



Digital and sustainable innovations within the ecosystem context: Qualitative explorative studies

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List of abbreviations

A2A	Actor-to-actor
BM	Business Model
BMI	Business Model Innovation
BMWi	Bundesministerium für Wirtschaft und Energie; Federal Ministry for Economic Affairs and Energy 2013–2021
CE	Circular Economy
CEF	Circular Economy Fit
CEO	Chief Executive Officer
CSR	Corporate Social Responsibility
D	Document
DAX	Deutscher Aktienindex
EN	Environmental Nongovernmental Organization
ES	Environmental Sustainability
F	Firm
FI	Firm Initiative
G	Governmental Organization
I	Interview
IA	Industry Association
IT	Information Technology
M	Media
M&A	Mergers and Acquisitions
MW	Megawatt
N.a.	Not available
N.d.	No document/No data
NGO	Nongovernmental Organization
PP	Political Party
R	Research Institute
R&D	Research and Development
SCOT	Social Construction of Technology
SDG	Sustainable Development Goals

TA	Trade Association
TM	Technology Maturity
TS	Trade Show
VHB	Verband der Hochschullehrerinnen und Hochschullehrer für Betriebswirtschaft e.V.
VPP	Virtual Power Plant

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I Synopsis - Prologue

I.1 Introduction

I.1.1 Relevance

In the face of current challenges, such as disruptive technological developments and climate change, 45% of the 4,702 chief executive officers (CEOs) surveyed by PwC believe their current business will be economically viable for, at most 10 years. PwC derives an accelerating reinvention imperative from this observation (PwC, 2024).

Table I.1-1: Business responses to current challenges

CEO Survey Question: What changes are you making in your business in response to these challenges?		
Strategy	• Launching new product and/or service offerings for sustainability	63%
	• Strengthening scenario planning and analysis capabilities	62%
	• Increasing R&D funding for sustainable innovation	39%
Governance	• Engaging in long-term strategic partnerships	66%
	• Re-evaluating my company's core purpose	41%
	• Linking my leadership's remuneration to sustainability targets	34%
	• Increasing the diversity of my company's board of directors	31%
	• Disclosing climate risk in my company's financial statements	24%
Workforce	• Upskilling/reskilling my workforce for the future labor market	74%
	• Offering physical and/or mental wellness resources for my workforce	58%
	• Increasing workforce diversity	56%
Value Chain	• Strengthening visibility into the social impacts of my company's value chain	54%
	• Duplicating and diversifying our value chain	37%
	• Reducing our total scope 3 emissions	34%
	• Incentivizing ESG outcomes for our value chain	33%
	• Conducting value chain vulnerability assessments	33%
	• Localizing our value chain	21%
	• Assessing my company's impact on biodiversity across the value chain	21%
Technology	• Digitizing business processes	72%
	• Improving cybersecurity to minimize hacks and data leakages	57%
	• Enhancing sustainability data collection capabilities across our value chain	55%
	• Transitioning to cloud infrastructure to enhance efficiencies	48%
	• Implementing artificial intelligence for real-time risk analysis	17%
Operations	• Investing in renewable energy sources to reduce our dependency on fossil fuels	49%
	• Transitioning to circular business models	49%
	• Initiating nature protection and/or restoration projects	35%

(Illustration based on United Nations Global Compact & accenture, 2023, p. 34 with some minor adaptations)

This finding is in alignment with the responses provided by CEOs regarding the changes they are making in the face of the current challenges (United Nations Global Compact & accenture, 2023, see Table I.1-1). The top business responses cited by more than 60% of the CEOs

surveyed are as follows: launching new product and/or service offerings for sustainability (63%), strengthening scenario planning and analysis capabilities (62%), engaging in long-term strategic partnerships (66%), upskilling/reskilling workforce for the future labor market (74%), and digitizing business processes (72%). While digitization efforts and the provision of sustainability-related offerings are directly related to the challenges of climate change and technological disruption, and the advancement of employee skills and the need for scenario planning and analysis techniques can also be attributed to the ongoing and uncertain change, the subject of long-term strategic partnerships stands out. In this dissertation, ecosystem collaboration is considered from different theoretical perspectives and in diverse contexts to explore how such partnerships are a key area for change in the face of the current challenges of climate change and technological disruption for organizations.

In contrast, far fewer CEOs surveyed see an increase in research and development (R&D) investment in sustainable innovation as a solution (United Nations Global Compact & accenture, 2023). To better understand this gap, it is fitting to take a brief look at corporate investment in R&D. Essentially; corporate spending on R&D continues to increase. The 1,000 European companies with the highest R&D investments spent a record sum of €229.9 billion in 2022 (European Commission. Joint Research Centre, 2023; see Figure I.1-1). This is an increase of 13.1% compared to the previous year (still 7.4% when adjusted for inflation). A look at the geographical distribution shows that German companies account for 46% of the total sum at €106.7 billion, while France is in second place with a total sum of €33.3 billion (14.5%). In the international arena, however, European companies are falling behind. While Chinese and U.S. companies in particular are increasingly joining the group of top R&D investors, development in Europe is less dynamic. From the figures on international investment behavior in R&D, it can be deduced that European countries, too, have already been subject to observable growth in recent years. It can therefore be assumed that the relevance of R&D investments is not a new concept for most CEOs. Against this background, it seems worthwhile to take a closer look at European innovation activities and discourse.

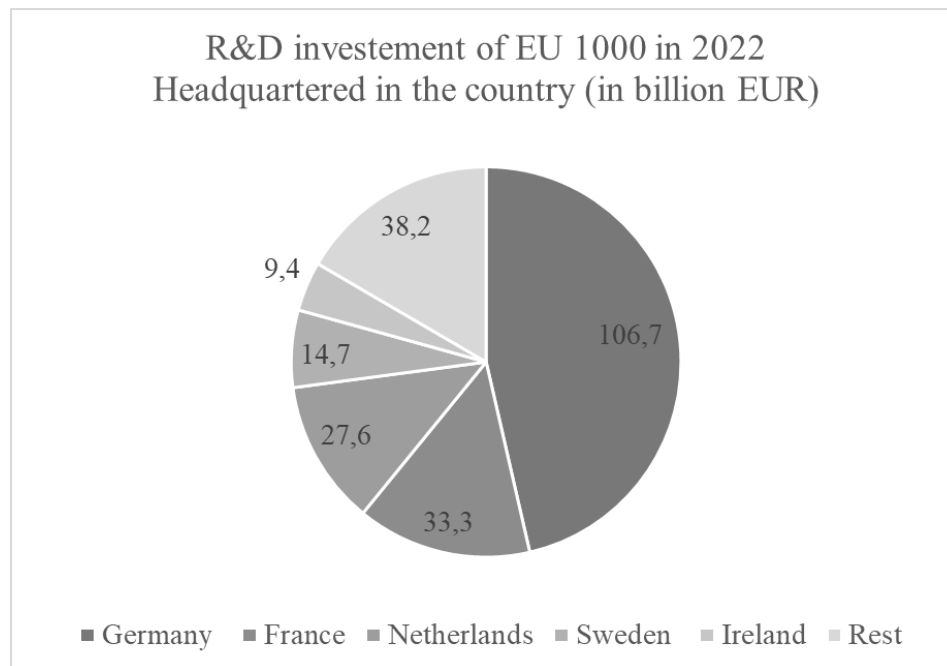


Figure I.1-1: R&D investments EU 1,000

(Author's own illustration based on European Commission. Joint Research Centre, 2023)

Current debates on R&D and innovation activities reveal that digitalization and sustainability dominate the socio-political and private sectors. The global appetite for sustainable development has been ignited by the United Nations Sustainable Development Goals (SDGs) adopted in 2015 (United Nations, 2015) and updated by annual reports (e.g., United Nations, 2023). These goals address several distinct topics that shape and direct research, development, and innovation for example, "affordable, reliable, sustainable and modern energy for all" (Goal 7) and "sustainable consumption and production patterns" (Goal 12). These goals explicitly address and call for action from firms "to apply their creativity and innovation to solving sustainable development challenges" (p. 34). Shortly afterward, international management research also recognized the need to contribute to solving these challenges (George et al., 2016).

In its new industrial strategy for Europe, the European Commission declares,

"Throughout its long history, industry has proven its ability to lead change. And it must now do the same as Europe embarks on its transition towards climate neutrality and digital leadership in an ever-changing and ever more unpredictable world. The **twin ecological and digital transitions** will affect every part of our economy, society and industry. They will **require new technologies, with investment and innovation** to

match. They will **create new products, services, markets and business models**. They will shape new types of jobs that do not yet exist which need skills that we do not yet have. And they will entail **a shift from linear production to a circular economy**." (European Commission, 2020, p. 1; author's emphasis)

This declaration shows the European Commission's effort to reconcile digitalization with the sustainability transition and to tackle both transitions together (Chatzistamoulou, 2023). This thesis aims to contribute to understanding these twin transitions and related industry solutions to the underlying current and pressing grand challenges.

Industrial business firms actively shape sustainability transitions by utilizing internal and external transformation processes (Delmas et al., 2019; Loorbach & Wijsman, 2013). Companies' market power creates excellent potential to contribute to the transitions to sustainability (Delmas et al., 2019). For example, socio-technical transitions research describes how radical innovations at the niche level might penetrate the socio-technical system if windows of opportunity emerge that enable adaptations of the whole system, including incumbents (Geels, 2019). Focusing on incremental innovation is risky in such settings (Loorbach & Wijsman, 2013). Although radical innovation also comes with significant challenges, such as high R&D investment requirements, appropriation difficulties, and tough competition with current solutions, sustainable transitions require groundbreaking innovation activities (Söderholm, 2020). Therefore, it may be concluded - as Cillo et al., (2019) revealed within their literature review - that sustainable innovations require disruptive change in products and processes to achieve sustainability goals since the incremental change in products, processes, markets, and values is not sufficient in itself.

Circular economy (CE) initiatives are one example of sustainability transitions that transcend firm and industrial borders to reshape resource consumption (Bertassini et al., 2021; Gandolfo & Lupi, 2021). Circularity challenges especially the business practices of established firms, such as industry incumbents, and involves technological innovation and supply chain collaboration (Bertassini et al., 2021; Gandolfo & Lupi, 2021; Sharma et al., 2021). Incumbents undergo a "fundamental shift" in business activities (Gandolfo & Lupi, 2021). According to Geisendorf and Pietrulla (2018), the core of a CE lies in maintaining the value of products and materials, avoiding waste, and keeping end-of-life products as resources within the economy (p. 779). The R-framework describes the primary principles of the CE, e.g., reduce, reuse, recycle, and recover (Kirchherr et al., 2017). Hence, CE initiatives help organizations achieve

sustainability goals (Sharma et al., 2021). The transition towards the CE involves coordinating with actors of the surrounding ecosystems, especially supply chain partners and the neighboring community (Asgari & Asgari, 2021). Finally, research has revealed that CE initiatives are strongly linked with innovation activities (Meili & Stucki, 2023; Prieto-Sandoval et al., 2018). Renewable and decentralized energy production and consumption are another prominent example of sustainability transitions involving radical innovations and novel industry structures (Lindberg et al., 2019; Weigelt et al., 2021).

Alongside sustainable development, digitalization is the second megatrend that is shaping companies and their innovation activities (PwC, 2024). While some studies discuss digital transition (e.g., Bianchini et al., 2023; Rosário & Dias, 2022), in the context of business digitalization, the concept of digital transformation is more commonly used (Guandalini, 2022; Konopik et al., 2022; Nambisan et al., 2019; Plekhanov et al., 2023). Although our understanding of digital transformation is fragmented with several definitions and subtle differences in meaning, broadly speaking digital transformation "highlights the process transition towards digitalization and therefore the increased use of digital technologies" (Guandalini, 2022, p. 441). Furthermore, digital transformation entails "organizational change triggered and shaped by the widespread diffusion of digital technology. The content of this change [...] comprises a move towards malleable organizational designs that are embedded in and driven by digital business ecosystems" (Hanelt et al., 2021, p. 1187). Firm boundaries become more permeable regarding external actors owing to stronger relationships and interaction patterns resulting in shared resources, value co-creation, and the emergence of digital ecosystems (Plekhanov et al., 2023).

As elaborated above, the innovation content regarding the twin transition addresses both digital and sustainable innovation, which incorporate green and circular innovation activity. These innovations significantly impact one's way of life and our future, but it is unclear what this future will look like, going forward. Hence, actors involved in or confronted by change and innovations such as new technologies must first perceive and interpret them. Therefore, this thesis builds on the theoretical perspective of framing and the resulting technological frames. Finally, the context of ecosystems is gaining increasing importance owing to the complexity of grand challenges and the ever-growing possibilities of digital technologies.

I.1.2 Research gaps and research questions

This thesis addresses several gaps in distinct research streams. While each article comprises a stand-alone explanation of the specific research gap and its purpose, a general and summarizing presentation of relevant research gaps follows at this point in the introduction. The various digital and sustainable innovations under consideration enable the introduction of new business models while at the same time bringing new challenges. Overall, digital and sustainable business model innovation continues to open up many research opportunities (Evans et al., 2017; Geissdoerfer et al., 2018; Schaltegger et al., 2012). Despite the growing body of research on business models for sustainability and digitalization, these areas remain largely disconnected. Recent studies are beginning to bridge this gap by exploring *digital sustainability (the content of innovation gap 1)*, where digital technologies enable business models that contribute to socioecological value and economic success (George et al., 2021; Guandalini, 2022). As *CE-oriented innovation* is still an emerging practice (*the content of innovation gap 2*), there is limited knowledge about the challenges and experiences of firms leading this transition (Piila et al., 2022). While previous research indicates that interorganizational collaboration is vital for CE success (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022), the mechanisms by which organizations can adapt existing collaboration patterns remain largely unexplored. Furthermore, the role of organizational structure in supporting or hindering CE implementation has been recognized, but there is insufficient research on how companies internally reorganize to facilitate this transformation (Eikelenboom & de Jong, 2022; Eisenreich et al., 2021). In particular, regarding *digital innovation (the content of innovation gap 3)*, researchers articulated open research questions regarding customer co-creation and the value creation from customer data in digital settings (Vaska et al., 2021), specific (digital) - technologies, including their application in sustainability-oriented contexts such as circularity (Ancillai et al., 2023; Vaska et al., 2021) - and the ecosystem perspective involving value creation with diverse actors (Ancillai et al., 2023; Shakeel et al., 2020).

Regarding the perception of innovation, there are two critical research gaps; the role of frames in sustainable business model innovation and the role of frame in(congruence) regarding ecosystem relationships. The theoretical perspective of perception, framing, and frames helps us to understand actors' cognitive interpretation processes and their impact on innovation activities (perception of innovation). While much valuable work on these interesting cognitive processes has been done in the past, knowledge is still incomplete. This thesis addresses three research gaps regarding technological frames. Many recent works of the technology frame

concept applications focus on digital technologies (Carlsson, 2023; Clausen et al., 2024; Keskin et al., 2024). However, today, as never before, digital and sustainability-oriented technological developments are relevant and challenging for society as a whole (e.g., energy, mobility, and solutions to pollution). It, therefore, seems logical to address the sustainability potential by observing the *role of frames in sustainable business model innovation (perception of innovation gap 1)*. Despite notable exceptions (Hahn et al., 2014; Scrase & Ockwell, 2010), the application of cognitive frames within sustainability research remains incomplete and presents opportunities for further study (De Giacomo & Bleischwitz, 2020; Lüdeke-Freund, 2020). Research on the perception of digital technologies in the context of sustainability transitions is still limited. This area presents a promising avenue for further investigation, as how organizations frame these technologies can significantly influence their business model innovation, value creation, and contributions to sustainability (De Giacomo & Bleischwitz, 2020; Lüdeke-Freund, 2020). Additionally, when disruptive technologies emerge, various actors within an ecosystem may develop different perceptions of these innovations, leading to divergent views. These perceptions, known as technology frames (Orlikowski & Gash, 1994; Spieth et al., 2021), can significantly influence how firms build relationships within ecosystems. Although technology frames have been extensively studied within organizations, *the role of frame in (congruence) regarding ecosystem relationships remains underexplored (perception of innovation gap 2)*. Scholars suggest expanding research to include intra- and inter-organizational aspects of sensemaking and sensegiving, particularly in terms of frame incongruence, which has been identified as a source of conflict (Orlikowski & Gash, 1994; Penttilä et al., 2020).

This thesis also addresses several interconnected research gaps regarding ecosystems. Ecosystems represent a critical research area for understanding technology-enabled changes that span industry boundaries. This broader perspective on value creation means that more and more diverse actors are gaining recognition in value creation (Ancillai et al., 2023; Shakeel et al., 2020), adding new roles such as complementors (Adner & Kapoor, 2010; Carst & Hu, 2023) and changing the roles from customers to prosumers (Rayna & Striukova, 2021; Wang & Yen, 2022; Weigelt et al., 2021). This first research opportunity regarding the *context of innovation (new actors, new roles)* is a recurring theme in this work, which aligns with the increasing relevance of strategic partnerships described above. Ecosystems and their emergence are relatively new research fields with many unanswered questions (Polese et al., 2021). While on the one hand, incongruent frames and resulting conflicts are often problematic, on the other

hand they may stimulate creativity and learning (Spieth et al., 2021). In the context of sustainability transitions, it is crucial to understand how framing and other legitimization processes support the creation of new meanings during the emergence of ecosystems (Bohnsack et al., 2024; Daymond et al., 2023; Snihur et al., 2022). This understanding is particularly relevant concerning established companies that engage in ecosystem emergence (L. D. W. Thomas et al., 2022). Hence, an exploration of *frame (in)congruence (context of innovation gap 2)* presents an opportunity to overcome difficulties during ecosystem emergence. While there is a consensus on the importance of collaboration in ecosystems for implementing sustainable and digital innovations alike (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022; Suchek et al., 2021), the *configuration between firms' internal organizing and external collaboration relationships* is still underexplored (*context of innovation gap 3*). The *roles of customers and their contributions to value co-creation* resulting from such new forms of collaboration within ecosystems is another critical gap (*context of innovation gap 4*). A vast body of literature highlights customers' role in value creation (Galvagno & Dalli, 2014; Nambisan & Baron, 2009; Ng et al., 2019) and the challenges of managing essential resources outside a firm (Hilton et al., 2013). Yet, there is a paucity of research on what customers contribute to value co-creation (Agrawal & Rahman, 2015). Furthermore, while interdependence and complementarity are fundamental ecosystem characteristics and thus shape resulting ecosystem roles, how the *implementation of digital (smart service) innovation in ecosystems* is dependent on actors' roles and the ecosystem evolution stages is less clear (*context of innovation gap 5*).

The synopsis is structured according to the conceptual framework that differentiates between the content of innovation, perception of innovation, and context of innovation. To use this structure as consistently as possible, the presented research gaps can be summarized based on the three perspectives (see Table I.1-2).

Based on the research gaps outlined previously, the research questions listed in the following Table I.1-3 are addressed. While Paper 1 answers three related research questions, the remaining articles each pursue one question. The research questions of paper one refer to two research gaps (content of innovation gap 1 and perception of innovation gap 1) and aim to understand how technological frames incorporate digital and sustainable perspectives and how these two distinct perspectives affect resulting business model innovation. The research question of Paper 2 links the mostly internal perspective of Paper 1 to the ecosystem level, focusing on the potentially sustainable technology of chemical recycling (without digital

components) by exploring how frame (in)congruence shapes ecosystem relationships. Paper 2 thus contributes to closing four of the earlier presented research gaps (content of innovation gap 2, perception of innovation gaps 2 and 3, context of innovation gap 2).

Table I.1-2: Research gaps

Content of innovation	Perception of innovation:
• Digital sustainability (digital and sustainable innovation) (<i>Paper 1</i>) • Sustainable and circularity-oriented innovation (<i>Papers 2, 3</i>) • Digital innovation (<i>Papers 4, 5</i>)	research gaps concerning theoretical perspective of framing • Role of frames in sustainable business model innovation (<i>Paper 1</i>) • Potential effects of frame (in-)congruence and relationships in ecosystem emergence (<i>Paper 2</i>)
Context of innovation: research gaps concerning theoretical perspective of ecosystem	
• New actors, new roles in ecosystems (<i>Paper 1</i>) • Potential effects of frame (in-)congruence in ecosystem emergence (<i>Paper 2</i>) • Organizational configuration of internal elements and external ecosystem (<i>Paper 3</i>) • Customer roles and customer contribution in ecosystem value co-creation (<i>Paper 4</i>) • Innovation implementation in ecosystems (<i>Paper 5</i>)	

(Author's own illustration)

Paper 3 continues the focus on sustainable innovation and ecosystem collaboration of Paper 2, but examines the general internal organization instead of the perspective of technology perception. Therefore, the research question “How do established firms of the plastics industry reorganize internally and externally toward achieving circularity?”, relates to content of innovation gap 2 and context of innovation gap 3. The remaining two research questions combine a focus on digital technologies with the ecosystem perspective (Paper 4: Which customer roles emerge in digital business ecosystems according to customers’ resource contribution to value creation?; Paper 5: Which customer roles emerge in digital business ecosystems according to customers’ resource contribution to value creation?). In this way, they contribute to closing the gaps content of innovation 3, context of innovation 4 and 5.

