, spare parts and services"
Collaborative consumption	Sharing economy	Passages describing practices facilitating the sharing of products, assets, or services owned by individuals without monetary exchange.	-
	Sharing or pooling systems	Passages describing practices where products, assets, or services owned by individuals or organisations are shared, lent, or pooled among multiple users through transaction	-
Product-service systems	Access model	Passages describing practices aimed at offering temporary access to products instead of ownership, e.g., through leasing or renting	C22: "With new business ideas such as rental models or the SECOND LIFE store, we already offer suitable starting points, and we want to expand these further in the future." C28: "With our new rental service"
	Performance or result model	Passages describing practices aimed at offering performance or result related to a product, rather than through product ownership.	-
Long life	Lifetime products	Passages describing practices where durabile and repairable products are offered.	C02: "With very high-quality raw materials, we lay the foundation for our longlasting products." C07: "A robust, very durable, material and still biodegradable when it has reached the end of its product life" C13: "The durability of [C13] products is an integral part of our sustainability concept and is therefore characteristic of all of our workwear collections, spanning all occupations." C17: "Instead of owning countless inferior garments that lose their shape after a few washes, slow fashion focuses on timeless designs and high-quality workmanship." C22: "Design & development - Longer-lasting aesthetics (colours and cuts)"
	Products with life extension services	Passages describing practices where durabile and repairable products and corresponding services are offered aimed at extending their lifespan.	C22: "We have already taken the first measures to extend the lifespan of products with our Repair & Care service" C24: "We employ 15 experienced tailors. Repairs are carried out here with a great deal of passion and original materials" C28: "With its own repair service, cooperation with iFixit and the Repair Cafés, VAUDE already offers a whole bundle of services for our customers so that their product can actually be repaired"
	Hybrid model	Passages describing practices where companies sell durable products and offer short-lived components or consumables (like Printer + Ink)	-

BM Categories	BM Archetypes	Code definition	Exemplary references
Next life	Direct reuse	Passages describing practices aiming at facilitating reuse of used or unwanted products through second-hand markets, redistribution, or exchange.	C28: "[C28] supports the private resale of used products on a "re-commerce platform" on eBay" C25: "[C25] is cooperating with the eBay Upcycling Store powered by [C28]. Here you can find high-quality functional materials for your DIY ideas
	Next life sales	Passages describing practices aiming at the take-back of used or unwanted products through convenient systems to the manufacturer, in order to extend product value through refurbishing, remanufacturing, or resaling for subsequent use.	C08: "we would rather try to keep them within circulation and give them a second life as special items. Thus, in 2020, we were able to save 394,000 kg of nonwovens from incineration and the landfill." C15: "Defective [return] items are sent back to our producers so that they can be inspected to improve their quality or, in the case of minor defects, can be offered for sale in the online shop With corners and edges." C22: "We sell cleaned, refurbished and repaired items that have been returned to us, as well as factory seconds with small imperfections."
	Product transformation	Passages describing practices aiming at take-back of used or unwanted products through convenient systems to the manufacturer to increase product value through the reuse of components, the reconditioning of items or their repurposing for new applications.	-