Table I.1-3: Research questions and their theoretical perspective

		Theoretical perspective:	Content of innovation		Perception of innovation	Context of innovation
	Research questions:		Digital	Sustainable		
Paper 1	- How do incumbent companies in the German energy sector frame currently emerging digital virtual power plant technologies? - Which role do digitalization and sustainability considerations play in their technological frames? - How do differences in incumbents' technological frames affect the design of sustainable value propositions and, as a consequence, the sustainability implications at the company and the broader societal level?	(x)	(x)	(x)		
Paper 2	How do frame congruence and incongruence, respectively, shape ecosystem relationships in an emerging ecosystem regarding chemical recycling?			(x)	(x)	(x)
Paper 3	How do established firms of the plastics industry reorganize internally and externally toward achieving circularity?			(x)		(x)
Paper 4	Which customer roles emerge in digital business ecosystems according to customers' resource contribution to value creation?	(x)				(x)
Paper 5	How do different ecosystem characteristics, the smart service design and the company's ecosystem position interact at the implementation of smart services in ecosystems?	(x)				(x)

(Author's own illustration)

I.1.3 Structure of thesis

A presentation of the conceptual framework of the dissertation follows this introduction to the topic. The conceptual framework consists of three sections. As an introduction to Chapter I.2, the theoretical ideas and assumptions that implicitly and explicitly inform this thesis are discussed. Subsequently, the understanding of innovation content is clarified (Chapter I.2.1). Secondly, the perception of innovation is introduced through the perspective of framing and the resulting frames (Chapter I.2.2). The third part of Chapter I.2 deals with the context of current innovation activities that increasingly take place in ecosystems. For this purpose, the term ecosystem is defined, and relevant theoretical foundations are presented.

The section on the theoretical framework is followed by an explanation and reasoning for the qualitative approaches adopted in this dissertation (Chapter I.3.1). Additionally, to these remarks on methodology a comment on the empirical contexts of the included works summarizes the entirety of the data basis of this thesis (Chapter I.3.2).

The introduction concludes with a summary of all the individual scientific papers (Chapter I.4). This summary points to the main part of the thesis (Chapter II), which comprises five included papers. The presentation of each scientific work begins with a note on its publication status at the time of submission of this thesis and, if applicable, a formal copyright note. Finally, contributing authors and related conference papers are mentioned in this note. The structure within the individual papers is based on established scientific practice. First, an abstract concisely overviews the research question, methodology, and results, and this is followed by the main body of the paper. Figures and tables are transferred to the dissertation format as copyright allows. Each article concludes with its own bibliography.

The second part of the synopsis, in the form of an epilogue, follows this main section (Chapter III). The epilogue begins with a summary of the core results of the work presented individually in the preceding main part. Subsequently, the author's contribution to the research is highlighted and incorporated into the existing discourse. Finally, there is a summary of central limitations along with an explanation of the possibilities for future research arising from these limitations. The thesis concludes with the list of references for the synopsis (prologue and epilogue).

I.2 Conceptual framework: Relevant perspectives on innovations in ecosystems

Research into the phenomenon of innovation has always been conducted by various disciplines and from numerous perspectives (Gopalakrishnan & Damanpour, 1997; Naeini et al., 2022). For instance, Harmancioglu et al. (2009) have identified adoption/diffusion theory and the resource-based view as the two dominant theories in innovation research, while relationship management is recognized as an emergent theoretical perspective (see Table I.2-1). Although adoption and diffusion research explains the organizational and individual intention to adopt innovations, the resource-based view argues that a bundle of superior resources creates a competitive advantage stemming from cost reduction or differentiation, resulting in superior firm performance (J. B. Barney et al., 2021; Harmancioglu et al., 2009; Kleinschmidt et al., 2007). Though assumptions of the resource-based view implicitly inform theoretical arguments throughout this thesis, it is enriched with the theoretical perspective of the emergent relationship-oriented research stream. The introduction will now explain this dissertation's relevant theoretical frameworks and perspectives, aiming to furnish a foundation for the individual papers in the main section.

Table I.2-1: Theoretical underpinnings in innovation research

Review of 238 articles published in journals with some focus on innovation research	
Adoption and diffusion theory of innovation (78 articles)	Resource-based view with contingency theory (160 articles)
• Focus on (individual) adoption and usage • Core constructs: Behavioral intention, perceived usefulness, perceived ease of use	• Superior internal resources and capabilities create competitive advantage • Resources and capabilities have to fit with external conditions (contingency) • External orientation (partnering) may reduce uncertainty
Emerging theoretical research stream: Innovation through relationship management	
• Driven by increased complexity and cost • Early examples: Strategic collaborations, joint new product development, and networks	

(Author's own illustration based on Harmancioglu et al., 2009)

According to the review of 238 research articles on innovation management, the resource-based view constitutes the dominant research paradigm, with 160 articles implicitly or explicitly referring to its theoretical arguments (Harmancioglu et al., 2009). Resource-based theory assumes that firms possess heterogeneous bundles of resources and that this heterogeneity may

persist over time (J. B. Barney & Arikan, 2005). Although resources and capabilities can be distinctly defined (Ford & Friesl, 2019; Friesl & Silberzahn, 2017; Konopik et al., 2022), they also can be used as synonyms (J. B. Barney et al., 2021). Hence, the resources are "the tangible and intangible assets firms use to conceive of and implement their strategies" (Barney & Arikan, 2005, p. 137). In his seminal publication, Barney lists the three resource categories: physical resources, human capital resources, and organizational resources (J. Barney, 1991). According to Barney, human capital resources cover the experience, knowledge, and relationships of individuals, while organizational resources span formal structures and relationships among groups within a firm and with external actors. Newbert (2007) provides an overview of the resources, capabilities, and competencies studied. When considering resources, in order to enable the creation of a competitive advantage, they have to be valuable and rare. If it becomes additionally costly or complicated to imitate the resources, and if they are unable to be substituted, the competitive advantage will be sustainable because firms can defend their superior position in competition over longer periods (J. B. Barney et al., 2021; J. B. Barney & Arikan, 2005).

Although the resource-based view has also attracted criticism (e.g., Priem & Butler, 2001), it is one of the most influential theories in management research for explaining the success of firms (Harmancioglu et al., 2009; Newbert, 2007). Ideas for further development are valuable due to the numerous empirical evidence for the explanatory power of the resource-based view. Two recently discussed ideas about further development of the resource-based view concerning the integration of networks and stakeholders are of particular interest. Although relatively few studies combine the perspective of a network with the resource-based view (Burt & Soda, 2021), there are several approaches to how people and relationships can be considered. Some approaches understand people and relationships themselves as resources (for a critical discussion, see Freeman et al., 2021); however, stakeholders can be integrated relatively easily into the explanatory mechanisms as the actors exercising control over resources (J. B. Barney et al., 2021; Freeman et al., 2021). Papers 2, 3 and 4 implicitly assume this control over resources and explore the resulting collaboration between firms, as well as firms and customers.

These ideas regarding control over resources correspond well with the research stream known as relationship management in innovation research (Harmancioglu et al., 2009). Nambisan et al. (2017) argue that the increasing relevance of digitalization and the associated distributed innovation activity signifies the following: Theories of innovation management should seek to

explain how companies can organize innovation when collaborating actors are diverse and undefined, and how these collaborating collectives form, develop, and contribute to innovation activity. Hence, several fundamental questions arise: "How do innovations form/evolve? How should actors/entities organize for innovation? How [do] the nature of innovation and the organization of innovation interact?" (Nambisan et al., 2017, p. 224).

An early focus of the work within the relationship-oriented perspective was on collaborations so-called strategic alliances. Strategic alliances refer to contractual relationships and non-contractual agreements between two or more companies for the joint development and commercialization of new technologies, including the resulting emerging organizational forms such as joint ventures (Teece, 1992). In the academic literature, these joint development activities are viewed from numerous theoretical perspectives, involving different explanations for their occurrence (Dacin et al., 2007; He et al., 2020; P. R. Varadarajan & Cunningham, 1995). There seems to be a consensus that the formation of strategic alliances is often linked to gaining a competitive advantage and the possibility of sharing costs and risks (Teece, 1992); however, different theoretical perspectives highlight different causal explanations of how firms achieve their individual and collective goals. For instance, companies involved in strategic alliances gain access to resources (resource-based view; e.g., Aggarwal, 2020; Das & Teng, 2000), knowledge, and the opportunity to learn (knowledge-based view; e.g., Grant & Baden-Fuller, 2004; Hamel, 1991; Mowery et al., 1996) or legitimacy with third parties (Dacin et al., 2007). Despite the many explanatory approaches that favor strategic alliances, the numerous risks and drawbacks of collaboration create difficulties for firms to achieve their desired goals (Das & Teng, 1999, 2001; Kotabe & Scott Swan, 1995).

Since there are various forms of organizing strategic alliances, not surprisingly, one stream of research has focused on the optimal relational and equity-related arrangements in strategic alliances (Elmuti & Kathawala, 2001; Todeva & Knoke, 2005). Nevertheless, contingency theory suggests there is no single best way because the optimal solution depends on situation-specific internal and external factors (He et al., 2020). Interestingly, complementary technologies and assets are relevant to innovation success, as seen in the early literature on strategic alliances (Teece, 1992). Accordingly, a mutual interdependency can exist between the successful commercialization of different innovations. Since the complementarity of innovation activity is also a central argument for the ecosystem perspective (Adner, 2017; Gomes et al., 2021; Jacobides et al., 2018), it is not surprising that the emergence of ecosystems makes new

theoretical developments appear necessary, which assumes the arguments of the strategic alliance literature, rethinking and redeveloping them through further thought (He et al., 2020).

One central assumption of the strategic alliance research stream has been questioned, that one firm's alliance is independent of its other alliances (Koka & Prescott, 2002). If the two alliances were independent, there would be no knowledge flow or resource exchange between the partners. In business reality, however, an actor may acquire knowledge and other resources from one partner and then pass it on to another (Koka & Prescott, 2002). Hence, it is necessary to consider the social context to a greater extent (Fliaster & Spiess, 2008; Gulati et al., 2011). Social capital represents the sum of actual and potential resources that are available through an organization's network relationships, and it can be described based on a structural (e.g., ego network size, structural holes, tie strength, and centrality), relational (e.g., trust and norms), and cognitive dimension (shared understanding) (Nahapiet & Ghoshal, 1998; Zheng, 2010). The positive impact of social capital on the technical value of innovations is significantly more prominent than that of other organizational and human resources (Meyer, 2023). Indeed, managing knowledge mobility is essential when orchestrating innovation networks (Dhanaraj & Parkhe, 2006; Fliaster & Golly, 2014; Fliaster & Sperber, 2020). Thus, social capital complements internal investments in research and development because it enables knowledge transfer, supporting organizational growth and innovation performance (Laursen et al., 2012; Maurer et al., 2011).

Now that the most relevant theoretical assumptions have been presented, it is necessary to introduce the central concepts and their relationships based on pertinent perspectives to develop a coherent theoretical framework. An overview of the perspectives and concepts outlined below is shown in Figure I.2-1. One perspective, the process perspective, is often the basis for understanding innovation activities (Adams et al., 2006; Bucherer et al., 2012; Gopalakrishnan & Damanpour, 1997; Mendoza-Silva, 2021; Tidd, 2021). Innovation activities can be divided into successive sub-activities such as idea generation, screening, experimentation, development, and commercialization (Truong & Papagiannidis, 2022). From the process perspective, innovation activities aim to transform inputs into innovation performance (e.g., Brown & Svenson, 1988; Geyer-Klingenberg & Steinmann, 2015; Möller & Janssen, 2009), and this transformation takes place in two steps. First, the processing system transforms inputs into innovation outputs such as new processes, products, and knowledge. Second, a company must create value from these outputs, e.g., realize cost reductions or increase sales. This second step

happens in the receiving system. Hence, the process perspective is the basis for considering inputs, determinants, or antecedents of innovation activities, as well as the resulting outputs (innovation and intellectual property rights) and outcomes. Further prominent outputs of innovation activity entail degrees and types of innovation (Bucherer et al., 2012; Gopalakrishnan & Damanpour, 1997; Horn & Brem, 2013; Mendoza-Silva, 2021; Tidd, 2001). This framework is delineated along distinct theoretical viewpoints on innovation and central concepts.

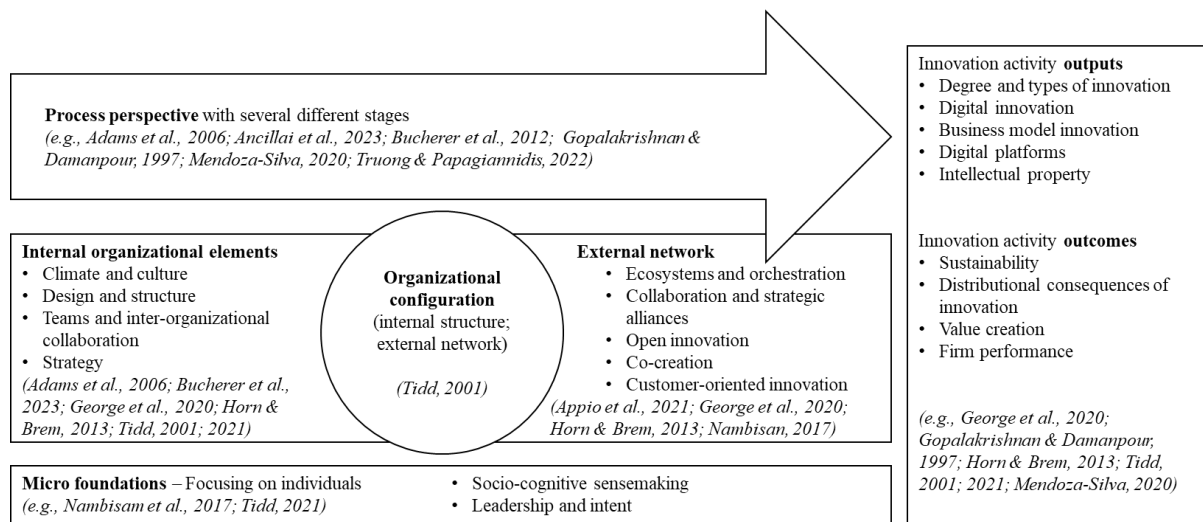


Figure I.2-1: Theoretical viewpoints and concepts in innovation research
(Author's own illustration based on mentioned reviews and editorials)

This dissertation explores how companies may succeed in generating and implementing innovations. Hence, it will expound upon the scope of innovation under scrutiny, encompassing digital and sustainable innovation. Subsequently, this work will delineate the perspective of perception and socio-cognitive sensemaking, and will briefly clarify its relevance to innovation and technology in more detail. Hence, this work will also examine socio-cognitive sensemaking (Nambisan et al., 2017) and individual roles, intent, and goals (Tidd, 2021), which are micro foundations of innovation activity, as this micro foundation perspective of technology and innovation complements the resource-based view (Benner & Tripsas, 2012; Palmié et al., 2023). Additionally, to explain innovation activities in an organizational context, the organizational configuration (Tidd, 2001) becomes relevant, as it entails both the intra-organizational

perspective and the inter-organizational perspective. Finally, this dissertation will introduce the selected theoretical organizational context of ecosystems.

I.2.1 Content of innovation: Digital and sustainable innovation

Early understandings of innovation go back to Schumpeter, who described innovation as a new combination (Hagedoorn, 1996; Schumpeter & Backhaus, 2003). Another understanding of innovation emerged back in the 1960s (Aiken & Hage, 1971). Thompson states, "By innovation is meant the generation, acceptance, and implementation of new ideas, processes, products or services. Innovation therefore implies the capacity to change or adapt" (Thompson, 1965, p. 2). In subsequent years, the understanding of innovation as the application of new ideas has become more firmly established (Adams et al., 2006).

Damanpour has coined another prominent definition,

"An innovation can be a new product or service, a new production process technology, a new structure or administrative system, or a new plan or program pertaining to organizational members. Thus, innovation is defined as adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization" (Damanpour, 1991, p. 556).

In addition to the first-time application of a new idea, the usefulness of this idea for solving a problem is central to the definition of innovation. For example, Amabile links creativity with innovation,

"Creativity is the production of novel and useful ideas in any domain. In order to be considered creative, a product or an idea must be different from what has been done before. (Few creativity theorists hold the strong position that a creative idea must be completely unique.) But the product or idea cannot be merely different for difference's sake; it must also be appropriate to the goal at hand, correct, valuable, or expressive of meaning. Innovation is the successful implementation of creative ideas within an organization." (Amabile, 1996, p. 2).

Innovation has numerous definitions and different types, but the overarching core of innovation can be described as "the implementation of a novel idea into a new product, process, or practice, or significant improvement of an existing product, process, or practice that creates value for the stakeholders" (Varadarajan, 2024, p. 8). This definitional understanding is also the basis of this thesis. Hence, an **innovation** is the implementation of a new and useful idea in, for example, technologies, products, production processes, business models, or administrative processes and organizational structures.

In particular, the consideration of usefulness as a defining characteristic also depends significantly on the content of the innovation activity. Therefore, the following section deals with the innovation content that is central to this work. As previously mentioned, the two currently most relevant objectives of innovation activities are digital and sustainable innovations.

Regarding **digital innovation**, it can be defined by referring to Schumpeter's understanding of innovation, who describes it as a new combination. For example, Yoo et al. (2010) take that further, defining digital innovation specifically as "the carrying out of new combinations of digital and physical components to produce novel products. [...] the new combination relies on digitization, i.e., the encoding of analog information into digital format" (p. 725). Concurrently, Nambisan et al. (2017) define digital innovation as

"the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology. [...] in digital innovation, digital technologies and associated digitizing processes form an innate part the new idea and/or its development, diffusion, or assimilation." (p. 224).

In their recent review of 227 articles, Hund et al. (2021) describe digital innovation in a similar fashion as "the creation or adoption, and exploitation of an inherently unbounded, value-adding novelty (e.g., product, service, process, or business model) through the incorporation of digital technology" (p. 6). Here, information attributes represent the physical product component in the digital realm (R. Varadarajan, 2024). Even though the concept of digital innovation shows a product focus on cyber-physical combinations, it has to be differentiated from information-technology innovation and information systems innovation that focus on the adoption and application of innovation (Kohli & Melville, 2019; Lee & Berente, 2012).

In general, digital innovation can be distinguished by two unique characteristics: generativity and convergence (Bogers et al., 2022; Lyytinen et al., 2016; Yoo et al., 2012; X. Zhang et al., 2017). In the case of digital technologies, the fundamental characteristic of *generativity* strengthens their power as an ecosystem-shaping force. The generativity of technologies generally means their "overall capacity to produce unprompted change driven by large, varied, and uncoordinated audiences" (Zittrain, 2006, p. 1980). According to Yoo et al. (2012), generativity highlights that digital technologies are inherently dynamic and malleable. Examples of technologies that are considered particularly generative are the internet, artificial intelligence, and big data. Still, generativity is not an exclusive attribute of digital technologies because it also characterizes, for example, nanotechnologies and genome editing (Dattée et al.,

2018). Recent works on digital innovation, however, argue that digital technologies show significantly higher generativity than non-digital technologies (Bogers et al., 2022; Leiponen et al., 2022; Lyytinen et al., 2018). Generativity cannot be narrowed down to a mere technical dimension but is rather a socio-technical concept (Bygstad, 2017; Cennamo & Santaló, 2019): Although different technologies offer fundamentally different potentials for generativity, the interactions of people with each other and with technology realize these potentials in actuality (Msiska & Nielsen, 2018).

Additionally, the characteristic of the *convergence* potential of digital technologies contributes to the interaction of previously unconnected industries, user experiences, and non-digital artifacts (Yoo et al., 2012), thus emphasizing the need for new organizing logic such as servitization, open innovation, and ecosystem innovation (Ciriello et al., 2018; Legner et al., 2017; X. Zhang et al., 2017). Yoffie (1996, p. 33) defines convergence as "the unification of functions – the coming together of previously distinct products which employ digital technologies." Further, "innovating digitally means innovating products, processes, or business models using digital technology platforms as a means or end within and across organizations" (Ciriello et al., 2018, p. 564). Digital innovation activities entail initiating, developing, implementing, and exploiting digital technology (Kohli & Melville, 2019). This definition of digital innovation activity implies that digital technology is the foundation and at the same time the result of such innovation activities, blurring the distinction between digital product and process innovation (Urbinati et al., 2022). Thus, ecosystems as collaborative arrangements emerge around digital technologies and entail the power to change market structures (Nambisan et al., 2019; Svahn et al., 2017).

The second topic that determines innovation activities besides digital technologies is sustainability. One definition of sustainable development, which is still decisive today, states sustainable development

"ensure[s] that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. But technology and social organization can be both managed and improved to make way for a new era of economic growth. The Commission believes that widespread poverty is no longer inevitable" (United Nations, 1987, paragraph 27).

This definition lays the foundation for the three important dimensions of sustainability. (1) The social dimension relates in particular to justice. This includes justice in the present by avoiding poverty, and justice between different generations by considering the interests of future generations. (2) The ecological dimension is reflected in the consideration of planetary boundaries (limited resources and negative environmental impacts). (3) The economic dimension is taken into account in particular by mentioning growth and technological improvement. The triple bottom line, another common conceptualization, introduced by Elkington in the 1990s, highlights that sustainability holistically addresses these three interconnected dimensions economic prosperity, environmental quality, and social justice (Elkington, 1994; Henriques & Richardson, 2013). Hence, **sustainable innovation** "improves sustainability performance, where such performance includes ecological, economic, and social criteria" (Boons et al., 2013, p. 2). This implies that the consideration of sustainability further specifies the defining usefulness criteria of innovation activity.

In the meantime, several concepts are used that are similar or synonymous with sustainable innovation, such as green innovation, eco-innovation, and social innovation (Boons & Lüdeke-Freund, 2013; Carrillo-Hermosilla et al., 2010; Hermundsdottir & Aspelund, 2021). A closer examination of the definitional basis reveals that these terms emphasize parts of sustainable innovation activities. Green and eco-innovation focus on the ecological dimensions and the third one stresses the social dimension. Green or eco-innovations "reduce the environmental impact caused by consumption and production activities, whether the main motivation for their development or deployment is environmental or not" (Carrillo-Hermosilla et al., 2010, p. 1073). Strictly speaking, therefore, these concepts are not synonymous but are rather linked to sustainable innovation. Summarizing, the defining characteristic of sustainable innovation is the implementation of an idea for a new product, process, or practice that enables value creation for societal stakeholders by causing fewer negative effects on the natural environment than previous products, processes, or practices (R. Varadarajan, 2024).

Significantly, the intersection between digital technologies and sustainability is also gaining increasing attention in the scientific debate. A number of recent reviews explore the upcoming research stream of digital sustainability (Cricelli & Strazzullo, 2021; Feroz et al., 2021; Guandalini, 2022; Rosário & Dias, 2022). George et al. (2021, p. 1000) define **digital sustainability** as "as the organizational activities that seek to advance the sustainable

development goals through creative deployment of technologies that create, use, transmit, or source electronic data."

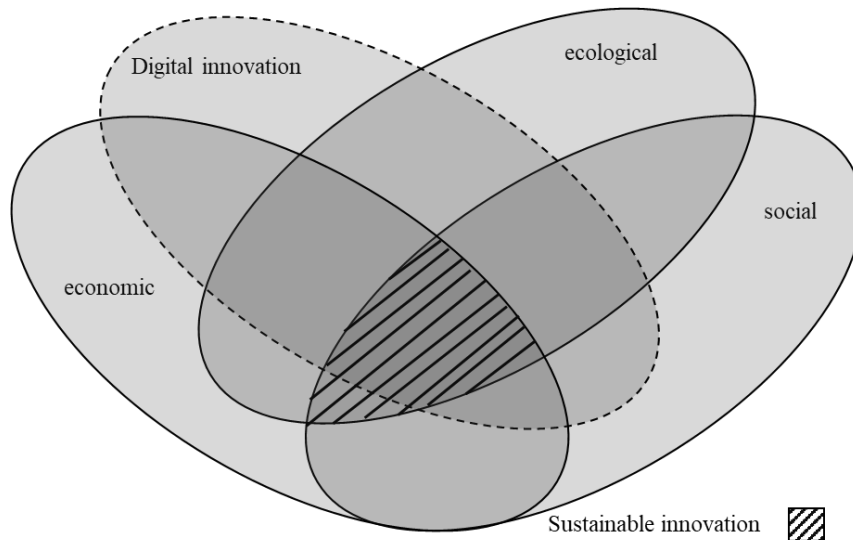


Figure I.2-2: Intersections of innovation types
(Author's own illustration)

Taking into account Amabile's definition of innovation mentioned above (Amabile, 1996), this definition of digital sustainability can be understood as an innovation activity. The research strand of digital sustainability represents a symbiosis of the objectives of sustainability and digitalization in order to make a positive contribution to society and the environment (Guandalini, 2022). While sustainable innovation may happen with or without the integration of digital technologies, digital sustainability lies at the intersection of digital and sustainable innovation (see Figure I.2-2).

Finally, due to the explained new value creation logic of digital innovation, the idea of the business model (BM) has emerged (Afuah & Tucci, 2003; Magretta, 2002). The BM captures the story that explains an enterprise, by providing answers to questions such as "Who is the customer? And what does the customer value? [...] How do we make money in this business? What is the underlying economic logic that explains how we can deliver value to customers at an appropriate cost?" (Magretta, 2002, p. 4). More abstract, the BM depicts "the rationale of how an organization (a firm or other type of organization) creates, delivers, and captures value (economic, social, or other forms of value) in relationships with a network of exchange

partners" (Massa & Tucci, 2014). This definition builds on early understandings of BMs (Afuah & Tucci, 2003; Osterwalder et al., 2005; Zott et al., 2011), yet the discussion of a BM's constitution continues beyond the presentation of this definition, as BMs are viewed from different perspectives and with different objectives (Geissdoerfer et al., 2018; Massa et al., 2017). Nonetheless, most definitions involve value creation (resources and processes), value delivery (products and services, environment), and value appropriation or capture (costs and revenues) (Ancillai et al., 2023; Shakeel et al., 2020; Sorescu, 2017; Teece, 2010).

Taking this concept further, business model innovation (BMI) is the sum of business model design (the creation of new business models) and business model reconfiguration (modification of an existing business model) involving new and unique features (Massa & Tucci, 2014). Mapping tools such as the business model canvas support the formulation of BMI ideas (Osterwalder et al., 2010), as BMI involves changing internal processes that are not fully depicted in well-known mapping tools and, hence, need experimentation (Chesbrough, 2010).

The explanations in this section have shown that innovation involves the application of new and useful ideas inside a company or the introduction of ideas as new products and services to the market. Digital and sustainable innovations are currently of particular relevance, and the emergence of digital technologies in particular has supported the emergence of the BMI perspective. Because novelty is a fundamental characteristic of innovation, emerging technologies, products, and services must initially be perceived and interpreted by the actors involved. This interpretation will be decisive for the use and the associated application of the innovation. Research on the perception and interpretation resulting from innovation will therefore be explained in the next section.

1.2.2 Perception of innovation: Technology frames and framing

Cognition theory builds on ideas from philosophy, neurosciences, linguistics, and psychology, among others, and can be described as a "theory of managerial knowledge" (Stubbart, 1989). The origin of research on cognition in organizations relies on the assumption that the actions of companies depend on a manager's interpretation of a complex and uncertain environment, resulting in frames or mental models (Kaplan, 2011; Porac & Thomas, 1994). According to the resource-based view, companies with superior resources were expected to be successful (J. B. Barney et al., 2021; Harmancioglu et al., 2009); however, researchers have revealed that cognition is an equally important explanation for success and failure in changing conditions

(Tripsas & Gavetti, 2017). Further, there is a long tradition of innovation adoption studies that explain adoption decisions according to an individual's perception of the innovation and its attributes (Ostlund, 1974; Rogers, 1962, 2003). Since its introduction, cognition theory has influenced a variety of theoretical currents within innovation management, such as BMI (Schneckenberg et al., 2022; Shepherd et al., 2023) and change management (Fox et al., 2024; Rajagopalan & Spreitzer, 1997). The following section provides a concise overview of relevant theoretical perspectives, that can be categorized as cognition theory. Furthermore, the delimitation of the different perspectives is discussed.

According to the Oxford English Dictionary, cognition is

“The action or faculty of knowing taken in its widest sense, including sensation, perception, conception, etc., as distinguished from feeling and volition; also, more specifically, the action of cognizing an object in perception proper.

A product of such an action: a sensation, perception, notion, or higher intuition¹.”

This definition, which consists of two aspects including actions and resulting products, corresponds to the scientific understanding. Scientific literature also summarizes the process of taking in, organizing, filing, and using information as well as the resulting structures such as patterns, categories, or systems under cognition (Cropley, 1999). For example, "sensemaking" captures how people create interpretations and (re-)construct meaning (D. A. Gioia & Chittipeddi, 1991; Weick, 1995). Hence, while making sense of events, their environment, or technology, organizational actors create frames of reference on a recurring basis (Cornelissen & Werner, 2014; Maitlis & Christianson, 2014). The resulting frames subtly direct managerial attention to some aspects and divert it from others (Edmondson, 2003). Thus, frames reduce the mental load and the perceived complexity by providing plausibility on the cost of accuracy (Kaplan, 2008; Kaplan & Tripsas, 2008; van Burg et al., 2014; Weick et al., 2005). In the meantime, several terms with similar meanings, such as "cognitive frame", "technological frame", "schema", and "category" have emerged in the various literature streams to capture the result of cognitive processes (Kaplan, 2011).

A distinct strand of research focuses on the sensemaking of technologies resulting in technological frames (Davidson, 2002; Ghobadi & Mathiassen, 2023; Orlikowski & Gash, 1994). The concept of the technology frame builds on the literature on the social construction of technology (SCOT, Keskin et al., 2024). In their work introducing this perspective, Bijker &

¹ https://www.oed.com/dictionary/cognition_n?tab=meaning_and_use#9078506

Pinch (1987) use the example of the development of bicycles to show that technological development is not clear-cut or linear. Instead, different social groups develop their own understanding of problems, solutions, and designs; thus, the SCOT shapes a process of variation and selection. A detailed discussion on the development of the SCOT literature shows that the original perspective has evolved over the last thirty years through its confrontation with criticism, but the unique approach has also been somewhat watered down in the process (Basu, 2023).

One focus of this thesis is technology frames within inter- and intra-organizational contexts (Davidson, 2002; Kaplan & Tripsas, 2008; Orlikowski & Gash, 1994; Spieth et al., 2021). Technology frames are "that subset of members' organizational frames that concern the assumptions, expectations, and knowledge they [organizational actors] use to understand technology in organizations" (Orlikowski & Gash, 1994, p. 178). These frames hold the actors' interpretation of technology and, hence, enable actors to compare and evaluate technologies (Kaplan & Tripsas, 2008).

The concept of technology frames, introduced in early works, already includes the idea of frame congruence (Orlikowski & Gash, 1994). Congruent frames occur when multiple actors share similar perceptions of technology. In contrast, incongruent frames arise when actors interpret the same technology differently (Azad & Faraj, 2008; Young et al., 2016), leading to "conflicting views" (Saarikko et al., 2020). In summary, past research indicates that incongruent technology frames are particularly problematic when they either go undetected or are ignored. On the one hand, high frame congruence is linked with transaction cost reductions, enhanced technology implementation speed, and higher user satisfaction due to homogeneous behaviors and fewer conflicts (Azad & Faraj, 2008; McGovern & Hicks, 2004; Shaw et al., 1997; Young et al., 2016). On the other hand, incongruence is argued to cause low adoption rates, missed benefits, and negative effects on implementation projects (Lundberg et al., 2022). Paper 1 uncovers congruence for the nature of technology and incongruence regarding strategy and use among energy companies of several ecosystems. Since subdomains contain distinct aspects of technology perception, Paper 2 explores the interplay between relationships and different forms of frame (in)congruence within an emerging ecosystem.

In addition to the cognitive perspective described above, frames can also be viewed from a strategic communication-oriented perspective rooted in social movement theory as the result of framing processes (Clausen et al., 2024; Kaplan, 2008). Framing in this perspective is

understood as a rhetorical strategy "with intent to represent the issue in a certain light and invite others to see it in this light; for example, in positive or negative terms or with certain associations and connotation" (Barrett et al., 2013, p. 207). Similarly, in research on social movements and collective action, framing "involves the generation of interpretive frames that not only differ from existing ones but that may also challenge them" (Benford & Snow, 2000, p. 614) and "captures the processes by which actors influence the interpretations of reality among various audiences" (Fiss & Hirsch, 2005, p. 30). Hence, framing shapes the prevailing frames in public discourse by relating them to existing institutional structures (e.g., ideas and expectations, regulation, and standards) and by defining the relationships between actors to forming coalitions or causing conflicts (Kaplan, 2008; Markard et al., 2016). The resulting theoretical framework connecting framing, frames, (in)congruence, and results is depicted in Figure I.2-3.

Although research into frames is currently making progress - for example the emotional dimension of technology frames is increasingly being addressed alongside the cognitive dimension (Arnold et al., 2022; Keskin et al., 2024) - there are still avenues for future research and unanswered questions. First, while early works on frames explicitly acknowledge the relevance of the external social environment (e.g. Kaplan & Tripsas, 2008), many current studies on technological frames examine an intra-organizational context (e.g., Carlsson, 2023), which seems to be neglecting the growing impact of relationships and resources external to the firm. It is, therefore, worthwhile both for the further development of theory and for business practice to better understand how frames and their (in)congruence work in contexts that cross company boundaries, such as partnerships and ecosystems (Hsu, 2009; Young et al., 2016). Furthermore, much of the recent application of the technology frame concept has focused on digital technologies (Carlsson, 2023; Clausen et al., 2024; Keskin et al., 2024). This may be explained by the fact that relevant and pioneering work has chosen this context (Orlikowski & Gash, 1994) and, as described above, digital innovation is associated with particular challenges. However, today, as never before, digital developments as well as sustainability-oriented technological developments are relevant and challenging for society as a whole (e.g. energy, mobility, solution to pollution). Therefore, it seems logical not only to consider digital technologies but also to address the sustainability potential of technologies from the perspective of frames.

In fact, some groundbreaking work can be used here as an additional basis, which particularly deals with the framing of sustainable technologies. For example, biogas plants have been contextualized with existing institutional structures, which means they have been framed as a technology for sustainable agriculture and waste recycling or a threat to conventional farming (Markard et al., 2016). Certain technological-focused framing mechanisms (substitute, pioneer, complementary frames) and (mis)alignments reflect conformity with social, political, and economic rules such as demarcation frames and are provided to help overcome lock-ins in electric vehicle diffusion (Bohn & Rogge, 2022). Another framing strategy lies in trade-off frames that compare costs and risks to the benefits of different technologies, for example, framing nuclear energy as less risky than fossil energy due to the emissions of fossil contributing to climate change (de Vries, 2017; Du & Han, 2020; Pralle & Boscarino, 2011). Another example relates to framing renewable, decentral energy technologies as degrowth-technologies that fit into a pessimistic energy future (Metze, 2018; Veenman et al., 2021).

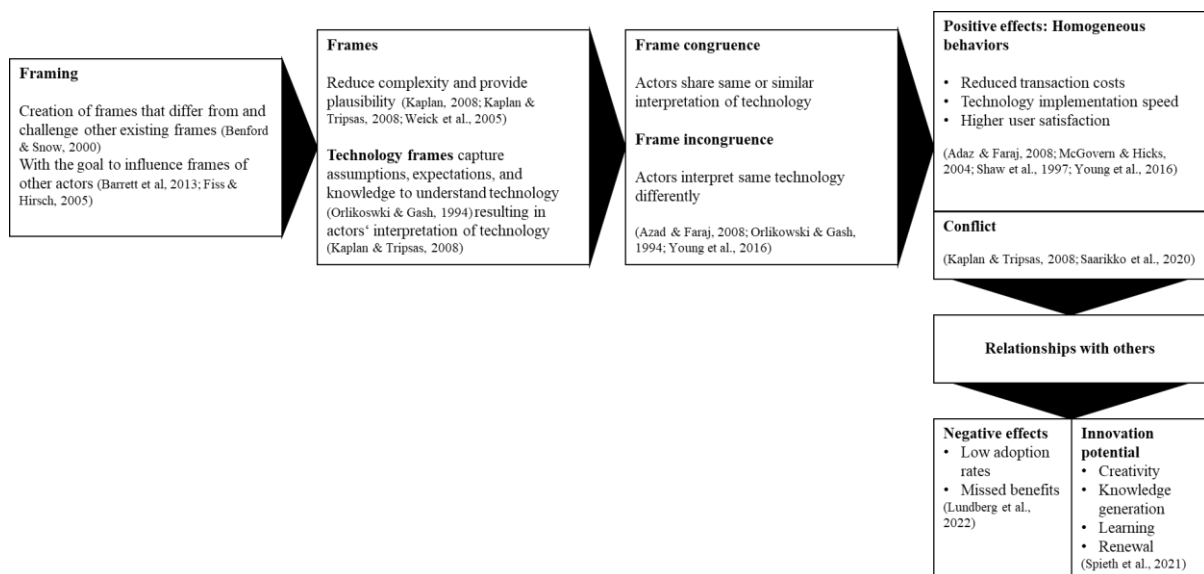


Figure I.2-3: Theoretical framework regarding technology frames

(Author's own illustration)

Due to the differing frames, proponents and opponents of a technology can engage in so-called framing struggles to help the technology gain cultural legitimacy or to deny it this legitimacy (Geels & Verhees, 2011). However, actors may also perceive positive frames that emphasize the benefits of technologies as manipulation, thus triggering a boomerang effect (de Vries, 2017). In summary, more research on actors' technology framing is still needed (Ghobadi &

Mathiassen, 2023; Markard et al., 2016), and generally, research examining the public framing of corporations and stakeholders is also needed (Bohn & Rogge, 2022). It would also be interesting to investigate the example of corporate actors' framing of chemical recycling (Jones et al., 2022). In particular, articles 1 and 2 add new insights to the perspective of perception of innovation explained in this chapter.

Having presented the first two theoretical perspectives underlying this work (content of innovation and perception of innovation), the next section is devoted to the third perspective, joint value creation in ecosystems as relevant context of innovation.

I.2.3 Context of innovation: Joint value creation in ecosystems

The previously mentioned review of 238 articles on theoretical lenses and the understanding of innovation concludes that classical innovation research can be traced back to two theoretical streams. These two dominant theoretical perspectives in innovation management are the adoption and diffusion theory and the resource-based view. Interestingly, the authors have identified an upcoming research stream "which deserves further research interest" that they call "innovation through relationship management" (Harmancioglu et al., 2009, p. 247). Among the topics identified, the authors of the review include, for example, strategic collaborations, new product alliances, networks, and joint new product development arrangements. Nambisan et al. (2017) come to a similar conclusion in their work on digital innovation management, propagating a trend toward more distributed and less predefined innovation agency, which appears as distributed innovation, open innovation, or network-centric innovation. Similarly, in their editorial for a special issue, Yoo et al. (2012) identify three traits associated with digital innovation activity, namely technology platforms, distributed innovations, and combinatorial innovations. These theoretical perspectives have emerged due to increasingly rapid changes in markets, increased competition, cost pressure, and greater overall complexity of innovation activities resulting in ecosystems (Harmancioglu et al., 2009; Nambisan et al., 2017).

The origins of this ecosystem perspective lie in the 1990s and 2000s, when various authors independently explored the complementarity, interdependence, and modularity of value creation (Adner, 2006; Adner & Kapoor, 2010; Moore, 1993, 2006). In the meantime, several ecosystem types such as business ecosystems, innovation ecosystems, platform ecosystems, entrepreneurial ecosystems, and knowledge ecosystems have developed from these beginnings, each with a different focus (Baldwin et al., 2024; Gomes et al., 2021; Shi et al., 2023). In line

with the innovation content already presented (digital and sustainable innovations), certain ecosystem manifestations are of particular interest for this work. For example, ecosystems evolving around digital innovation and defining digital technology as an important layer of value co-creation are becoming digital business ecosystems (Bohnsack et al., 2024; Papert & Pflaum, 2017; Senyo et al., 2019; Suuronen et al., 2022). Papers 4 and 5 discuss this manifestation in more detail. In addition to digital ecosystems, ecosystems that arise in the context of sustainable (e.g., Nylund et al., 2021; Xin et al., 2023) or circular innovations (e.g., Kanda et al., 2021; Trevisan et al., 2022) are also becoming increasingly relevant in scientific and practical scenarios. Papers 2 and 3 explore this direction.

In addition, increasing efforts are being made to fill the perspective of the ecosystem with theories (e.g., Gueler & Schneider, 2021; Jacobides et al., 2018; Shipilov & Gawer, 2020). Therefore, while there is agreement on the relevance of ecosystems and their unique focus on value creation that integrates complementary resources, the theoretical foundation is still controversial. The following section introduces recent research on ecosystems, thus forming the basis for Papers 2, 3, 4, and 5.

Table 1.2-2 shows the evolution of selected definitions of the ecosystem concept. A more comprehensive listing is provided by Shi et al. (2023). However, the definitions mentioned in the following table should sufficiently highlight key developments and relevant works. This discussion does not aim to be exhaustive, but it will address particularly important works. For instance, the origins of the ecosystem are often attributed to Moore (e.g., Jacobides et al., 2018; Shen et al., 2024; Shi et al., 2023), who highlights the cross-industry nature of ecosystems, the simultaneity of competition and cooperation in relationships to achieve innovation and customer satisfaction, and the evolution phases of ecosystems (Moore, 1993). Furthermore, he chooses the term ecosystem very deliberately to transfer the metaphor of a natural ecosystem to the economic realm, as the companies in an ecosystem are interdependent and share the same fate (Moore, 1993, 2006). While Teece (2007) as well as Autio and Thomas (2014) define ecosystems via the relationships with and the impact of the focal company, Adner (2017) shifts this focus from the focal firm to the focal value proposition. The majority of later definitions adopt his idea that value creation through the focal value proposition defines the core of an ecosystem (e.g., Hannah & Eisenhardt, 2018; Kapoor, 2018). Additionally, Jacobides et al. (2018) substantiate the idea of complementarity as a central defining characteristic of ecosystem, and more recent definitions converge these ideas (e.g., Baldwin et al., 2024). Each

paper that focuses on ecosystems (Papers 2, 4, 5) will provide a more nuanced definition that considers the unique conditions of the research question and empirical context.