	Extending resource value	Passages describing practices aiming at take-back of used or unwanted products through convenient systems with the aim of recycling, reusing or recovering them.	C15: "Our partnership with SOEX/I:Collect seamlessly continues, meaning that you can send us your old [C15] favorites twice a year free of charge" C18: "We integrate textile recycling into the service offers for our retailers and end customers." C20: "As a manufacturer, we are committed to taking back our products at the end of their life cycle and ensuring that the material can be returned to the biological cycle" C24: "After a long life, the trousers are collected - not disposed of. After the zips are removed, the trousers are shredded, further decomposed by depolymerisation and insulation and then processed into PET pellets."
Circular sourcing	Asset management	Passages describing practices aimed at optimising the use of assets (e.g. buildings, vehicles, equipment) through pooling, sharing, lending, reuse, refurbishment or resale in order to reduce underutilisation or extend the asset life.	C01: "Our fleet is now 90% comprised of hybrid or electric vehicles, and we encourage carpooling" C07: "own e-charging stations for cars and bicycles on its premises, which can be used both for its own vehicle fleet and for visitors." C09: "To minimise the amount of scrap metal generated, defective machines or machine parts are rebuilt or repaired in our highly specialised metalworking shop"
	Industrial Symbiosis	Passages describing practices where waste streams (products, materials or by-products) from production/manufacturing are turned into valuable inputs for other processes or products	C01: "We are also exploring the possibilities of collecting, reusing, and incorporating production and cutting waste from other production partners into our products." C02: "Since 1997, our textile waste (edge pieces, corner trimmings, etc.) has been collected and recycled by the French company KATZ. The newly recovered, recycled blended yarn is used to make felt fillings for the automotive industry and various cleaning products such as the mop." C09: "Used textiles that can no longer be used are processed into nonwovens by a partner in the region."
	Natural / circular / renewable material and energy	Passages that describe strategies where value is created by sourcing circular inputs such as recycled or natural materials, renewable energy or ensure non-hazardous chemicals input to reduce environmental impacts	C01: "We are working to further reduce the use of synthetic fibers and to offer a cellulose-based product." C03: "We only use recycled polyester of the REPREVE® brand from Unifi." C04: "Our plan is to transition completely from natural gas to hydrogen by 2030. As an interim target, we aim to install a solar park near our production plant." C06: "The new collection features natural, biodegradable or recycled fibre blends for crepe and crinkle fabrics, combining wool and silk with Lenzing Ecovero and recycled polyamide." C08: "The chemicals we use undergo a strict approvals process before they are cleared for use in production. This is how we prevent the use of hazardous substances. At the same time, we regularly check the auxiliaries we use for possible substitutions with more environmentally friendly alternatives." C12: "We are also expanding our product portfolio of goods which are certified according to the Global Recycled Standard (GRS)." C15: "Modal belongs to the regenerated fibre family and is made from 100% natural cellulose from beech wood. Some production processes are resource-intensive. That is why we have opted for TENCEL™ Modal from Lenzing in Austria" C17: "Organic cotton, recycled fabrics and natural fibres are just a few examples."