Table I.2-2: Evolution of ecosystem definitions

Year of publication	Authors	Definition	Publication
1993	Moore	"suggest that a company be viewed not as a member of a single industry but as part of a business ecosystem that crosses a variety of industries. In a business ecosystem, companies coevolve capabilities around a new innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations." (p. 76)	Harvard Business Review
2006	Moore	"'business ecosystems,' refer to intentional communities of economic actors whose individual business activities share in some large measure the fate of the whole community" (p. 33)	The Antitrust Bulletin
2007	Teece	"the business 'ecosystem' - the community of organizations, institutions, and individuals that impact the enterprise and the enterprise's customers and supplies. The relevant community therefore includes complementors, suppliers, regulatory authorities, standard-setting bodies, the judiciary, and educational and research institutions." (p. 1325)	Strategic Management Journal
2014	Autio & Thomas	"'ecosystem' usually refers to a network of interconnected organizations that are linked to or operate around a focal firm or platform" (p. 205)	The Oxford Handbook of Innovation Management
2017	Adner	"ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize" (p. 42)	Journal of Management
2018	Kapoor	"an ecosystem encompasses a set of actors that contribute to the focal offer's user value proposition" (p. 2); "Set of actors that contribute to the user value proposition of a focal product or service, designed with or without a platform-based technological architecture" (p. 10)	Journal of Organization Design
2018	Jacobides et al.	"ecosystems are groups of firms that must deal with either unique or supermodular complementarities that are nongeneric, requiring the creation of a specific structure of relationships and alignment to create value" (p. 2263)	Strategic Management Journal
2018	Hannah & Eisenhardt	"we define ecosystems as groups of firms that produce products or services that together comprise a coherent solution. Examples include 3D printing (i.e., printers, scanners, feedstock, software) and smartphones (i.e., handsets, apps, operating systems, networks)." (p. 3164)	Strategic Management Journal
2024	Baldwin et al.	"define an ecosystem as a set of interacting autonomous organizations and individuals united around a focal value proposition. Members of the ecosystem each capture enough of the value created by the group to keep them involved. The value created by the combination minus the value created by the separate parts is the complementary surplus of the ecosystem. In an innovation ecosystem, value is created by innovations — new products and services linked by an architecture that users (including user-innovators) are willing to expend resources to acquire." (p. 3)	Research Policy

(Author's own illustration)

Depending on the chosen definition and the different subtypes of ecosystems (innovation ecosystems, digital ecosystems, and platform ecosystems), the boundaries of an ecosystem are drawn differently. This means that the considered group of actors differs. Usually one or more companies are at the center of an ecosystem. This central company coordinates the ecosystem and may also be referred to as leader (Moore, 1993), architect (Daymond et al., 2023), orchestrator (Furr & Shipilov, 2019; Lingens et al., 2021, 2022), focal company (Adner, 2017;

Gandolfo & Lupi, 2021), hub (Iyer et al., 2006), or keystone (Iansiti & Levien, 2004; Iansiti & Richards, 2006). From this perspective, the other companies are participants or followers (Moore, 1993).

In addition to the leader-follower perspective, ecosystems can be analyzed in terms of actors' roles in value creation. This results in four roles: (1) a value proposition provider/producer that bundles components, (2) suppliers (Adner, 2006; Iansiti & Levien, 2004; Kapoor, 2018), (3) customers (Dedehayir et al., 2018; Frow et al., 2016; Iansiti & Levien, 2004; Moore, 1993), and (4) complementors (Dedehayir et al., 2018; Kapoor & Agarwal, 2017; Ozalp et al., 2018). Complementors supplement the central value proposition with additional offerings in the form of further products and services that customers can bundle together to enhance the value proposition. This bundled value proposition creates more value than the original offering of the producer/service provider. Hence, actors in ecosystems are linked by two central mechanisms: interdependence and complementarity (Kapoor, 2018).

In particular, technology complementarity means "the value of an innovation depends on altering the nature of one or more existing technologies and/or on creating new ones" (Gomes et al., 2021; Teece, 2018, p. 1374). Regarding ecosystems, complements can be distinguished from components regarding the bundling actors. For instance, the focal firm bundles components together to create its offering, and the customers combine this offering with additional complements to maximize their value (Adner & Kapoor, 2010). In the context of innovation, Adner (2013) differentiates between co-innovation risk and adoption chain risk to explain interdependency. According to Adner, the former draws attention to innovations that have to emerge from other actors for the focal value proposition to create value (e.g., new generation consoles and new generation games), while the latter emphasizes the adoption of other actors precedes the adoption of end customers. In the prominent example of Michelin's inflatable tire, garages were not addressed as relevant adopters, meaning that the complementary service of repair for customers was missing due to low incentives and high prices for necessary repair instruments; hence, the potential value of the tire could not be created (Adner, 2013, 2017).

Some argue that ecosystems evolve only around non-generic or strong complementarity in both production and consumption (Hou & Shi, 2021; Jacobides et al., 2018; Shipilov & Gawer, 2020) and that non-generic complements show either unique (co-specialization) or supermodular complementarity (Jacobides et al., 2018). On the one hand, generic complementarity can be

found, for example, in bread and butter or water and tea bags, where greater value is created when both components are consumed together, but they can still be produced, used, and exchanged without coordination. On the other hand, unique complementarities in production arise when production without coordination or adherence to a standard is impossible; one might argue that coffee capsules and the matching coffee makers might already present unique modularity so they are creating an ecosystem because capsules must fit into the coffee makers. This strict definition highlighting the need for non-generic complementarity in both production and consumption is not without controversy (Gomes et al., 2021; Hou & Shi, 2021); however, it helps to distinguish the different forms of ecosystems from each other.

Considering interdependence, it is necessary for a constellation of actors to become an ecosystem (Burford et al., 2022; Gomes et al., 2021; Kapoor, 2018). Interdependencies in ecosystems "represent a structural relationship between offers in terms of how they are connected for the value to be created and how a change in one offer may affect the contribution of other offers towards value creation" (Kapoor, 2018). Interdependence results from direct upstream component-product interactions and indirect downstream user interactions (Adner & Kapoor, 2010; Agarwal & Kapoor, 2023; Kapoor, 2018). Conjunctive interdependence describes situations "in which a focal actor's success is dependent not only on its own ability to execute the task, but on the successful execution of other tasks by other actors" (Adner & Feiler, 2019, p. 110). In addition, Ganco et al. (2020) introduce technology interdependence and flow interdependence. While technology interdependencies "arise between components such that a redesign of one of the components (e.g., batteries for an electric car) alters the performance contribution of the other component (e.g., steering and suspension system—due to the weight and location of the batteries)", flow interdependencies "stem from how firms' inputs and outputs are ordered for the focal value proposition" (p. 650). Ganco et al. (2020) conclude that the combination of both forms of interdependence results in different search strategies during innovation activities for upstream and downstream firms. While interdependencies enable higher value creation in stable situations, they become liabilities in situations of an external shock, for example, due to a new technology, that negatively affects performance (Burford et al., 2022). The explanations show that interdependence arises in line with the complementarity and the need to align value propositions in ecosystems (Hou & Shi, 2021).

As research on ecosystems as a whole is still relatively young, it is not surprising that the initial focus was on describing the basic characteristics of ecosystems and understanding general

relationships between roles, strategies, and success in the ecosystem. In the meantime, there is growing interest in the various development stages of the ecosystem (Daymond et al., 2023; Holgersson et al., 2022). Like natural organisms, ecosystems undergo a dynamic and continuous development process mirroring a natural life-cycle (Meynhardt et al., 2016; W. Zhang et al., 2017). This idea of different stages of development was already explained in Moore's pioneering work (1993). In his early work, Moore (1993) described the four stages - birth, expansion, leadership, and self-renewal or death - in relation to cooperative and competitive challenges that arise in each stage (see Table I.2-3). For example, Holgersson et al. (2022) argue that ecosystems arise when there is a balance between cooperation benefits (challenges) and competition benefits (challenges) and that change arises due to forces that drive actors toward integration (centripetal forces) or arm's length market transactions (centrifugal forces). More specifically, they attribute the cause of ecosystem change over time to technological innovation that leads to commoditization, generalization and standardization of complements, besides new management techniques. They argue, for example, "the stronger the complementarity, the larger the need for coordination" (p. 8), which results in co-specialized investments and close partnerships.

Recently, there has also been a growing interest in understanding more precisely ecosystem emergence, focusing on how ecosystems are born (Daymond et al., 2023; Fang et al., 2021; Hannah & Eisenhardt, 2018; L. D. W. Thomas et al., 2022). Modularity is an important prerequisite to enable complementary to emerge (Baldwin et al., 2024), and government bodies and public research funding may support the development of interfaces and open standards that pave the way for modularity and ecosystem interdependency (Kuan & West, 2023). The emergence of ecosystems is particularly relevant for business practice, as upcoming ecosystems offer opportunities for innovation and business performance but also create new uncertainty (Daymond et al., 2023). For instance, initial resource constraints push firms toward ecosystem co-creation when developing new value propositions (Pushpanathan & Elmquist, 2022). Hence, Fang et al. (2021) show how hackathons hosted by platform owners, as examples of temporal gatherings, raise awareness of emergent ecosystems among potential complementors by enabling sponsorship, social learning, knowledge exchange, and social coordination. If interdependent actors develop shared intentions, then ecosystem emergence will be driven forward (Taillard et al., 2016). Several processes, such as value discovery, collective governance, platform resourcing, and contextual embedding are associated with ecosystem emergence (L. D. W. Thomas et al., 2022). Focusing on contextual embedding and building

legitimacy during emergence, discursive legitimation (framing, sensemaking, positioning, recognizing), and performative legitimation (strategic action, value realization, adoption, intervention) will support ecosystem identity construction and build on collective action and institutional theoretic arguments (L. D. W. Thomas & Ritala, 2022).

Table I.2-3: Evolution of an ecosystem

	Cooperative challenges	Competitive Challenges
Stage 1: Birth	• Co-creation with customers and suppliers • Define new value proposition around seed innovation	• Knowledge and ideas • Relationships to lead customers and key suppliers
Stage 2: Expansion	• Market introduction with partners • Upscaling and market penetration	• Competition with similar ideas (other ecosystems) • Definition of market standards • Dominate key market segments
Stage 3: Leadership	• Future vision for ecosystem cooperation • Continues improvement and extension of value proposition	• Bargaining power in relation to other ecosystem actors
Stage 4: Self-renewal or death	• Create niches for innovators to grow and integrate new ideas	• Entry barriers to prevent emergent ecosystems from market entry • High customer switching cost to buy time for innovation

(Author's own illustration based on Moore, 1993)

Although knowledge about the formation of ecosystems is growing, numerous questions still exist for future research. It seems particularly interesting to use qualitative research on communication patterns to shed light on the role of frames and framing, especially in established companies (Roundy et al., 2018; Snihur et al., 2022; Taillard et al., 2016; L. D. W. Thomas et al., 2022). Furthermore, the misalignment of institutional arrangements and processes that attack the legitimacy of emerging ecosystems is also relevant for improving understanding about this important topic (Polese et al., 2021; L. D. W. Thomas & Ritala, 2022). Hence, Paper 2 focuses on this interesting research avenue and builds on the summarized knowledge.

I.3 Remarks on methodology

I.3.1 Rationale for the qualitative explorative research approach

According to the Oxford English Dictionary, exploration means, among other things the following:

“The action of examining thoroughly; investigation, scrutiny, study; an instance of this.

The action of travelling to or around an uncharted or unknown area for the purposes of discovery and gathering information; (later also) the action or activity of going to or around an unfamiliar place in order to learn about it. Also as a count noun: an instance of this; an expedition for the purpose of discovery.”

With this in mind, the following section explains the methodologies and their assumptions that were applied to the study and enabled the discovery in this work. For a long while, qualitative research was the exception rather than the rule in relevant management research, but it is becoming increasingly important (Bluhm et al., 2011; Cassell, 2016; Eisenhardt, 2020; Gephart, 2004). Qualitative research builds on inductive theorizing of static and dynamic words and visuals that make up qualitative data, requiring detailed descriptions and an interpretation of the database (Bansal et al., 2018; Gephart, 2004). An advantage of qualitative research is that these research designs allow the analysis of phenomena taking place on different levels (Bansal & Corley, 2011). Since the individual papers in this dissertation regularly deal with phenomena taking place at the level of the individual, the organization, and the surrounding ecosystem, the chosen qualitative approaches have an advantage over quantitative methods. Finally, qualitative research methods increase the comprehension of how individuals interpret their experiences (Bluhm et al., 2011; Gephart, 2004). To summarize, qualitative methods help reach the goal of better understanding (Bettis et al., 2015).

Qualitative research questions seek to understand complex, messy, and new phenomena (Arino et al., 2016; Bansal et al., 2018). In these instances, the existing literature cannot explain the new phenomena fully; hence, advancements by additional detailed descriptions, informed interpretations, and theoretical explanations are needed (Bluhm et al., 2011). To achieve the goal of describing, understanding, and explaining, qualitative research is especially valuable for answering research questions about how and why (Arino et al., 2016; Bansal et al., 2018; Gephart, 2004; D. A. Gioia et al., 2013; Volmar & Eisenhardt, 2020). Table I.3-1 contains the research questions of all papers that are part of this dissertation. The question wording has been highlighted in *italics* for emphasis. All of the listed research questions follow the goals of gaining understanding about behaviors, patterns, and mechanisms.

Table I.3-1: Research questions

Paper 1	• <i>How</i> do incumbent companies in the German energy sector frame currently emerging digital virtual power plant technologies? • <i>Which</i> role do digitalization and sustainability considerations play in their technological frames? • <i>How</i> do differences in incumbents' technological frames affect the design of sustainable value propositions and, as a consequence, the sustainability implications at the company and the broader societal level?
Paper 2	• <i>How</i> do frame congruence and incongruence, respectively, shape ecosystem relationships in an emerging ecosystem regarding chemical recycling?
Paper 3	• <i>How</i> do established firms of the plastics industry reorganize internally and externally toward achieving circularity?
Paper 4	• <i>Which</i> customer roles emerge in digital business ecosystems according to customers' resource contribution to value creation?
Paper 5	• <i>How</i> do different ecosystem characteristics, the smart service design and the company's ecosystem position interact at the implementation of smart services in ecosystems?

(Author's own illustration)

Although different qualitative methods are used (e.g., case studies and grounded-theory informed Gioia Method) in the individual papers of this thesis, there are some unifying general assumptions. Hence, I argue in line with Eisenhardt that qualitative research with the aim of theory building has some important commonalities (Gehman et al., 2018): using diverse data sources with deep immersion, theoretical sampling, and grounded theory building based on insights from data. These commonalities can be observed in all included works and, hence, are introduced in the following.

As the first relevant research methodology *grounded theory* will be mentioned. The grounded theory method was first formulated by Glaser and Strauss in 1967 and has since been divided into various camps (Glaser & Strauss, 1967; Heath & Cowley, 2004). To make matters more complicated, the ideas of the two original researchers have also developed in different directions. For example, there is now a current of grounded theory according to Glaser (Glaser, 2002) as well as a separate understanding according to Strauss and Corbin (Strauss & Corbin, 1997). Based on these developments, Glaser's interpretation is understood as classical grounded theory (Heath & Cowley, 2004). A primary argument of both currents revolves around the question of when and to what extent the existing scientific literature and its findings are incorporated into the research process (Thornberg & Dunne, 2019). While Glaser sticks to the original argument that interest in the phenomenon and only a rough knowledge of the literature are decisive, as he contends that a deeper theoretical examination would distort the voice of the

data, Strauss recommends a research question developed on the basis of the available literature as a starting point (informed grounded theory).

The core of all methods based on the idea of grounded theory lies in the ongoing comparison of emergent concepts, patterns, and mechanisms with each other and existing theoretical findings, simultaneous data collection and data analysis, theoretical sampling, and theoretical saturation (Charmaz & Thornberg, 2021; Corbin, 2021). These methods correspond to inductive theory building (Heath & Cowley, 2004). The continuous comparison with a focus on one's own data is made possible by the core element of the method, inductive coding. Although there are also different nuances in understanding and nomenclature regarding inductive coding, the basic process remains quite similar (Heath & Cowley, 2004). In the first step, relevant and interesting aspects for the research question or the understanding of the phenomenon are named (coded; also known as open coding or substantial coding). In this step, it is advisable to remain very close to the wording of the data basis in order to avoid unintentional interpretation. Then, similar codes should be grouped into superordinate categories, which requires a repeated comparison of the previously formed codes with each other and the categories, considering the actual message of the database. Since this analysis step is central to the understanding of grounded theory, both the considerations for category formation and its result are addressed accordingly in the corresponding works.

As a second relevant research methodology, *case study research* has helped shape the individual papers in this dissertation because it brings its own focus and advantages (e.g., Easterby-Smith et al., 2021; Eisenhardt, 1989, 2021; Yin, 2018). While case study research also emphasizes a systematic and rigorous data analysis, it remains less clear in the details, as the concrete analysis steps - especially the step from the raw data to first case descriptions - are often not specified but are designed depending on the available data (Harrison et al., 2017). When theory building from case studies, as Eisenhardt (2020) notes, the methodology blends early takes of case study research (Yin, 1984, 2018) with grounded theorizing (Glaser & Strauss, 1967).

Since it seems that research in the social sciences can formulate little to no universally valid predictive and context-independent theories, an understanding of specific empirical realities is essential to provide context-dependent insights (Flyvbjerg, 2006). Case studies can be used to pursue various research objectives such as theory building, illustration, and even testing a theory (G. Thomas, 2011; Yin, 2018). In particular, theory building is used in this work, as well as illustrations of subtypes and patterns. This also takes advantage of the benefits of case

studies, namely that they communicate research in a clear, understandable, and tangible way (Flyvbjerg, 2006). Hence, a core characteristic of case study research is the careful and meticulous selection of cases, for which very different strategies can be used (Eisenhardt, 2021; G. Thomas, 2011). Therefore, the individual papers explain why and how the research context or individual cases were identified in detail.

Interpretivist studies such as the Gioia methodology, a specific application and advancement of grounded theory, are particularly suitable for focusing on people's experiences, perceptions, and sense-making (Eisenhardt, 2020; D. A. Gioia & Chittipeddi, 1991; D. A. Gioia & Thomas, 1996). Since, for example, the perception of technology and the resulting technological frames fall under this category, an orientation toward this methodological direction can realize the advantages of the two qualitative methodologies presented above. Fittingly, some methodologists argue that "methodological slippage" can be seen it moves away from the stricter assumptions of both case study research and traditional classic grounded theory (Cornelissen, 2017; Eisenhardt, 2020).

Nevertheless, Gioia and colleagues base their research methodology on two fundamental assumptions (D. A. Gioia, 2021; D. A. Gioia et al., 2013; Magnani & Gioia, 2023). They assume that the world is socially constructed and that agents are knowledgeable. In this understanding of a socially constructed world, the actions of individuals are guided by their perception of the world, i.e., their individual construction of reality, whereby the constructed world becomes reality for the individual and shapes resulting behaviors. By characterizing the acting agents as knowledgeable, the assumption is made that all actors involved in the research have valuable knowledge about their own activities and the reasons for these activities. This assumption includes, on the one hand, researchers who know what they study and why they study a topic and can uncover important interpretations and perspectives, and, on the other hand, organizational actors who know their work practices, tasks, goals, and aspirations (D. A. Gioia et al., 2013; Magnani & Gioia, 2023).

In order to reflect the two perspectives of researchers and organizational actors adequately, these two different perspectives are taken into account at different points in the data structure (Gehman et al., 2018). The Gioia methodology develops a static data structure that presents first-order codes (organizational actors' perspective), second-order themes, and superordinate third-order dimensions (researchers' perspective). In the next step, these concepts are transformed into a dynamic grounded model that also maps the interactions and relationships

between the individual concepts in detail (Magnani & Gioia, 2023). The creation of first-order codes follows an inductive logic, building on emergent topics that are present inside the data, while the systematic combination that results in second-order themes and third-order dimensions shifts toward abduction as it combines data insights with theoretical knowledge (Magnani & Gioia, 2023).

Usually, inductive theory building can be distinguished from deductive theory building (Okoli, 2023). Inductive theorizing starts with data and researchers developing possible theoretical explanations for empirical observations (Earl Rinehart, 2021; Timmermans & Tavory, 2012). In deductive theorizing, researchers derive hypotheses from theory that explain what the patterns of empirical data should show. If the derived correlations are not reflected in the data, the theory is considered falsified. If the derived correlations are reflected in the data, the observations support the formulated theory but do not prove it (Okoli, 2023; Timmermans & Tavory, 2012).

In addition to inductive and deductive theorizing, abduction is also increasingly being discussed as a third possibility in the scientific literature (Sætre & Van de Ven, 2021, 2024). While Okoli (2023) argues that abductive theorizing "starts with a rudimentary theory or theory-in-progress, which should ideally result in a proposed or supported theory" (p. 308), Timmermans and Tavory (2012) explain that abduction "refers to an inferential creative process of producing new hypotheses and theories based on surprising research evidence. A researcher is led away from old to new theoretical insights" (p. 170). In the latter case, abductive theorizing depends on the ability of researchers to recognize new and surprising findings in contrast to the existing scientific literature. Hence, abduction highlights the need for "knowing the literature" and "knowing the theories" (Timmermans & Tavory, 2012). This knowledge of the literature seems to be in conflict with Glaser's understanding of grounded theory (Bruscaglioni, 2016; Glaser, 2002) but in line with Gioia's assumption about knowledgeable agents (D. A. Gioia, 2021; D. A. Gioia et al., 2013). Therefore, abductive reasoning complements inductive theory building in the following works. Finally, considering informal prompts and hints from others provides support to researchers in abduction (Earl Rinehart, 2021), which underscores the value of discussing research findings with peers in informal and formal ways. Accordingly, conference presentations are mentioned.

While best practices for taking specific steps in qualitative data collection and analysis exist, there is not a "single 'right' method" (Bansal & Corley, 2011). Despite the lack of generally

accepted standards, high demands are placed on qualitative research (Bluhm et al., 2011; Flick, 2018); hence, researchers are called to be transparent regarding their methodological choices and data by providing detailed accounts, quotes, and examples (Bansal & Corley, 2011; Elsahn et al., 2020; Gephart, 2004; Goffin et al., 2019). These efforts to achieve transparency support the further development of best practices (Aguinis & Solarino, 2019; Bluhm et al., 2011). Unfortunately, the increasing success of qualitative research not only leads to an ongoing development and refinement of methodological approaches, but also to standardization pressure and rigid evaluation criteria (Cassell, 2016; Cassell & Bishop, 2019; T. Köhler et al., 2022; Symon et al., 2018). The methodological choices in each of the included works represent a purposeful mélange of existing techniques that consider the research question and its particular challenges.

I.3.2 Empirical contexts, cases, and data sets

All studies that are part of this thesis analyze digital innovations in ecosystems, sustainable innovations in ecosystems, or a combination of both. Regarding digital innovation ecosystems, this thesis covers the example of virtual power plants (Paper 1), several examples of digital technologies providing opportunities for customer co-creation (Paper 4), and smart services implementation in digital ecosystems (Paper 5). Potential resulting sustainability transitions are discussed in relation to the energy industry (Paper 1) and the circularity of plastics (Papers 2 and 3). Table I.3-2 shows an overview of empirical contexts, cases, and data sets. All empirical contexts will be explained in more detail in each paper. Papers 1-3 are classic empirical studies that use qualitative analysis (Papers 1-3) and network visualization (Paper 2) based on qualitative data, and Papers 4 and 5 use real-world cases for illustration and to support the theoretical arguments. Hence, Papers 4 and 5 differ slightly regarding the focus and process of case selection as well as the description of the resulting data set.

As described above, the three pillars of qualitative research methodology regarding the conception of the data basis are theoretical sampling, triangulation, and theoretical saturation (Eisenhardt, 1989, 2021). The first important pillar, theoretical sampling, goes back to the conception of grounded theory, meaning that the selection of cases follows theoretical considerations to generate or reduce variance and ultimately support inductive theorizing (Charmaz & Thornberg, 2021; Eisenhardt, 1989; Glaser & Strauss, 1967).

Table I.3-2: Overview of empirical contexts, cases, and data sets

	Empirical context	Cases	Data set
Paper 1	German energy transition	Seven incumbent companies in the German energy sector that adopted virtual power plant technology	• 12 semi-structured formal interviews (234 pages) • Publicly available corporate data (36 press releases, 47 annual reports, magazine and newspaper articles)
Paper 2	Circularity of plastics	• Evolving ecosystem of chemical recycling • 271 actors that engage in or are mentioned in the discourse on chemical recycling	• 516 publicly available corporate documents
Paper 3	Circularity of plastics	German and French incumbent companies • With at least 10 years business experience • Companies that are already making outstanding contributions to the circular transition (awards, certificates, media coverage)	• 25 semi-structured formal interviews with 26 top and middle-managers (in one interview participated two people) • Publicly available corporate data (60 press releases, 3014 pages in business reports, 771 pages in corporate social responsibility reports, 100 website pages, 321 article pages, 120 pages of other material)
Paper 4	Customer co-creation in digital business ecosystems	Several case examples for eight ideal types of co-creation	• Identification of at least two fitting case examples for each ideal type • Case descriptions based on publicly available data
Paper 5	Smart service implementation in business ecosystems	Eight cases that represent ideal types of the different forms	• Initial identification of 47 smart service ecosystems • Case descriptions based on publicly available data

(Author's own illustration)

Theoretical sampling (also purposeful sampling) must be clearly distinguished from convenience sampling and random sampling (Charmaz & Thornberg, 2021; Eisenhardt, 2021; Lincoln & Guba, 1985; Pratt, 2009), as the latter two reduce the value of a qualitative study because, for reasons of convenience, either particularly easily accessible cases are considered (e.g., friends) or random cases are selected from a population to represent them using statistical methods (Baxter & Jack, 2008; Eisenhardt, 1989). These two approaches do not help in the formation of theories, because they either follow no logic (convenience) or they follow a deductive logic that contradicts inductive theory formation (random sampling). The criteria for case selection might change over the course of the study, but this should not be confused with snowball sampling (Charmaz & Thornberg, 2021; Pratt, 2009). In snowball sampling, the sample is purposely expanded by contacts or references in the initial data (e.g., Schabram & Maitlis, 2017), while in theoretical sampling, interview participants give hints to question concepts or how to better understand emergent concepts, guiding further data collection

(Charmaz & Thornberg, 2021; Foley et al., 2021). Both approaches are part of the simultaneous data collection and data analysis in the qualitative methodology described above (Gehman et al., 2018; Glaser & Strauss, 1967). Due to the diverse possibilities and the different objectives, and to meet the requirements of good qualitative research, each individual paper addresses sampling and the case selection procedure (Aguinis et al., 2018; Aguinis & Solarino, 2019).

Theoretical saturation is the second important pillar of the chosen qualitative research methodology (Eisenhardt, 1989, 2021; D. A. Gioia et al., 2013; Glaser & Strauss, 1967). If theoretical sampling does not provide any new insights into concepts and their interrelationships, theoretical saturation occurs (Strauss & Corbin, 1997). The categories formed become fully sophisticated and can explain newly emerging concepts and their relationships (Foley et al., 2021). In this instance, additional data cannot reveal any new characteristics of the theoretical categories (Charmaz & Thornberg, 2021). Or as Eisenhardt (1989) puts it, "theoretical saturation is simply the point at which incremental learning is minimal because the researchers are observing phenomena seen before" (p. 545). Theoretical saturation also determines the appropriate number of cases (Eisenhardt, 2021). In inductive theory-building empirical studies, this means that a new case no longer yields any new findings. The literature regularly states that 4-8 cases are optimal for comparison, but the quantitative argument is not sufficient without considering theoretical saturation (Eisenhardt, 2021). The case selection in Papers 1 and 3 was designed according to the assumptions of theoretical sampling and saturation logic. In Papers 4 and 5, however, the cases are selected on the basis of predefined criteria in order to demonstrate different ideal types. Thus, this is another form of theory-led case selection that achieves theoretical saturation when all defined ideal types are covered (Eisenhardt, 1989). The details are explained in the corresponding papers.

The third pillar of qualitative research methodology is triangulation (Eisenhardt, 1989). Triangulation can be understood as the combination of different methods (Denzin, 2017); however, Flick (2015) differentiates mixed methods (triangulation 2.0) from data triangulation, noting that data triangulation is as the combination of existing data (documents) with created data (interviews) to create a triangulation of different perspectives. In the meantime, different evolutionary stages of definitions of triangulation can be distinguished. The evolution starts with the "original idea of confirming results by other data and results (triangulation 1.0). It has become a reflexive framework of using mixed methods (Triangulation 3.0). Triangulation is also a concept for challenging data with other data and methods with other methods

(Triangulation 4.0)" (Flick, 2019, p. 719). In her groundbreaking work on the case study, Eisenhardt (1989) also mentions various possibilities of triangulation such as triangulation of evidence, investigator triangulation, and triangulation with theory. In this understanding as well, the aim is to consider differing and numerous perspectives through triangulation (Baxter & Jack, 2008). Although triangulation in this thesis is mainly applied as data and investigator triangulation (Papers 1 and 3), Paper 2 is as an example of method triangulation because it combines qualitative analysis with network visualization.

Now that the fundamental considerations and decisions surrounding the chosen methodology have been explained, this introduction concludes with a brief overview of the individual works included.

I.4 Overview of included papers

The structure of the included works builds upon the aforementioned conceptual framework (see Table I.4-1). First, works are included that show a primary focus on the content and perception of innovation (Papers 1 and 2). While Paper 1 has an internal company focus and examines the effect of technological frames regarding potentially sustainable digital technologies on value propositions, Paper 2 combines the perspective of technology frames with ecosystem relationships and, thus, represents a link between these two theoretical perspectives. The second part of the presented works focuses on ecosystems (context of innovations), while also using examples of digital and sustainable innovations. Paper 3 accompanies the path of companies in the plastics industry toward a CE and shows that this change intertwines internal organizational and external ecosystem-related adjustments. The last two papers deal with the opportunities that arise for companies through business ecosystems (Papers 4 and 5). Paper 4 focuses on value co-creation with customers and explains how the various forms can be designed for companies. Paper 5 in the main part of this thesis highlights how the implementation of innovative smart services in ecosystems is also characterized by additional strategic alternatives. After this initial overview, each paper will be briefly summarized.

Table I.4-1: Summary - Structure and focus of included papers

Content of innovation:	Digital innovation	Sustainable innovation
Theoretical perspective:		
Perception of innovation: technology frames	Paper 1: Bähr, K., Fliaster, A. (2023). <i>The twofold transition: Framing digital innovation and incumbents' value propositions for sustainability</i>. Business Strategy and the Environment, 32(2), 920-935.	
Context of innovation: ecosystems	Paper 4: Bähr, K. (2022). <i>Customer roles in digital business ecosystems: Different forms of customer contribution in value creation</i>. In: Baumann, S. (Ed.), Handbook on Digital Business Ecosystems: Strategies, Platforms, Technologies, Governance and Societal Challenges, Edward Elgar Publishing, 194-211. Paper 5: Laut, P., Bähr, K. (2022). <i>Implementierung von Smart Services in Ökosystemen</i>. In: Bruhn, M., Hadwich, K. (Eds.), Forum Dienstleistungsmanagement 2022 Smart Services, Springer Nature, 463-496.	Paper 2: Bähr, K. (2024). <i>Framing struggles in emerging ecosystems: Frames of chemical recycling and ecosystem relationships</i>.* Paper 3: Fliaster, A., Bähr, K. (2024). <i>How companies move to circularity: Adjusting external collaboration and internal reorganizing</i>**

* Submitted for publication.

** Submitted for publication. After peer review, the paper has been invited to be revised and resubmitted.

(Author's own illustration)

Paper 1. *The twofold transition: Framing digital innovations and incumbents' value propositions for sustainability* introduces important foundations for the other works (see Figure I.4-1).

Paper 1 The twofold transition

Bähr, K., Fliaster, A. (2023). The twofold transition: Framing digital innovation and incumbents' value propositions for sustainability. *Business Strategy and the Environment*, 32(2), 920-935.

Research questions

- *How* do incumbent companies in the German energy sector frame currently emerging digital virtual power plant technologies?
- *Which* role do digitalization and sustainability considerations play in their technological frames?
- *How* do differences in incumbents' technological frames affect the design of sustainable value propositions and, as a consequence, the sustainability implications at the company and the broader societal level?

Theoretical perspective

- Technological frame, framing of technology
- Business models for sustainability

Research design

- Qualitative multicase study of virtual power plants
- Qualitative data collection (interviews and available corporate data)
- Qualitative interpretative analysis (grounded theory in line with Gioia)

Key findings

- Two groups of companies with different technological frames engage in virtual power plant technology
- A single-focused technological frame leads to a concentration on economic value missing sustainable value creation opportunities
- The twofold digital and sustainable technological frame opens up additional socioenvironmental value components (system support, renewable energy enabling)

Figure I.4-1: Overview Paper 1 – The twofold transition

(Author's own illustration)

This study explores how incumbent companies in the German energy sector are framing emerging digital virtual power plant technologies. It investigates the role played by

digitalization and sustainability considerations within their technological frames. Additionally, the study examines how differences in these technological frames influence the design of sustainable value propositions and, consequently, the broader sustainability implications at both the company and societal levels. The research is grounded in theoretical perspectives on technological frames (Orlikowski & Gash, 1994; Spieth et al., 2021), as well as BMs for sustainability (Evans et al., 2017; Geissdoerfer et al., 2018; Schaltegger et al., 2012). The study employs a qualitative multicase approach, focusing on virtual power plants, with data collected through interviews and available corporate sources. The analysis follows a qualitative interpretative methodology, aligned with Gioia's grounded theory approach (Gehman et al., 2018; D. A. Gioia, 2021; D. A. Gioia et al., 2013). The key findings reveal two distinct groups of companies, each with different technological frames, engaged in virtual power plant technology. It is observed that a single-focused technological frame tends to concentrate on economic value, missing opportunities for sustainable value creation. In contrast, a twofold focus on digital and sustainable technological frames opens up additional socio-environmental value components, such as system support and enabling of renewable energy. In particular, the insights into incongruence between the frames of the different actors motivated Paper 2.

Paper 2. *Framing struggles in emerging ecosystems: Frames of chemical recycling and ecosystem relationships* investigates how frame congruence and incongruence influence ecosystem relationships within an emerging ecosystem focused on chemical recycling (see Figure I.4-2). Chemical recycling, a technology that converts plastic waste into substances akin to crude oil, is the chosen context due to its potential yet controversial role in advancing the CE (Jones et al., 2022; Ragaert et al., 2017). Paper 2 builds on the theoretical perspectives related to the technological framing of technology (Orlikowski & Gash, 1994; Spieth et al., 2021), business ecosystem relationships (Adner, 2017; Baldwin et al., 2024; Jacobides et al., 2018), and processes during ecosystem emergence (Daymond et al., 2023; Taillard et al., 2016; L. D. W. Thomas et al., 2022). The research design involves qualitative data collection, which employs qualitative frame analysis on 500 documents from 271 actors (Ghobadi & Mathiassen, 2023), as well as qualitative network visualization (Borgatti et al., 2002, 2018). The key findings reveal that congruent technology maturity frames do not necessarily prevent conflict, nor do incongruent technology maturity frames inherently cause conflict. However, congruence in CE fit frames significantly enhances collaboration, whereas incongruence in these frames tends to lead to conflict. After the first two papers primarily address technological frames as a

theoretical basis, the perspective of the ecosystem in the remaining papers is increasingly coming to the fore.

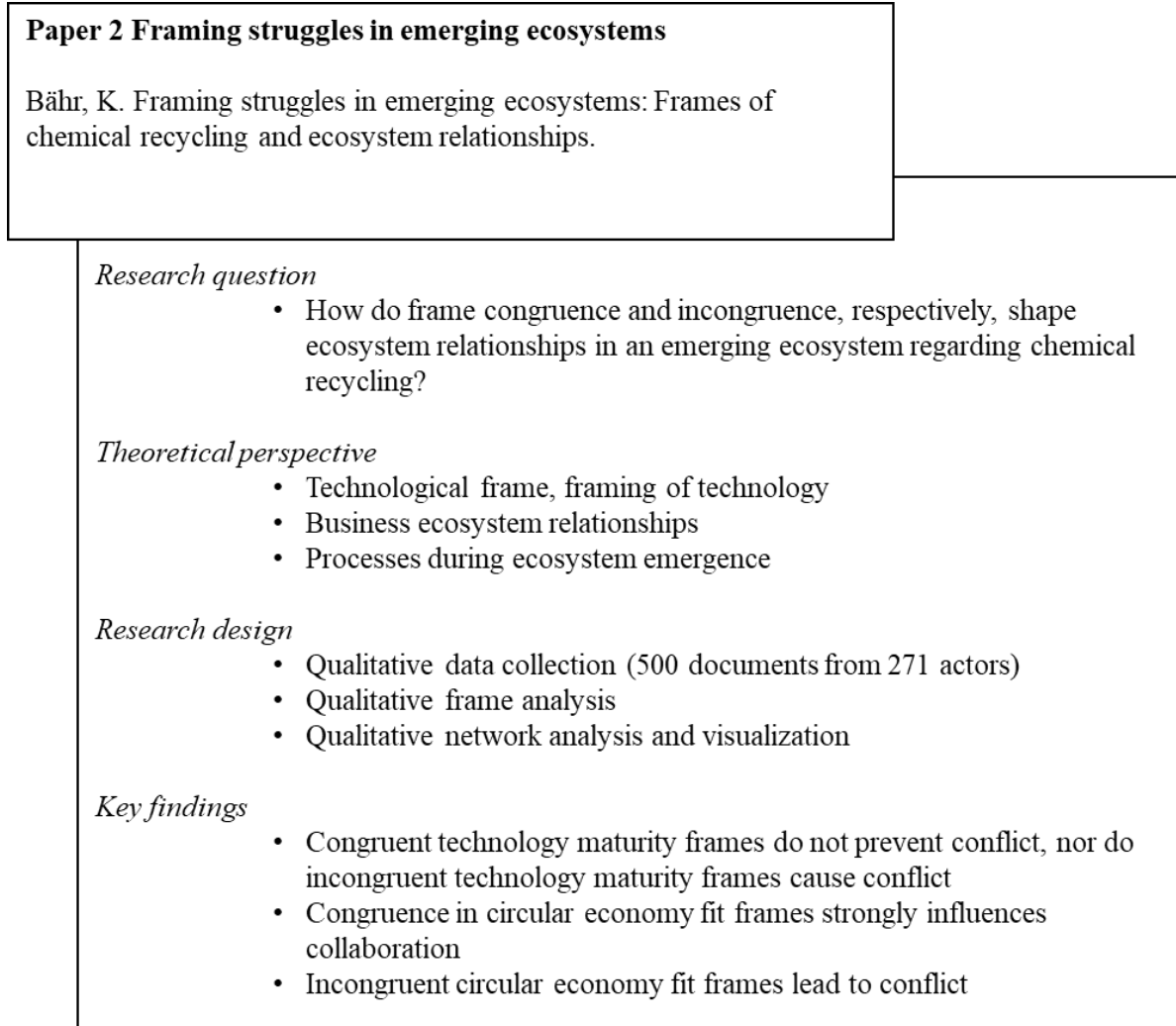


Figure I.4-2: Overview Paper 2 - Framing struggles in emerging ecosystems
(Author's own illustration)

Paper 3. *How companies move to circularity: Adjusting external collaboration and internal reorganizing* connects the level of the ecosystem with the internal organization of companies as they undergo a transformation toward a CE (see Figure I.4-3). This study addresses how established firms in the plastics industry are reorganizing both internally and externally to achieve circularity. The research is grounded in theoretical perspectives on CE transformation (Asgari & Asgari, 2021; Gandolfo & Lupi, 2021; Kirchherr et al., 2017; Suchek et al., 2021), organizational structures and processes (Argyres et al., 2020; Bakker et al., 2016; Damanpour

& Gopalakrishnan, 1998; Lundin & Söderholm, 1995), and CE collaboration (Aarikka-Stenroos et al., 2022; Kleine Jäger & Piscicelli, 2021; J. Köhler et al., 2022).

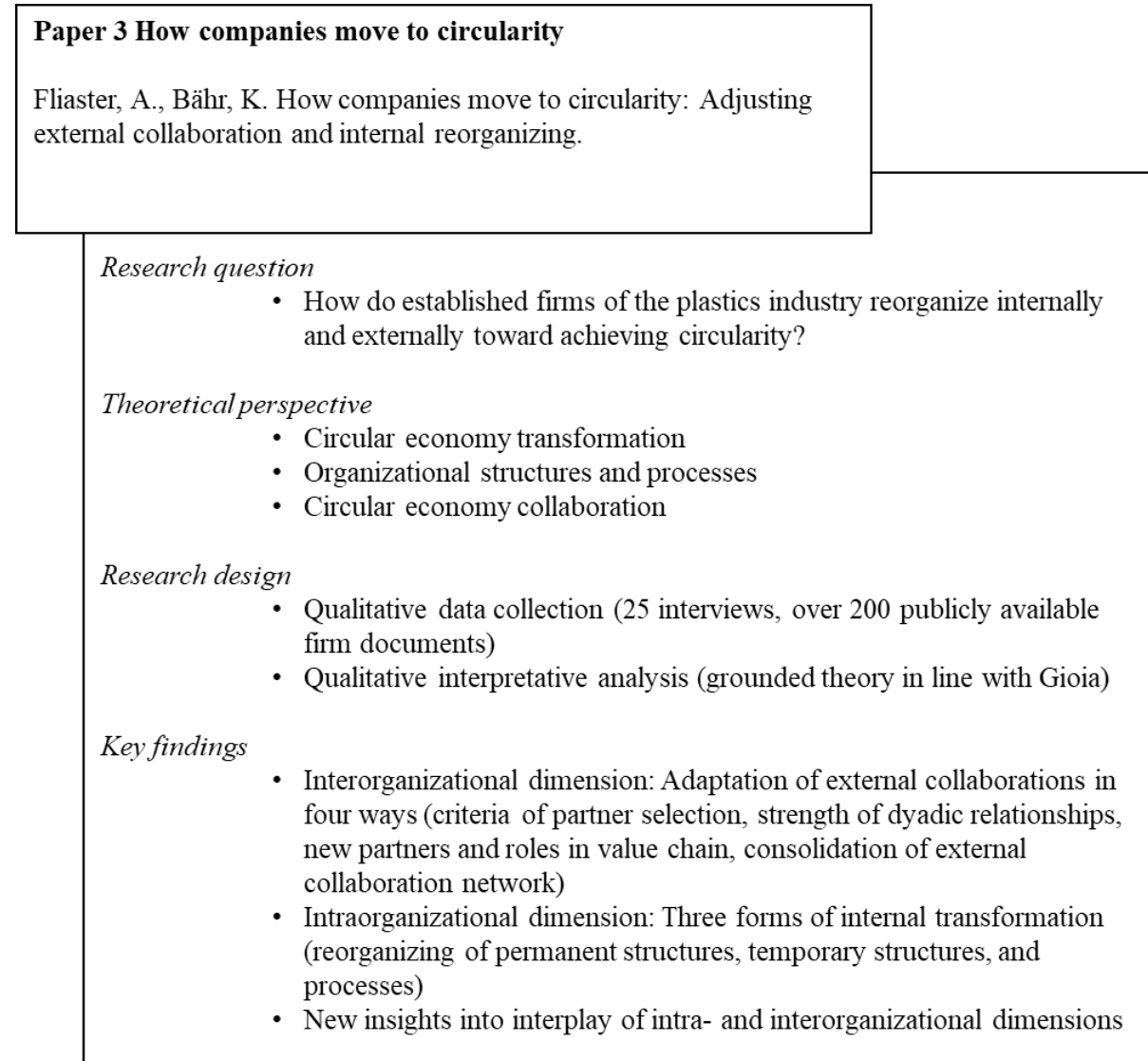


Figure I.4-3: Overview Paper 3 - How companies move to circularity
(Author's own illustration)

The research design involves qualitative data collection, including 25 interviews and over 200 publicly available firm documents, followed by qualitative interpretative analysis using grounded theory in line with Gioia (Gehman et al., 2018; D. A. Gioia, 2021; D. A. Gioia et al., 2013). The key findings reveal adaptations in external collaborations in four key areas: the criteria for partner selection, the strength of dyadic relationships, the involvement of new

partners and roles in the value chain, and the consolidation of external collaboration networks. Internally, firms are undergoing three forms of transformation, involving the reorganization of permanent structures, temporary structures, and processes. Additionally, the study provides new insights into the interplay between intra- and interorganizational dimensions.