BM Categories	BM Archetypes	Code definition	Exemplary references
Next life	Direct reuse	Passages describing practices aiming at facilitating reuse of used or unwanted products through second-hand markets, redistribution, or exchange.	C28: "[C28] supports the private resale of used products on a "re-commerce platform" on eBay" C25: "[C25] is cooperating with the eBay Upcycling Store powered by [C28]. Here you can find high-quality functional materials for your DIY ideas
Circular production	On demand	Passages describing practices or approaches in which products are only manufactured after customer demand has been confirmed, to avoid overproduction, excess inventory and waste.	C07: "Our production is order-based" C10: "We produce only when we receive an order, not for stock. We've been doing this for 30 years."
	Cleaner production and ecoefficiency	Passages describing practices, or approaches in production / manufacturing or distribution aimed at increasing material productivity, energy and resource efficiency or reducing waste, emissions or environmental pollution	C01: "Through modern planning and the reuse and treatment of wastewater within the factory, approximately 50% of total water consumption is expected to be saved in the long term, equating to about 110,000 liters of drinking water per year" C05: "The STeP certification attests us above-average values in the area of energy efficiency [...] All existing equipment was completely replaced by new, energy-efficient ones from 2022 to 2023" C15: "Our direct production partners are located at only a few sites in Europe. The textiles produced are manufactured exclusively in sewing factories with certified environmental and social standards" C22: "Optimizing and reducing packaging, avoiding air freight" C28: "we try to make the most of the fabric width in production. To do this, we work closely with our producers to keep improving our material efficiency"
	Collection, take back, and reprocessing of used products and materials / Create value from waste	Passages describing practices aimed at facilitating collection and processing of end-of-life products /materials	C01: "We avoid combining different materials, fibres and chemicals in a single textile product where possible so that further down the line the resources can be recovered without complications" C03: "In the production process, textile "waste" accumulates at various points, for example, as offcuts, or in sample production. These remnants are sold directly to a textile recycling company and are, therefore, not officially declared as waste." C04: "By operating recovery plants, we meet the requirement for both material and thermal utilization of waste gas streams. Waste generated on-site is thermally recycled within the plant. Our sulphuric acid plant significantly contributes to our energy production without emitting CO2) C09: "We received funding for the next 30 months to research the recycling of process-related selvedges and fabric waste for the production of fabric tubes as seating furniture." C13: "Cut waste from production is collected and recycled into new yarn by a partner company. The recycled yarn is then used for the production of the new shirts." C09: "In-house production of upcycling products and sale of residual materials." C28: "Residual material that can no longer be used for production, for example because the quantity is too small for series production, is donated locally in the countries of production. If residual material that can no longer be used for production accumulates in Germany or Europe, it is upcycled or sold as material boxes on eBay in aid of Save the Children."