Paper 4. *Customer roles in digital business ecosystems: Different forms of customer contribution in value creation* investigates the roles of customers in digital business ecosystems, specifically focusing on how customers' resource contributions influence value creation (see Figure I.4-4).

Paper 4 Customer roles in digital business ecosystems

Bähr, K. (2022). Customer roles in digital business ecosystems: Different forms of customer contribution in value creation. In: Baumann, S. (Ed.), *Handbook on Digital Business Ecosystems: Strategies, Platforms, Technologies, Governance and Societal Challenges*, Edward Elgar Publishing, 194-211.

Research question

- Which customer roles emerge in digital business ecosystems according to customers' resource contribution to value creation?

Theoretical perspective

- Digital business ecosystems
- Value co-creation
- Customers as ecosystem actors

Research design

- Conceptual paper
- Diverse case method: exploring customer roles through case examples

Key findings

- Theoretical deduction of two dimensions (level of interaction and integrated resource) with manifestations (active/passive, time/skill/physical resources/data) resulted in eight ideal types
- Four customer roles with active integration of resources: self-service seekers, content creators, product/service providers, and data providers
- Four customers roles with passive integration of resources: service graders, skill sources, co-producers/prosumers, and data generators

Figure I.4-4: Overview Paper 4 - Customer roles in digital business ecosystems
(Author's own illustration)

The study is grounded in the theoretical frameworks of digital business ecosystems (Bohnsack et al., 2024; Senyo et al., 2019; Suuronen et al., 2022), value co-creation (Frow et al., 2015, 2016; Payne et al., 2008; Vargo & Lusch, 2010), and the role of customers as ecosystem actors (Agrawal & Rahman, 2015; Prahalad & Ramaswamy, 2000; Ramaswamy & Ozcan, 2018; Rayna & Striukova, 2021). The research paper is a conceptual piece that utilizes a diverse case method to explore different customer roles through case examples (Nylund et al., 2021; Seawright & Gerring, 2008). The key findings include the theoretical deduction of two primary dimensions: (1) the level of interaction, which can manifest in two forms such as active and passive engagement, (2) along with the integrated resource (time, skill, physical resources, or data). These dimensions resulted in the identification of eight ideal customer roles. Four of these roles involve active resource integration: self-service seekers, content creators, product/service providers, and data providers. The other four roles involve passive resource integration: service graders, skill sources, co-producers/prosumers, and data generators. The motivational basis for contributing customers, and the potential of co-destruction in digital business ecosystems have emerged as particularly relevant aspects in the discussion. Paper 4 focuses on customers' roles in digital business ecosystems, while Paper 5 complements this perspective with a look at ecosystem-based implementation strategies for smart services.

Paper 5. *Implementation of smart services in ecosystems* explores the interaction between different ecosystem characteristics, smart service design, and a company's position within the ecosystem during the implementation of smart services. The study is framed within the theoretical perspective of business ecosystems with a focus on roles (Iansiti & Levien, 2004; Lingens et al., 2021; Moore, 1993) and ecosystem evolution (Meynhardt et al., 2016; Moore, 1993; W. Zhang et al., 2017). It employs a comparative case study design, using theoretical sampling across eight cases: PhilipsHue, Siemens MindSphere, Smart Forst Stihl, Uber Technologies Inc., OP 4.1, AppleHomeKit, HERE, and adidas GMR (Eisenhardt, 1989, 2021; Eisenhardt & Graebner, 2007; Yin, 2018). The data for analyzing these cases were gathered from publicly available sources. The key findings include the identification of eight ideal types of ecosystem roles: Digital Enabler, Digital Incumbent, Service Extender, Digital Disruptor, Digital Optimizer, Digital Ecosystem Extender, Vertical Integrator, and Horizontal Bridge Builder. Each of these roles is associated with specific potentials for implementing smart services. The study also differentiates between incremental, radical, and disruptive smart service implementations. Additionally, it highlights that the implementation of smart services can be oriented either toward coordination or cooperation (see Figure I.4-5).

As already seen from the references in the figures, three of the five articles included in this thesis have already been published. The other two are in the process of being published. More detailed information on each article can be found in the subsection *Notes on publication* that precedes the article. Each individual article included in the following main section is a stand-alone work. Contextualization of the results and the subsequent contributions of all articles are provided in the epilogue following the main part of this work.

Paper 5 Implementation of smart services in ecosystems

Laut, P., Bähr, K. (2022). Implementierung von Smart Services in Ökosystemen. In: Bruhn, M., Hadwich, K. (Eds.), *Forum Dienstleistungsmanagement 2022 Smart Services*, Springer Nature, 463-496.

Research question

- How do different ecosystem characteristics, the smart service design and the company's ecosystem position interact at the implementation of smart services in ecosystems?

Theoretical perspective

- Roles in business ecosystems
- Evolution of business ecosystems

Research design

- Comparative case study with multiple cases
- Theoretical sampling of eight cases: PhilipsHue, Siemens MindSphere, Smart Forst Stihl, Uber Technologies Inc, OP 4.1, AppleHomeKit, HERE and adidas GMR
- Publicly available data on selected cases

Key findings

- Characterization of eight ideal types: Digital Enabler (I), Digital Incumbent (II), Service Extender (III), Digital Disruptor (IV), Digital Optimizer (V), Digital Ecosystem Extender (VI), Vertical Integrator (VII), and Horizontal Bridge Builder (VIII)
- Different ecosystem roles encounter specific implementation potentials
- Incremental, radikal and disruptive smart service implementations can be differentiated
- Implementation of smart services can happen with coordination or cooperation orientations

Figure I.4-5: Overview Paper 5 - Implementation of smart services in ecosystems
(Author's own illustration)

II Main part: Research papers

II.1 The twofold transition: Framing digital innovations and incumbents' value propositions for sustainability

II.1.1 Notes on publication

The following academic article titled “The twofold transition: Framing digital innovations and incumbents’ value propositions for sustainability” was co-authored by my supervisor Prof. Dr. Alexander Fliaster and myself. The detailed division of tasks can be found in the authorship declaration.

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited. How to cite this article: Bähr, K., & Fliaster, A. (2023). The twofold transition: Framing digital innovations and incumbents' value propositions for sustainability. *Business Strategy and the Environment*, 32(2), 920–935. <https://doi.org/10.1002/bse.3082>

As corresponding author, I submitted the article to the Journal Business Strategy and the Environment for consideration to the Special Issue “Corporate and Entrepreneurial Contributions to Sustainability Transition” in August 2020. The journal *Business Strategy and the Environment* is rated as an important and respected journal in business administration (B) in VHB’s Publication Media Rating 2024, section Sustainability Management. Three rounds of revision took place. The revised version was accepted for publication in March 2022. The online preliminary version was published in April 2022. The final version of the article in the Special Issue has been available since 2023.

Earlier and shorter versions of the article including the research idea, research design and initial results were presented at influential international conferences with competitive submission processes and double blind peer review:

- Fliaster, A., Bähr, K., Kolloch, M. (2018). Digital Organizing in the Energy Sector: New Value Propositions, New Network Ties. *Academy of Management Specialized Conference “Big Data and Managing in a Digital Economy”*, 18-20 April, Surrey/UK.
- Bähr, K., Fliaster, A. (2020). The twofold transition: How digital innovations pave incumbents’ pathways to sustainability. *36th EGOS Colloquium 2020 – Organizing for*

a Sustainable Future: Responsibility, Renewal & Resistance, 2-4 July, Hamburg/GER, virtual.

Publicized Acknowledgements: Earlier versions of this manuscript were presented at the Academy of Management Specialized Conference 2018 'Big Data and Managing in a Digital Economy' in Surrey, UK, and at the virtual 36th EGOS Colloquium 2020 'Organizing for a sustainable future: Responsibility, Renewal, and Resistance' in Hamburg, Germany. We would like to thank all discussants for their helpful comments. This research did not receive any specific grant from funding agencies. Open access funding enabled and organized by Projekt DEAL.

II.1.2 Academic article

Abstract: Although digital technology offers many sustainable business model opportunities, they are not always exploited. We argue that the framing of technology is still rarely considered a cognitive antecedent of business models for sustainability, despite that it offers insightful explanations, connecting technology's sustainability potential to its business model implementations. We conduct a qualitative multicase study of virtual power plants, adopted by seven incumbent companies in the German energy sector, and explore how they frame innovative digital technology, as well as how it affects their value propositions and the energy transition. Our research reveals several value proposition differences between two company groups. The first generates a singlefocused technological frame, concentrating on economic value. The second constructs a twofold digital and sustainable technological frame, resulting in additional socioenvironmental value components. Overall, companies that create a twofold frame operate as renewable energy enablers or system supporters and contribute to the energy transition.

Keywords: business models for sustainability, digital innovation, energy, sustainability, technological frame, value proposition

List of abbreviations/acronyms: BM, business model; BMWi, Bundesministerium für Wirtschaft und Energie; Federal Ministry for Economic Affairs and Energy 2013–2021; ES, environmental sustainability; IT, information technology; MW, megawatt; VPPs, virtual power plants.

Introduction

Today's societies and organizations face the fundamental evaluative, ambiguous, uncertain and highly complex challenges of sustainability (Farla et al., 2012; Ferraro et al., 2015; Markard, 2017). Transitions towards sustainability imply enacting major changes in the established sociotechnical systems to prioritize more environmentally friendly production and consumption (Markard et al., 2012). These changes are nonlinear or disruptive and span longer periods (Loorbach et al., 2017). Sustainability transitions are highly dependent on context and policy

and involve interactions between technology, institutions, and the social sphere (Hölscher et al., 2018; Markard, 2017). For companies, sustainability transition challenges refer to the need to move towards completely new and more sustainable value propositions and business models (Schaltegger, Hansen, & Lüdeke-Freund, 2016). Accordingly, scholars advocate for sustainable business models that permit the creation of ecological and social value, beyond purely economic benefits (Freudenreich et al., 2020; Lüdeke-Freund, 2020). Moreover, these business models must provide value not only to the company but also beyond its organizational borders, to its stakeholders and society as a whole (Hahn et al., 2014). Overall, sustainability aims to consider both today's and tomorrow's generational interests and to foster an acceptance that our environment's natural resources and ability to withstand pollution are limited (World Commission on Environment and Development, 1987).

Along with these sustainability transition challenges, companies are increasingly confronted with another fundamental issue, business digitalization. Several authors offer distinct definitions of digitization, digitalization, business digitalization, and digital transformation (Bharadwaj et al., 2013; Nambisan et al., 2017; Ritter & Pedersen, 2020). In this study, we define digitalization at the organizational level as the adoption of new digital technologies intended to enable new market offerings, business processes or business models (Brennen & Kreiss, 2016; Gregori & Holzmann, 2020; Nambisan et al., 2017). Past research provides substantial empirical evidence that companies deliberately deploy new digital technologies, such as social media, big data analytics or digital platforms, to achieve ‘major business improvements (such as enhancing customer experience, streamlining operations or creating new business models)’ (Fitzgerald et al., 2013, p. 2). In simpler terms, scholars argue that business digitalization can increase a firm's internal efficiency and organizational growth by adding value to customers (Björkdahl, 2020).

While one main objective of business digitalization is to create economic value, sustainable business models enabled by digital technologies also aim for higher ecological and social value. Thus, while the challenges of digitalization and sustainability transitions are likely to be strategically relevant for the vast majority of industry sectors, they play a particularly decisive role for energy companies (Flaherty et al., 2019; Kolloch & Golker, 2016). Startups and established companies each make a unique contribution to the energy transition (Palmié et al., 2021; Schaltegger & Hansen, 2017). According to Palmié et al. (2021), incumbents excel at testing capital-intensive and complex business models, while startups, in particular, create

business models that are characterized by a high ecological orientation, digital capabilities and a strong customer focus. In some industries, this business model innovation enables market players to initiate the sustainability transition, while in others, such as energy, the support of political and institutional players is essential (Schaltegger & Hansen, 2017). For instance, the German 'Energiewende' ('energy transition') policy explicitly strives to reduce greenhouse gas emissions, boost energy efficiency and enhance renewable energy (Umweltbundesamt, 2018), resulting in the energy sector's decarbonization. The changing regulation has also led to the German energy sector's decentralization (Lindberg et al., 2019), essentially transforming the competitive landscape and severely increasing competitive pressure on market players (Geels et al., 2016). This market pressure forces companies to put additional efforts into developing economically feasible solutions, such as more profitable value propositions, through digitalization (Kolloch & Golker, 2016). Furthermore, new German regulations, such as the Act on the Digitalization of the Energy Transition (BMWi, 2016), also promote energy companies' digitalization efforts. Consequently, more than three out of four energy companies in the German-speaking countries Austria, Germany and Switzerland are currently working on a digitalization strategy (Kearney, 2020), with 44% rating digitalization as their top priority (Basilio, 2020).

While research on business models for sustainability and business digitalization is burgeoning, these topics are largely disconnected in previous works, despite that companies are already facing these issues. Acknowledging this research gap, recent studies are increasingly addressing digital sustainability: the use of digital technologies for new business models that also enable social and environmental value creation (George et al., 2021; Gregori & Holzmann, 2020). These studies perceive business model innovation as a mediator between digital technologies and socioecological value creation and between sustainability innovations and business cases for sustainability (Lüdeke-Freund, 2020; Parida & Wincent, 2019). For example, sonnen uses software that can optimize charging and discharging processes to improve the life of batteries used to store renewable energy, and LichtBlick offers analyses of smart meter data to boost customers' energy efficiency (see for more information LichtBlick, 2022; sonnen Group, 2022). As such, the current study aims to contribute to this new and promising research area. From a theoretical perspective, we argue that companies' framing of underlying digital technologies is likely to affect how they support ongoing transitions to sustainability.

The energy transition builds on the belief that societies should replace fossil energy with renewable energy systems enabled, in particular, by technological innovations (Loorbach et al., 2017). An example of such technologies is virtual power plants (VPPs). VPPs virtually integrate several distributed power-generating, power-storing and powerconsuming units to permit aggregation and remote control of individual units with different digital technologies (Nosratabadi et al., 2017; Othman et al., 2015). Aggregation and remote control of distributed units that use wind, solar energy or biogas help balance fluctuating power generation and grant access to more electricity markets due to minimum market entry constraints (Naval & Yusta, 2021; Nosratabadi et al., 2017; Othman et al., 2015). For example, Next Kraftwerke (n.d.) was a new entrant in 2009 and operated a VPP with more than 9500 MW and 13,000 units in 2021. In sum, VPPs unfold a huge potential to transform energy systems as they change established roles of industry incumbents (e.g., producer and consumer) by introducing new actors like citizens and their engagement in energy production.

Past research already indicates that similar organizations might interpret the same technology differently, depending on framing, which results in very different organizational actions (Edmondson, 2003; Spieth et al., 2021). Innovation studies use the framing construct at the meso level to explore vital organizational processes, such as administrative innovation implementation (Kennedy & Fiss, 2009), organizational responses to discontinuous innovations (Weber et al., 2019) and knowledge transfer interactions (van Burg et al., 2014). However, despite some notable exceptions (Hahn et al., 2014; Scrase & Ockwell, 2010), the application of cognitive frames in sustainability research, especially in sustainable business model research, is still limited and constitutes a promising avenue for research (De Giacomo & Bleischwitz, 2020; Lüdeke-Freund, 2020; Rovanto & Bask, 2021). De Giacomo and Bleischwitz (2020, p. 3362) propose in their literature review, ‘to investigate the managerial cognitive dimension linked to BM [business model] for ES [environmental sustainability]’, because cognition is still neglected in this literature. Additionally, Lüdeke-Freund (2020, p. 678) concludes his ‘list of barriers [to business models for sustainability innovation] is extensive but not yet conclusive. Further barriers might be added, such as cognitive effects’. To address this gap, we explore the following research questions:

- RQ1. How do incumbent companies in the German energy sector frame currently emerging digital VPP technologies?

- RQ2. Which role do digitalization and sustainability considerations play in their technological frames?
- RQ3. How do differences in incumbents' technological frames affect the design of sustainable value propositions and, as a consequence, the sustainability implications at the company and the broader societal level?

Our findings extend existing knowledge in several ways. First, we enrich the discussion on sustainable business model innovation by adding the technological frame as an important cognitive antecedent (Bocken et al., 2014). Thus, we answer the call to inform sustainability research with an established concept from organization studies (De Giacomo & Bleischwitz, 2020; Köhler et al., 2019; Lüdeke-Freund, 2020). Second, we add knowledge on the system perspective within business models for sustainability research by providing two explanations for how business models' value creation connects company- and system-level sustainability (Bidmon & Knab, 2018; Bocken et al., 2014; Sarasini & Linder, 2018; Schaltegger, Lüdeke-Freund, & Hansen, 2016). We elaborate on two crucial sustainable business model facets: considering many stakeholders and delivering a blended value (Gregori & Holzmann, 2020; Schaltegger et al., 2012). Lastly, we add insights on incumbents' role in the energy transition, as they are powerful actors whose support offers important opportunities for societal transitions to sustainability (Loorbach et al., 2010; Loorbach & Wijsman, 2013; Rovanto & Bask, 2021; Schaltegger, Lüdeke-Freund, & Hansen, 2016).

Primarily, we discuss technological framing and its relevance in sustainable business model research. Subsequently, we describe our data collection and analysis, followed by our empirical findings. In particular, we reveal that companies that create a twofold, digital and sustainable technology frame contribute to sustainability transitions beyond their organizational borders, operating as renewable energy enablers or system supporters. Finally, we highlight our managerial implications. For instance, we argue that influential incumbents should adopt potential sustainable technologies and that their communication strategy should encourage important sustainability-oriented stakeholders, such as green prosumers, to adopt digital technology to further promote society's sustainability transitions. The paper concludes with our limitations and suggestions for future research.

Sustainable Value Creation and the Technological Frame Construct

To create our theoretical framework, we respond to several sustainability scholars' recent calls for applying concepts from organizational studies to transition-related research questions (Köhler et al., 2019). One of the most influential theoretical constructs in management and organization theory is framing (Cornelissen & Werner, 2014). First applied to explore managerial cognition, and individuals' sense-making and decision making in organizations (Weick, 1995), framing has since expanded from the micro to the meso analysis level (Cornelissen & Werner, 2014; Maitlis & Christianson, 2014). Generally, framing helps us understand how organizations interpret information and how these interpretations guide organizational decisions and activities to adopt innovations and initiate organizational change (Edmondson, 2003; Kennedy & Fiss, 2009; van Burg et al., 2014; Weber et al., 2019).

Past research reveals that framing helps actors deal with high uncertainty situations, stemming from ambiguous or missing information (van Burg et al., 2014). Thus, framing is likely to be relevant in the process of adopting new digital technologies associated with both high technological and market uncertainty (Nambisan et al., 2017; Yoo et al., 2012). We believe that the framing of those technologies is also important in the context of sustainability transitions, in which 'the potential solutions and outcomes are not well-understood, societal preferences unclear and/or diverse, and political processes and techno-economic developments often unpredictable' (Markard, 2018, p. 628). In this context, technological framing should help organizations link novel digital technologies to broader societal discourses and design and articulate new visions concerning potentially sustainable innovations (Gish & Clausen, 2013). Hence, drawing on previous studies (Edmondson, 2003; Kennedy & Fiss, 2009), we argue that organizational actors' technological framing will guide their specific application patterns, such as new digital technologies' sustainability-oriented value propositions.