Appendix D Operational Framework Assessment – Questionnaire

(Note, the Figure 45 and Tables 43,46,47 were presented directly in the questionnaire and were also translated to German)

Original Questionnaire in German	English Translation
Sehr geehrte Teilnehmerin, sehr geehrter Teilnehmer, vielen Dank für Ihre Unterstützung im Rahmen meiner Forschung am Übergang zu Nachhaltigkeit, Kreislaufwirtschaft und Digitalisierung in der Textil- und Bekleidungsindustrie. Basierend auf Fallstudien wurde ein operativer Rahmen mit Maßnahmenkatalog für den Transformationsprozess in Unternehmen entwickelt. Ziel ist es Unternehmen eine einfache Orientierung zu geben, wie sie ihre heutigen Praktiken prüfen, Verbesserungen erkennen und mit Hilfe digitaler Lösungen Nachhaltigkeit und Kreislaufwirtschaft voranbringen können. Diese Online-Umfrage dient der Bewertung des entwickelten Rahmens aus Expertensicht. Ich möchte Sie daher bitten: • lesen Sie sich die kurze Beschreibung zum operativen Rahmen durch und sehen Sie sich die Abbildung an • bewerten Sie dann die Aussagen aus Ihrer Sicht • im Falle der vollständigen Ablehnung einer Aussage geben Sie bitte einen kurzen Kommentar (Erklärung) an.	**Dear Participant,** Thank you very much for your support in my research on the transition to sustainability, the circular economy, and digitalisation in the textile and clothing industry. Based on a case study, an operational framework and action list has been developed to support companies in their transition process. The aim is to provide firms with clear guidance on how to assess their current practices, identify opportunities for improvement, and use digital solutions to advance sustainability and circular economy implementation. This online questionnaire serves to evaluate the framework from an expert perspective. I would therefore like to ask you to: • read the brief description of the operational framework and review the accompanying figure • then assess the statements from your point of view • in the case of complete disagreement with a statement, please provide a short comment (explanation).
Operativer Rahmen für den Übergang zu Nachhaltigkeit, Kreislaufwirtschaft und Digitalisierung in der Textil- und Bekleidungsindustrie Der operative Rahmen wurde entwickelt, um den Übergang zu Nachhaltigkeit und Kreislaufwirtschaft inkl. der Nutzung digitaler Technologien in der Textil- und Bekleidungsindustrie abzubilden und Unternehmen in diesem Prozess zu unterstützen. Nachhaltigkeit wird in diesem Zusammenhang verstanden als die Integration ökonomischer, ökologischer und sozialer Ziele, um die langfristige Tragfähigkeit unternehmerischer Aktivitäten sicherzustellen. Kreislaufwirtschaft wird als Ansatz zur Umsetzung von Nachhaltigkeitszielen betrachtet. Dabei sollen Produkte, Materialien und Ressourcen so lange und hochwertig wie möglich im Umlauf gehalten und gleichzeitig Abfall und Emissionen minimiert werden. Drei zentrale Strategien leiten diesen Ansatz: Verringerung (use less), Verlangsamung (use longer) und Schließung (use again) von Ressourcenflüssen. Digitale Technologien umfassen digitale Systeme und Anwendungen, die große Datenmengen verarbeiten, übertragen und speichern können. Im Rahmenwerk fungieren sie als Baustein, um die praktische Umsetzung von Nachhaltigkeits- und Kreislaufwirtschaftsstrategien zu unterstützen. Bei Bedarf finden Sie hier eine Übersicht potentieller Technologien inkl. Beschreibung und Beispielen. Der operative Rahmen umfasst drei Veränderungsdimensionen – Organisation, Produkte und Prozesse. Die Organisation bildet den Ausgangspunkt der Veränderung. Hier werden Strategien, Strukturen und Werte für Nachhaltigkeit, Kreislaufwirtschaft und Digitalisierung festgelegt. Produkte sind der wichtigste Hebel für Wertschöpfung und Umweltwirkung und müssen im Zuge der Transformation an veränderte Strategien und Anforderungen in Bezug auf Nachhaltigkeit und Kreislaufwirtschaft angepasst werden. Prozesse umfassen die internen und externen Tätigkeiten und Abläufe entlang der Lieferkette und deren Ausrichtung auf veränderte Strategien und Anforderungen in Bezug auf Nachhaltigkeit und Kreislaufwirtschaft. Für jede dieser Dimensionen werden Handlungsfelder definiert und wichtige Maßnahmen, Herausforderungen und Einflussfaktoren einer erfolgreichen Umsetzung sowie passende digitale Technologien aufgezeigt. Für eine größere Darstellung des Rahmenwerks klicken Sie hier.	**Operational Framework for the Transition to Sustainability, Circular Economy, and Digitalisation in the Textile and Clothing Industry** The operational framework was developed to illustrate and support the transition to sustainability and the circular economy, leveraging the potential of digital technologies for the textile and clothing industry. In this context, sustainability is understood as the integration of economic, environmental, and social objectives to ensure the long-term viability of business activities. The circular economy is regarded as a practical way to achieve sustainability goals. Its main idea is to keep products, materials, and resources at their highest utility and value for as long as possible, while reducing waste and emissions. This approach is based on three main strategies: narrowing (use less), slowing (use longer), and closing (use again). Digital technologies include digital systems and applications that can process, transmit, and store large volumes of data. Within the framework, they serve as enablers to support the practical implementation of sustainability and circular economy strategies. If required, you can find an overview of potential technologies, including descriptions and examples, here. The operational framework comprises three change dimensions– organisation, products, and processes. The organisation represents the starting point of change. It is where strategies, structures, and values related to sustainability, the circular economy, and digitalisation are defined. Products are the main lever for value creation and environmental impact and must be adapted to evolving strategies and requirements concerning sustainability and circularity. Processes include the internal and external activities and operations along the supply chain and their alignment with new strategies and requirements related to sustainability and the circular economy. For each of these dimensions, the framework defines fields of action and highlights key actions, challenges, and influencing factors for successful implementation, as well as suitable digital technologies. To view a larger version of the framework, please click here.