To address technological frames, we refer to Orlikowski and Gash (1994), who identify three broad domains: the nature of technology, technology strategy and technology in use. Several studies address these key domains (Olesen, 2014), providing empirical evidence that the domains 'are a useful starting point for examining key actors' interpretations of technology, and the nature and extent of differences among them' (Orlikowski & Gash, 1994, p. 204). The first domain, the nature of technology, involves the innovator's 'understanding of its capabilities and functionalities' (Orlikowski & Gash, 1994, p. 183), or features and uses (Davidson, 2002), and

can be linked to the question, 'What is it?' (Saarikko et al., 2020). The second domain, technology strategy, captures innovators' 'views of why their organization acquired and implemented the technology' and denotes 'the motivation or vision behind the adoption decision and its potential value to the organization' (Orlikowski & Gash, 1994, p. 183). Additionally, it includes standards for judging the success of technology adoption and answers the question, 'Why should it be used?' (Davidson, 2002; Saarikko et al., 2020). Particularly, this domain gains significance when organizations begin to use these technologies and public discourses translate into specific organizational contexts (Linderoth & Pellegrino, 2005). Finally, the technology in use domain entails innovators' 'understanding of how the technology will be used on a day-to-day basis and the likely or actual conditions and consequences associated with such use' (Orlikowski & Gash, 1994, p. 183), referring to the question 'How is it used?' (Saarikko et al., 2020).

Previous studies reveal that technological frames are dynamic, as a contextual change can trigger organizations to reinterpret existing information and gain new insights (Davidson, 2002). Accordingly, the German energy sector is currently undergoing substantial changes, due to digitalization, deregulation, and decarbonization. This changing context may open up fresh opportunities to adapt and modify technological frames (Davidson, 2006), reflecting the growing awareness of sustainability issues. Hence, we expect energy companies to conduct business activities that use digital innovations to create economic value and solve ecological or social problems (Freudenreich et al., 2020; Lüdeke-Freund, 2020). These business activities can be embedded into novel business models that follow a 'rationale which positions sustainability as an integral part of the company's value proposition and value creation logic' (Schaltegger et al., 2012, p. 102).

Recent research also reveals that value creation and the resulting value propositions are central to business models in general and sustainable business models in particular (De Giacomo & Bleischwitz, 2020; Eyring et al., 2011; Geissdoerfer et al., 2018; Schaltegger, Hansen, & Lüdeke-Freund, 2016). To address sustainable value creation enabled by digital technologies, we refer to the business model paradigm (Amit & Zott, 2001), specifically to business models that combine value creation and capturing (Chesbrough, 2007). Despite the ongoing debate on business model concept definitions, the consensus on some central functions is growing (Zott et al., 2011). First, the business model describes value creation for all stakeholders, not just the focal firm's value capture logic. Second, it considers thirdparty activities, such as suppliers or

customers. Third, it explains business logic at the system level and constitutes a new perspective for analysing organizations (Zott et al., 2011). Overall, business model innovation creates new business models through experimentation and exploration (Afuah, 2014; Chesbrough, 2010; Foss & Saebi, 2017).

We must also briefly address business cases of sustainability, as business model innovations may result in different business cases, depending on the corporate sustainability strategy (Schaltegger et al., 2012, 2019). Nonetheless, repetitive reproductions of single event-driven business cases can create business models for sustainability (Schaltegger et al., 2012). The literature discusses several different business cases in the context of sustainability (Schaltegger et al., 2012, 2019; Schaltegger & Burritt, 2018). For instance, Schaltegger et al. (2012) differentiate between regular business cases, business cases of sustainability and business cases for sustainability. According to the authors, business cases of sustainability create economic profit while companies consider social and environmental issues, whereas business cases for sustainability entail ‘voluntary activity with the intention to contribute to the solution of societal or environmental problems’, (p. 98) which must involve executive action and result in positive business effects. More recently, Schaltegger and Burritt (2018) introduce four business cases, depending on managers' ethical motivations for sustainability activities. Moreover, by integrating stakeholder theory, we can add other business cases, pertaining to stakeholder management and sustainability (Schaltegger et al., 2019). The commonality in all these concepts is that they differentiate between business cases' initial purpose, beneficiaries and sustainability roles (Schaltegger et al., 2012, 2019; Schaltegger & Burritt, 2018). Similarly, the technological frame addresses the purpose and benefits of technology adoption (Davidson, 2002; Orlikowski & Gash, 1994; Saarikko et al., 2020). These similarities constitute an excellent point of departure for the following ideas.

Recent studies argue that three essential features characterize corporate sustainable business models: (1) creating value beyond economic benefits, involving ecological and social value components; (2) systematically recognizing the interests of and creating monetary/non-monetary value for multiple stakeholders, not only for themselves, their customers and shareholders; and (3) addressing several stakeholders' individual demands, while contributing to societal welfare (e.g., communities) (Bocken et al., 2014; Evans et al., 2017; Freudenreich et al., 2020; Hahn et al., 2014; Lüdeke-Freund, 2020; Schaltegger, Hansen, & Lüdeke-Freund, 2016). However, others present a more nuanced view. For instance, the system perspective

within sustainable business model research discusses how sustainable business model innovation can support sustainability transitions at the system level, such as the business environment, regulations or institutions (Bocken et al., 2014; Schaltegger & Wagner, 2011). Accordingly, Rovanto and Bask (2021) show that incumbents can support societal transitions through their influence on suppliers. Incumbents can also support industry sustainability if they replicate the sustainable business models of more sustainable entrants or commercialize their new technologies (Bidmon & Knab, 2018; Schaltegger, Lüdeke-Freund, & Hansen, 2016), as they have superior experience and infrastructures (Richter, 2013).

The relationship between business models and technology is especially intriguing in the context of sustainability, as the same technology might have different sustainability impacts depending on the chosen business model (Sarasini & Linder, 2018). Overall, scholars argue that new digital technologies can contribute to these key sustainable business model features by supporting the creation of blended value propositions that embed several stakeholders' social, ecological and financial values (Emerson, 2003; Gregori & Holzmann, 2020). Although prior studies demonstrate the importance of technological framing for digital technology adoption, research on sustainable business models has not yet employed this cognitive perspective (De Giacomo & Bleischwitz, 2020; Lüdeke-Freund, 2020). This cognitive perspective adds important insights as it helps to understand additional barriers to sustainability innovations and is essential to overcome these barriers. Thus, we empirically address this important gap by exploring how digital technological frames lead to more sustainable value propositions and contribute to sustainability transitions beyond organizational borders.

Data Collection and Analysis

The multicase study methodology appears particularly useful for understanding complex phenomena, such as technological framing during sustainability transitions (Cunningham et al., 2017; Geels, 2002; Gregori & Holzmann, 2020; Yin, 2017). As it builds on constant case comparisons (Bansal et al., 2018), this methodology helps strengthen the reliability of emerging theoretical arguments. Concerning data collection, we focused on incumbent companies, taking a cue from prior studies that identify incumbents' contributions to the promotion of renewable technologies as one of the central and underexplored themes in sustainability transitions, especially in the energy sector (Markard, 2017). Thus, we collected and analysed data on

incumbents in the German energy sector that adopted VPP technology. Innovative digital service platforms (Midttun & Piccini, 2017), such as VPPs, allow for the integration of several renewable and decentralized power-generating units (Nosratabadi et al., 2017). The VPPs have recently attracted the attention of key actors, resulting in creative efforts to collaboratively explore new business models and address the challenges of weak profitability (Breuer & Lüdeke-Freund, 2017; Richter, 2013).

The VPPs contain several features that make them particularly suitable for our research objectives with regard to energy transition. For instance, they integrate especially renewable power-generating units, such as photovoltaics, wind turbines, hydro turbines and biogas. More advanced VPPs also embed power-generating unit and energy storage tool controllability, such as batteries, pumped storage or electric vehicles (Kasaei et al., 2017; Nosratabadi et al., 2017). As VPPs make decentralized, renewable power-generating units visible to system participants, they help avoid overcapacity and resource underutilization (Pudjianto et al., 2007).

Aggregation and controllability are particularly critical, due to renewable energy sources' high volatility: a VPP aggregator controls and manages the entire VPP system by load dispatching, selling and purchasing energy to and from the energy market, while also considering diverse data sources, such as weather, operating cost and forecast data (Nosratabadi et al., 2017). Furthermore, VPPs not only rely on the activities of different industry actors, such as energy producers, software and hardware developers and marketer service providers, but also transform key components of the ecosystem (e.g., the actors and their business relationships). Within the VPP ecosystem, many energy customers play a dual role, serving as both electricity consumers and producers (prosumers) (Dellermann et al., 2017). As those ecosystem changes will have profound consequences on different sectors, sustainability scholars have recently called for more research on platform technologies, including VPPs (Markard, 2018).

In this study, we identified the incumbent companies as the 10 biggest energy firms and 20 biggest municipal utilities in Germany. We conducted desk research and scanned publicly available information to determine which incumbents engage in VPP projects. As we could not obtain any information on VPP engagement for eight of the incumbents, we excluded them, as well as the incumbents that publicly reported using technologies developed by other incumbents that were already part of our case selection. Then, we contacted 78 middle managers and employees from 10 incumbents. From these, 53 did not respond, 12 answered our request, but

were unwilling to participate, and one person agreed to have an informal exchange, but did not grant us permission to be cited. Thus, we were able to obtain 12 semi-structured formal interviews with respondents from seven incumbent companies (total interview duration 12.5 h, see Appendix A).

All informants were or are still directly involved in projects related to VPPs and can be considered knowledgeable agents (Gioia et al., 2013). This is particularly advantageous for our explorative study on technological framing and sustainability, because as previous research demonstrates, middle managers and employees offer valuable insights for analysing potentially radical changes (Jarzabkowski et al., 2019; Lassen et al., 2009). The interviews took place in person, via phone or video conference, following the interviewee's preferences, and all were recorded and transcribed with the interviewee's consent. The transcripts totalled 91,600 words on 234 pages.

We asked the interviewees to define VPPs, explain how their company uses them and describe what kind of value these VPPs have created for their company, customers and other constituencies. In this process, we followed the best practices for interview design (Rowley, 2012) and rigorous qualitative data collection and analysis in general (Gioia et al., 2013; Rheinhardt et al., 2017). For example, we returned to interviewees if new questions emerged during data analysis and flexibly adjusted our interview process to react to their answers. We also deployed additional sources to obtain information on the companies and their VPPs. Similar to other qualitative studies (Nag et al., 2007; Nag & Gioia, 2012), we collected and analysed publicly available corporate data (see Appendix B). Specifically, we studied 36 press releases and 47 annual reports covering VPPs, as well as archival data published in business magazines and newspapers (e.g., *Handelsblatt*), and energy industry journals (e.g., *Zeitschrift für Energiewirtschaft*). We used this additional information to develop a deeper understanding of the industry context and its current dynamics.

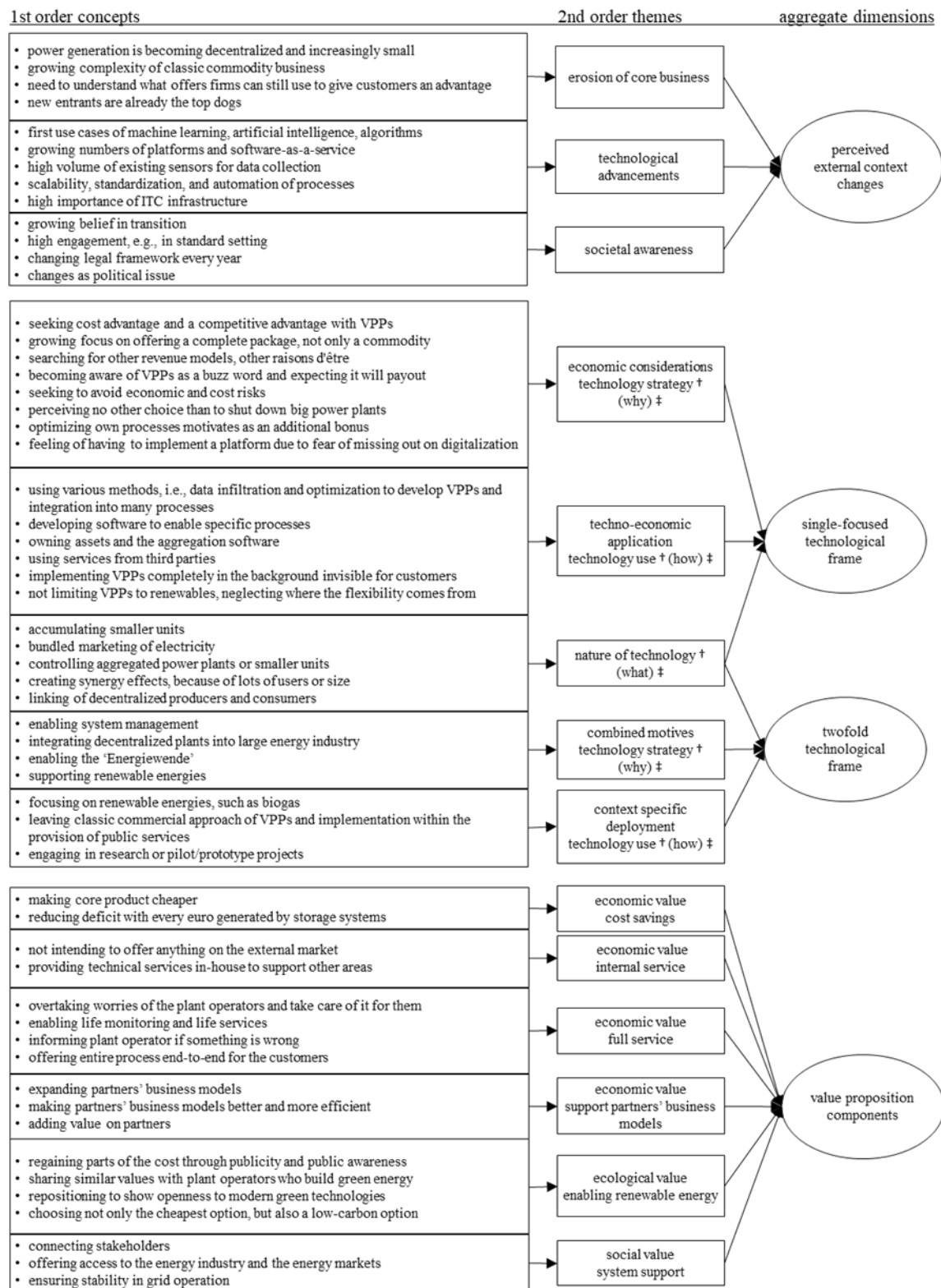
We took several additional steps to ensure that our data met Lincoln and Guba's (1985) seminal criteria for trustworthiness, which are particularly important for qualitative research designs. For instance, both authors were involved in the data analysis to ensure that the findings did not solely rely on a single analyst's interpretations. Following Gioia et al.'s (2013) recommendations, we also read the interview data several times and engaged in mutual discussions to achieve agreements. Moreover, we also gained outsider perspectives by

discussing emerging insights with four other industry experts, who work in the energy sector, but are not directly involved in the studied VPP projects, and with several other sustainability and digitalization scholars during two international research conferences (Corley & Gioia, 2004).

We used MAXQDA® Plus 2020 to code the interview data, specifically applying inductive open coding to identify central topics from an informant's perspective and allow insights to emerge (Corley & Gioia, 2004). We searched for important issues to grasp what is occurring and highlighted the corresponding interview text passages, which resulted in informant-centric central concepts (Thornberg & Charmaz, 2014). We clustered similar concepts to form first-order categories and assembled them into second-order themes, based on theoretical considerations (Gioia et al., 2013; Nag et al., 2007; Nag & Gioia, 2012). In this second-order analysis, we considered whether the emerging theoretically distinctive themes can better explain the companies' different technological frames and value propositions (Gioia et al., 2013).

The data analysis consisted of several rounds. We went back and forth between the interview data and theoretical concepts, refining our framework based on accumulated evidence. Connecting emergent facets to previous technology framing literature, we concluded that several first-order categories could be optimally clustered into Orlikowski and Gash's (1994) three frame dimensions, while the other nine second-order themes emerged directly from the aggregation of informant-based first-order codes. In the final step, we further consolidated the second-order themes, eventually building four overarching dimensions shown on the right-hand side of Figure II.1-1 (Corley & Gioia, 2004; Gioia et al., 2013). Our constant comparisons between codes, themes, dimensions and cases produced insights into the value propositions resulting from VPPs' technological framing in the face of the twofold energy transition. Figure II.1-2 presents the resulting model.

The twofold transition: Framing digital innovations and incumbents' value propositions for sustainability



†Emergent first-order categories are further clustered into nature of technology, technology strategy and technology use, referring to Orlikowski and Gash (1994) suggested concepts. ‡The questions 'what', 'how' and 'why' originate from Saarikko et al. (2020)

Figure II.1-1: Data structure
(Author's own illustration)

Findings

Altogether, context is important for understanding technological frames and value proposition designs, as it shapes the environment in which they emerge (Thomas et al., 1993; Weick, 1995). Thus, our analysis allows us to conclude that the perception of contextual changes comprises three distinct themes: erosion of core business, technological advancements and the societal awareness. First, changes in the competitive landscape result in the erosion of the traditional core business, stemming from the decentralization of energy production. The business model of operating large power plants is disappearing (Interviewee 8), the ongoing commoditization of energy is perceived as a considerable challenge (Interviewee 7) and the emergence of new competitors is perturbing the industry (Interviewee 2). In fact, some customers quit and re-emerge as competitors (Interviewee 5). Overall, the new competitors demonstrate how to use VPPs to generate profits (Interviewee 11) and challenge established players to compete with lower prices (Interviewee 1).

Second, the technological advancements are growing in importance in the energy industry, with the emergence of artificial intelligence, cloud-based services and big data (Interviewee 2). These digital technologies enable the automation of processes (Interviewee 9), by integrating existing sensors for data collection (Interviewee 11). Similarly, Interviewee 6 explains that the management of minor decentralized power-generating units necessitates more digital technology implementation. Additionally, the existing digital infrastructure either enables or limits the opportunities stemming from small decentralized units (Interviewee 8).

Third, there seems to be a high societal awareness and acceptance of Germany's energy transition (Interviewee 4). Although the interviewees believe that the energy transition can work (e.g., Interviewee 4, Interviewee 8, Interviewee 11), many stress that the energy transition's design is dependent on regulation (e.g., Interviewees 1, 5 and 7). In other words, many actors, such as proactive customers (Interviewee 9) or standard-setting associations (Interviewee 4), support the energy transition, but the challenge lies in regulation, due to its imperfect (Interviewee 11) and fast-changing nature (Interviewee 3). In sum, the findings highlight how the energy companies perceive the energy transition and help us to contextualize their technological frames. Additionally, their perception supports our perspective that VPPs and the energy industry are a suitable case to study technological framing during sustainability transitions.

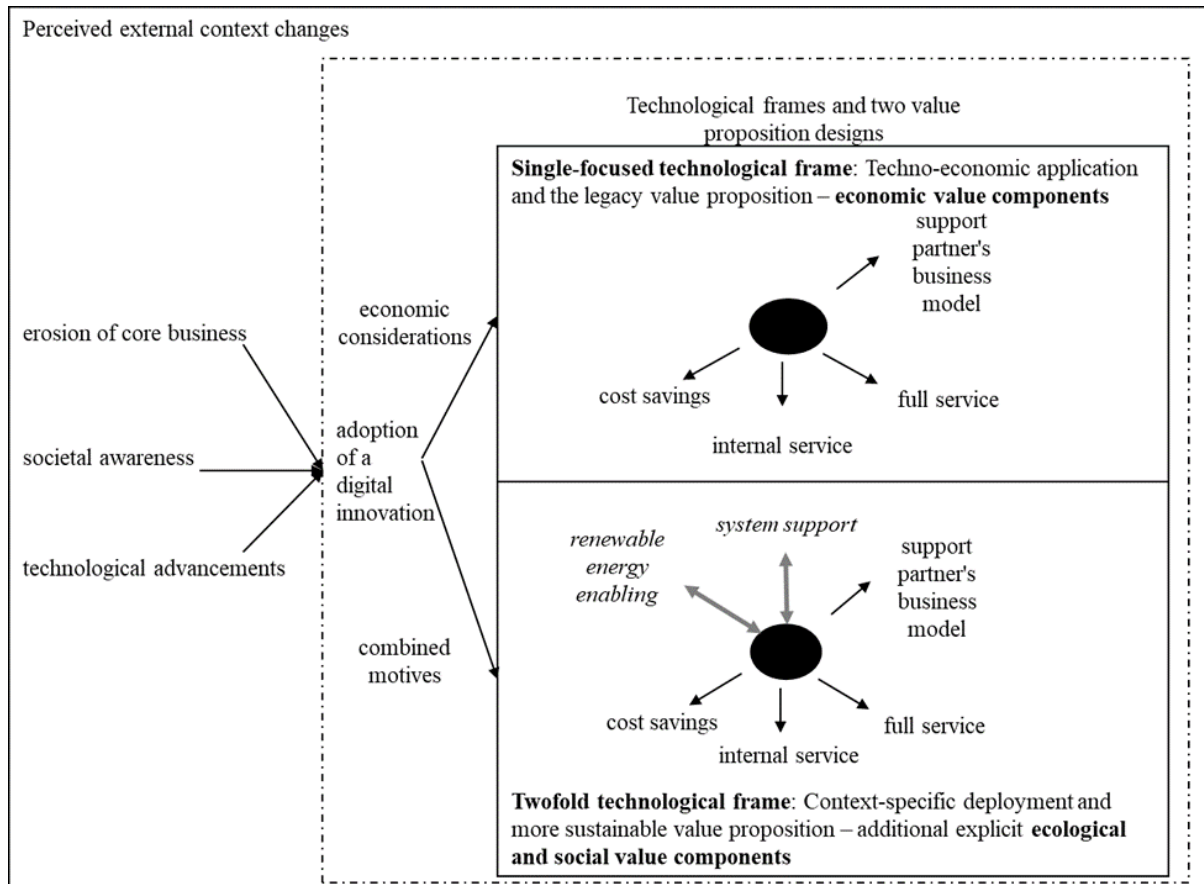


Figure II.1-2: Resulting model of single-focused versus twofold technological frames: Incumbent companies' value propositions
(Author's own illustration)

On the one hand, our data analysis reveals that all energy incumbents share a similar understanding of the first technological frame domain (the nature of technology) and stress the same fundamental issues: the virtual integration of small, decentralized power-generating units, the potential to include storage units and the active management of energy flows and market access. On the other hand, we find substantial differences between the incumbents regarding the two other domains (technology strategy and technology in use). Overall, the companies have two different patterns of framing VPP technology, leading to two different ways of designing value propositions and contributing to sustainability transitions.