Likert and Multiple-Choice Questions

Nr.	Original Questionnaire in German	English Translation	SA	A	N	D	SD
	Ich bin tätig in der * O Textilindustrie O Bekleidungsindustrie	I work in the * O Textile industry O Clothing industry					
1	Globale Nachhaltigkeitsziele wie die Sustainable Development Goals (SDGs) und das Pariser Klimaabkommen bieten wichtige Orientierung für die Ausrichtung unternehmerischer Nachhaltigkeitsziele.	Global sustainability goals such as the Sustainable Development Goals (SDGs) and the Paris Climate Agreement provide guidance for corporate initiatives, and for aligning corporate sustainability goals.					
2	Die Kreislaufwirtschaft und darauf ausgerichtete Praktiken stellen einen Ansatz dar, um Nachhaltigkeit innerhalb unternehmerischer Aktivitäten und Maßnahmen zu operationalisieren oder Nachhaltigkeitsbezogene Ziele zu erreichen.	The circular economy is regarded as an approach to operationalise sustainability within corporate activities and actions.					
3	Digitale Technologien dienen als wichtige Wegbereiter und Unterstützer für Unternehmen bei der Umsetzung nachhaltiger und kreislaufwirtschaftlicher Praktiken.	Digital technologies serve as enablers and supporters for companies in the implementation of sustainable and circular economy practices.					
4	Der operative Rahmen und die Maßnahmenliste sind insgesamt klar und verständlich.	Overall, the operational framework and action lists are clear and comprehensible					
5	Die drei Dimensionen – Organisation, Produkte und Prozesse – bieten eine klare und geeignete Struktur für den Übergang zu Nachhaltigkeit und Kreislaufwirtschaft in Textil- und Bekleidungsunternehmen.	The three dimensions – organisation, products, and processes – provide a clear and suitable structure for the transition to sustainability and the circular economy in textile and clothing companies					
6	Das Rahmenwerk geht davon aus, dass organisatorische Veränderungen der zentrale Ausgangspunkt und die Voraussetzung für Fortschritte in den Produkt- und Prozessdimensionen sind. Inwieweit stimmen Sie dieser Annahme zu?	The framework assumes that organisational change is the central starting point and prerequisite for progress in the product and process dimensions. To what extent do you agree with this assumption?					
7	Die im Rahmenwerk beschriebenen Handlungsfelder und Maßnahmen spiegeln die in der Praxis notwendigen Ansätze für den Übergang zu Nachhaltigkeit und Kreislaufwirtschaft angemessen wider.	The activities and key actions outlined in the framework appropriately represent the approaches necessary for companies' transition in practice					
8	Die im Rahmenwerk dargestellten Herausforderungen entsprechen den wichtigsten Barrieren denen Unternehmen beim Übergang zu Nachhaltigkeit und Kreislaufwirtschaft begegnen.	The challenges outlined in the framework correspond to the main barriers companies face in the transition to sustainability and the circular economy.					
9	Die im Rahmenwerk dargestellten Einflussfaktoren wirken sich positiv auf den Übergang aus, wenn sie vorhanden sind.	The influencing factors outlined in the framework have a positive effect on the transition when present.					
10	Das Rahmenwerk enthält angemessene Anwendungsfälle digitaler Technologien zur Unterstützung von Kreislaufwirtschaft und Nachhaltigkeit.	The framework contains appropriate use cases for digital technologies to support the circular economy and sustainability.					
11	Das Rahmenwerk wäre für unser Unternehmen bei seinem Übergang zu Nachhaltigkeit und Kreislaufwirtschaft von Nutzen.	Overall, the framework would be valuable for guiding our company in its transition to sustainability and circularity					

12	In welcher der Veränderungsdimensionen sehen Sie die größten Lücken oder Herausforderungen beim aktuellen Übergang Ihres Unternehmens zu Nachhaltigkeit und Kreislaufwirtschaft? *O Organisation* *O Produkte* *O Prozesse* *O Andere (bitte spezifizieren)*	In which of the three change do you see the *biggest gaps or challenges* in your company's current transition towards sustainability and the CE?" *O Organisation* *O Products* *O Processes* *O Other (please specify)*
13	In welcher der drei Veränderungsdimensionen hat Ihr Unternehmen aus Ihrer Sicht bisher die größten Fortschritte erzielt? *O Organisation* *O Produkte* *O Prozesse* *O Andere (bitte spezifizieren)*	In which of the change dimensions (Organisation, Product, Processes) has your company made the *most progress* so far? *O Organisation* *O Products* *O Processes* *O Other (please specify)*

Open ended questions

NR	Original Questionnaire in German	English Translation
14	Gibt es aus Ihrer Sicht wichtige Aspekte des Übergangs zu Nachhaltigkeit, Kreislaufwirtschaft und Digitalisierung, die im Rahmenwerk fehlen? (z.B. Maßnahmen, Herausforderungen, Einflussfaktoren oder Technologien)	In your opinion, are there any important aspects of the transition to sustainability, circular economy and digitalisation that are missing from the framework? (e.g. actions, challenges, influencing factors or technologies)
15	Was sind Ihrer Meinung nach die größten Stärken des Rahmens?	In your view, what are the main strengths of the framework?
16	Was sind Ihrer Meinung nach die größten Schwächen des Rahmenwerks?	In your view, what are the main weaknesses of the framework?