The single-focused technological frame: VPP's sole focus on business digitalization

The first group of incumbent companies primarily emphasizes the technological aspects of adopting VPPs, such as automation and modifying existing organizational IT systems, and focuses on the economic benefits of technology adoption, such as operational efficiency. Even when they strive to attract new customers, owing to increased digital capabilities, these companies adhere to their existing customer value propositions that were in place before using VPPs, which we refer to it as their 'legacy' value propositions (upper rectangle, Figure II.1-2).

Economic considerations and strong market-pressure perceptions characterize the technology strategy domain of incumbents with a single-focused frame. For instance, Interviewee 1 explains: 'It is important to offer not only a commodity, but also a complete package, even though we are by far not the only one who can do this'. Similarly, Interviewee 8 declares: 'We need other revenue models, other *raison d'être*, and of course, the topic of VPP came up as a buzzword'. Furthermore, perceived market pressures and sense of urgency lead to prioritizing economic goals. As Interviewee 4 states, VPPs make it possible 'to grant small units grid access and if necessary, to avoid economic risks. Balancing energy and avoiding cost risks, these are the objectives'. The ongoing commoditization trend drives incumbents to invest in innovative technologies to optimize their product/services portfolio (Interviewee 3) and target efficiency through digitalization, automation, and better process management (Interviewee 11). In this context, Interviewee 11 expresses digitalization's importance for competition in the energy industry: 'Everyone felt they had to have a platform, otherwise they would miss out on digitalization'.

Regarding the technology use domain, we find that synced technological and economic considerations also dominate the ways in which these companies adopt VPPs. For instance, Interviewee 8 explains: 'From the very beginning, we focused on small assets when we built our platform, both on the IT side and product side'. These techno-economic application facets outshine VPP sustainability. As Interviewee 1 notes: 'It's not just about renewables, it does not matter where the flexibility comes from'.

Our data analysis reveals that legacy value propositions, which focus solely on economic value, consist of four main components (see Figure II.1-2). The first component, cost savings, centres on making the provided services more affordable for the customer and/or more profitable for the incumbent company. The VPP plays a limited and subordinate role, mainly supporting the

legacy business model by adding flexibilities in the operations of heating or storage systems. The second component, internal service, means that the legacy business model's external customers obtain no economic benefits. Instead, the unit that operates a VPP creates economic advantages for other internal units of the same incumbent company. This internal service can be the first step in testing the value proposition that can then be scaled up. However, several incumbent companies do not currently plan to scale up their VPP operations, focusing solely on internal processes and services. The third component, full service, involves very intense customer service, as companies can use their existing knowledge and competencies in the energy business to organize end-to-end processes for their customers. The fourth component is to support partners' business models, entailing a strong external service orientation that is not limited to VPP processes. The services are bundled on digital platforms that enable partners to extend their business models by integrating third-party services.

In sum, the value proposition of incumbents with a single-focused technological frame is built around creating economic value for the focal company and its customers. For instance, Interviewee 3 summarizes: 'At the end of the day, for us, it was a purely monetary issue, so we had financial expectations. For customers, the plant operator [...], their role in the VPP is profit maximization'. This sole focus on economic benefits also dominates the value propositions that companies with a single-focused technological frame offer to stakeholders other than customers. As Interviewee 8 notes: 'Yes, the added values can vary depending on the stakeholder. However, at the end of the day, it is usually about automation, reducing process costs, reducing complexity [...], and expanding individual business models'.

The twofold technological frame: VPPs as digital and sustainable technology

For the second group of energy incumbents, VPP adoption is a digital innovation that contributes to economic objectives and is an essential shift towards sustainability resulting in combined motives. For some, the shift towards renewable energy has been 'a very digital topic from the start' (Interviewee 2). Specifically, regarding the technology strategy, Interviewee 2 notes:

The purpose is making the whole thing manageable, reasonably integrating decentralized plants into the large energy industry, and enabling Germany's Energiewende. It is a very ambitious goal to offensively expand renewable energies.

Within my company, this goal is on every poster, in every office, and in every meeting room. The strategy is communicated very strongly here and to the outside world.

The twofold frame's technology use domain mainly addresses context-specific deployment decisions that are in sync with the technology strategy mentioned above. For example, Interviewee 2 explains that VPP activities occur outside the purely profit-oriented business field. The company sees them as a 'general public service', because granting citizens access to basic energy supplies is an important responsibility of municipal utilities. Other respondents mention the opportunity to 'balance small generation plants in the region' (Interviewee 6) and 'respond very individually to a plant's needs' by switching it off and on remotely, depending on its particular requirements (Interviewee 5).

Within this group, our analysis identifies two subcategories (lower rectangle, Figure II.1-2). The first involves renewable energy enablers, who explicitly state that they aim to promote the energy transition at the societal level (Interviewee 2) and perceive themselves as pioneers in this process (Interviewee 5). Some of these incumbents declare contributing to a sustainability business model that acknowledges the natural environment as a salient stakeholder (Haigh & Griffiths, 2009; Stubbs & Cocklin, 2008). In addition, these companies feel connected to their customers, due to shared green values, and particularly appreciate lead users' contributions to the energy transition (e.g., prosumers) (Dellermann et al., 2017). As these incumbents recognize that their stakeholders have both economic and ecological concerns, they strive to extend their value propositions by blending economic and ecological values. For instance, Interviewee 6 observes: 'The generation plant itself is usually ecologically motivated. In the second step, there is the issue of integration into a VPP to generate additional revenues for this plant'. Interviewee 2 also explains: 'We are, of course, very close to the plant operators who produce green energy. This means that we work together and can also score very well with our green image'.

The second group involves system supporters, who particularly stress the importance of regional embeddedness and frame the VPP as a means to decentralize renewable power. In this 'new energy world' (Interviewee 9), the innovative digital infrastructure helps balance the fluctuating supply and demand of renewable energy by coordinating among a large number of small and diverse energy producers and consumers. System supporters also serve as enablers of further technological advancements in the area of e-mobility. As Interviewee 2 states, this is where 'we take over the control of the charging points in our VPP'. From a societal perspective, system supporters establish measures to sustain distribution and transmission grid stability by

regulating plants and balancing energy production and consumption at the regional level. In other words, being a system supporter also implies that these incumbents target sustainable value creation for a multitude of stakeholders, including societal ones (e.g., communities) (Schaltegger et al., 2019).

Furthermore, our data indicate that the impact of these two additional value components is not just additive but also transformational (Stubbs & Cocklin, 2008). However, this may also change the roles of the four legacy components mentioned above. Not only are incumbents with the twofold frame likely to introduce sustainability or hybrid goals (Alberti & Varon Garrido, 2017), but they also install new sustainable decision-making criteria for business development, resulting in a conscious abandonment of market opportunities when the latter do not meet firms' self-imposed sustainability standards. In sum, our data analysis shows that creating these two additional value proposition components shifts the economic perspective of business digitalization towards a more sustainable value proposition for energy incumbents and their stakeholders, and contributes to sustainability transitions at the societal level. For instance, Interviewee 7 explains:

In our grid region, we increasingly have to deal with challenging situations, with grid bottlenecks for example. As a result, feed-in management becomes too expensive for everyone from a societal perspective. Therefore, we consider the entire system to be advantageous if we can offer a means to regionally balance this. This is already inherent in a VPP to some extent.

Eventually, this broader perspective redefines value creation towards sustainability, because 'the lower economic benefit is compensated or outweighed by the second benefit of supporting the new energy world' (Interviewee 9).

Discussion

Our study reveals several differences between energy companies with single-focused and twofold technological frames that are related to their value definitions, the constituencies they consider relevant for the specific value they deliver and the technology frame domains that probably cause these differences.

Incumbent companies' development of sustainable business models

Overall, the differences related to both value propositions and relevant constituencies highlight the particular ways incumbents in the energy industry strive to build sustainable business models (Freudenreich et al., 2020; Schaltegger, Hansen, & Lüdeke-Freund, 2016; Stubbs & Cocklin, 2008). Companies with a single-focused frame target economic value and as a result, implement VPPs as a typical business digitalization project (Fitzgerald et al., 2013; Ritter & Pedersen, 2020). Incumbents with a twofold frame strive to generate a blended value proposition (Emerson, 2003; Gregori & Holzmann, 2020), integrating economic, social and environmental components. They believe that customers or prosumers, such as farmers who own biogas plants, are not only interested in economic benefits, but also in the supply and demand of green energy.

Moreover, this shift towards more sustainable value propositions is associated with a broader definition of the constituencies energy companies target as value recipients (Schaltegger et al., 2019). Companies with a single-focused technology frame generate economic value, especially for themselves, their customers and customers' business partners. This can include banks that finance plant owners' investments in new technologies. On the contrary, as argued in previous studies, sustainable business models aim to deliver value to a broader set of stakeholders (Freudenreich et al., 2020; Lüdeke-Freund, 2020). These findings elucidate two different sustainability facets: (1) companies consider stakeholders' interests more holistically, involving social and environmental concerns that exceed mere economic interests, and deliver a more sustainable, blended value (Evans et al., 2017; Hörisch et al., 2014; Lüdeke-Freund, 2020); and (2) incumbents consider a broader range of constituencies as value recipients, not only their primary stakeholders (e.g., owners and customers) (Hörisch et al., 2014). Therefore, we argue that combining these two dimensions supports the creation of sustainable business models and fosters their contribution to sustainability transitions.

Finally, sustainability scholars argue that a key constituency associated with sustainable business models is societal stakeholders particularly interested in social and environmental value (Freudenreich et al., 2020). Previous studies indicate that beyond considering individual stakeholders' interests, sustainable business models encompass the system's perspective, as companies and their stakeholders are a part of this system (Stubbs & Cocklin, 2008). For instance, Bidmon and Knab (2018) argue that business models mediate technological niche

innovations and established regimes. Our findings provide insights into several pathways that sustainable business models can use to build around VPPs' potential sustainable technology. We argue that energy companies that integrate broader societal stakes within their value propositions, such as system supporters, contribute to system-level sustainability beyond their organizational boundaries by creating value propositions that support stable electric power supplies in entire regions. These companies collaborate with important stakeholders, such as prosumers (Stubbs & Cocklin, 2008). Hence, they also encourage the transformation of prosumers' attitudes towards sustainability. Accordingly, sustainability scholars theorize that to facilitate both firm-level and system-level sustainability, cultural changes, such as more sustainable customer attitudes, are necessary (Stubbs & Cocklin, 2008).

Our study also highlights industry incumbents' roles in sustainability transitions. Innovation research frequently portrays incumbents as resistors who frame innovation as a threat and try to delegitimize innovators (Christensen et al., 2015; Weber et al., 2019). Scholars also perceive incumbents' struggle as a critical issue for sustainability and believe they are slowing down the energy transition (Markard, 2018). However, sustainability researchers are increasingly questioning these portrayals (Köhler et al., 2019), with some claiming that incumbents can support sustainability transitions by using their influence on other industry actors and diffusing business models (Bidmon & Knab, 2018; Rovanto & Bask, 2021; Schaltegger, Hansen, & Lüdeke-Freund, 2016). Our work also contributes to this different perspective, because we reveal how the same technology can influence sustainability transitions in different ways, depending on technological frames and the resulting value propositions. For example, incumbent companies with a single-focused frame, with digital and economic orientations, contribute to technology diffusion, but their value propositions represent a business case of sustainability instead of a business case for sustainability (Schaltegger et al., 2012), due to their focus on customers' economic benefits. Specifically, we identify two incumbent company groups in the energy sector (renewable energy enablers and system supporters), who actively promote innovative digital technologies and foster sustainability transitions in several ways. In sum, our findings reveal three ways energy firms can build such models: (1) companies provide economic and blended values, (2) they provide value to many stakeholders and (3) they meet individual stakeholders' particular demands, while contributing to societal welfare.

The relationship between technological frames, value creation and sustainability

We found that how companies frame emerging digital technologies, such as VPPs, shapes business digitalization strategies at the firm level and firms' contributions to sustainability transitions, beyond their organizational borders. Scholars are already integrating framing, cognition and sense-making to contemplate sustainability issues (Hahn et al., 2014; Weick, 1995). For instance, within the fields of global health and indoor air pollution, they highlight frames' powerful role in tackling sustainability impasses (Jerneck & Olsson, 2011). Our findings in the energy sector provide further empirical evidence supporting the notion that different frames generate 'different sets of key questions, understandings and actions' (Jerneck & Olsson, 2011, p. 263). We particularly show that energy companies' sustainability strategies, drawing on the twofold technology frame, include configuring new value propositions.

Moreover, we find that the technology frame's three domains probably play different roles in value propositions and sustainability (Davidson, 2002; Orlikowski & Gash, 1994). Concerning the nature of technology, all incumbent companies in our study share similar views on the functionalities of VPPs. However, crucial differences emerge in the technology strategy and technology use domains. Thus, we conclude that mere knowledge about the functionalities of technology and its sustainability potential is not enough to create value propositions that release this potential, as the primary driver of sustainability seems to lie in technology strategy. As the latter entails the vision behind technology adoption and performance indicators, it is probably closely linked to an organization's purpose (Davidson, 2002; Evans et al., 2017; Hörisch et al., 2014; Orlikowski & Gash, 1994).

Finally, previous studies on cognitive frames and adopting innovations frequently define framing as issue interpretations in categories, such as gain opportunities versus potential losses (Kennedy & Fiss, 2009; van Burg et al., 2014). However, our research indicates that framing innovative technologies is more complex. Sophisticated technological innovations, especially digital technologies, involve flexible affordances that make them potentially useful in different contexts and for different purposes, such as sustainability transitions (Yoo et al., 2012). Therefore, we argue that technological framing in today's organizations includes perceiving and interpreting the nature of technology and creating new value propositions and stakeholder relationships (technology strategy and use).

Conclusions

In several industries, companies must address the challenges of sustainability transitions and digitalization, especially those within the energy sector, which plays a fundamental role in the economy and society (Flaherty et al., 2019; Kolloch & Golker, 2016). Although previous research disconnected digital innovations and sustainable business models, recent scholars are increasingly integrating them (George et al., 2021; Gregori & Holzmann, 2020; Parida & Wincent, 2019). In our qualitative multicase study, we explore how incumbent companies in the energy sector frame new digital technology, promote business digitalization and contribute to sustainability transitions beyond their organizational boundaries. Particularly, we find that different technology frames lead to different value propositions and contributions to sustainability transitions. While renewable energy enablers contribute by only operating with green electricity, system supporters sustain distribution and transmission grid stability by balancing energy production and consumption in their regional environment. Our findings extend existing knowledge in several ways. We introduce the technological frame as a crucial cognitive antecedent of sustainable business model innovation. We also add empirical knowledge to sustainability research by considering the system perspective within business models. Overall, our empirical insights contribute to a better understanding of incumbents' supportive role in sustainability transitions.

Additionally, these findings have managerial implications. First, as all companies in our sample are business organizations that must compete in the energy market, their value propositions must include economic values. Our empirical findings reveal several economic components in the value propositions, such as cost savings, that new digital technologies enable, while increasing efficiency and profitability. Figure II.1-2's summary may guide managers in combining economic and non-economic value proposition components in several ways. The figure summarizes possible value proposition components and, therefore, helps managers to avoid missed opportunities for additional value creation. In other words, other energy companies can learn how pioneers adopt and deploy VPPs in an economically feasible way. Consequently, potentially sustainable VPP technology can be disseminated within the energy industry, contributing to sustainability transitions beyond organizational borders.

Second, our research shows that implementing VPP technology allows for more sustainable value creation. However, if this digital technology is primarily used for managing conventional

energy, as several companies with single-focused frames do, it can reduce energy flows. Specifically in these cases, the positive ecological effect remains limited to minor carbon emission reductions. As companies with a twofold frame enrich their value propositions with system support and green energy, those that aim to employ digital technologies for blended value creation and promoting the energy transition should unequivocally focus on renewable energy and projects that involve green stakeholders (e.g., prosumers, such as biogas plant owners). The juxtaposition of both value proposition designs may help managers to become aware of their single-focused technological frame and motivate them to expand their framing.

Third, we encourage incumbents with a twofold frame to extensively communicate their contributions to sustainability transitions through several communication channels, as some already do in their public reports. Practically, active communication pertaining to new sustainable business models based on digital innovations can generate two positive effects: (1) publicly available information about a company's commitment to sustainable value creation can help attract likeminded sustainability-oriented stakeholders; and (2) as opinion leaders play a crucial role in innovation diffusion (Rogers, 2003), sustainability pioneers' effective communication can motivate other companies to develop twofold technology frames and eventually contribute to sustainability transitions.

Finally, our qualitative research methodology did provide valuable insights, but like all methods, it has its limitations that highlight attractive avenues for further research. First, our research considers only one industry with several idiosyncratic characteristics, such as high regulation, the importance of physical infrastructures, high commoditization and high change dynamics. These features might affect the technological frame and organizational responses, such as the configuration of value proposition components. Future research could show whether and how our insights can be transferred to other industrial settings.

Second, regarding the twofold transition, we argue that business digitalization and developing more sustainable business models can unfold at different speeds. Thus, longitudinal research is needed to investigate the dynamics of the interaction between these two change processes at the organizational level. Third, from a theoretical perspective, our explorative study focuses on technological frames' impact on innovation responses, such as creating new value propositions. As mentioned above, the notion that a specific framing supports a proactive implementation of technology corresponds well with previous research findings on the impact of technological

frames on technology adoption (e.g., Jerneck & Olsson, 2011). From this perspective, the twofold framing paves the way for further progress in the energy transition because it enables incumbents contribute proactively to niche creation and development. We encourage scholars to explore the intra-organizational mechanisms that affect technology framing to build an effective bridge between managerial cognition, technological innovation (particularly digital) and sustainability. For example, we speculate that proactive incumbents might find it easier to create a twofold frame because of their general sustainability orientation (Schaltegger et al., 2012, 2019). Moreover, we suggest that a longitudinal research design may shed more light at the cause-effect relationships between a company's technology framings and its contribution to sustainability transitions.

Fourth, prior studies argue that congruent technological frames support digital technologies' successful implementation and stress that sustainable business models must consider multiple stakeholders (Freudenreich et al., 2020; Hörisch et al., 2014; Lin & Silva, 2005). As diverse stakeholders might have different demands and objectives, we assume that incongruences between their technological frames will emerge and hinder the successful adoption of sustainable digital technologies. Hence, further research should address the frames produced by multiple stakeholders and investigate how these frames emerge and how innovators can influence framing to promote adoption. We hope that our study spurs additional research on the intriguing issues of sustainable business models, digital innovations and technology framing.

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Appendices

Table II.1-1: Appendix A - Formal semi-structured interviews

Interviewees' positions/units	Interview duration
Business and business model innovation	64 minutes
Business customer management VPP	59 minutes
Controlling renewable production	58 minutes
Head of close to market services	70 minutes
Head of commercial management	80 minutes
Head of decentralized commercialization	70 minutes
Key account management VPP	81 minutes
Product development and product management VPP	71 minutes
Product management for new businesses	39 minutes
Product management for new businesses	35 minutes
Senior innovation engineer	55 minutes
Smart and digital trading manager	57 minutes

(Author's own illustration)

Table II.1-2: Appendix B - Short case descriptions and data sources

Cases	Case descriptions	Data sources (covering VPP or the firm in general)
A	Case A primarily offers green energy and energy services. The VPP service focuses on the coordination of controllable energy users and producers, such as biogas plants.	• 1 interview • 1 informal interview • 6 press releases • 7 reports
B	Case B offers complex energy solutions on a supra-regional level. The VPP focuses on aggregations of controllable units, especially regarding the provision of flexibility and grid management.	• 1 interview • 1 press release • 3 reports
C	Case C offers smart energy or heat solutions, particularly by controlling combined heat and power plants.	• 1 interview
D	Case C offers the management of decentralized power generating units, the establishment of regional markets, and pooling services to gain market access.	• 2 interviews • 8 press releases • 17 reports
E	Case E concentrates on the provision of general public services and uses the VPP to integrate decentralized power producing and consuming units into the energy grid.	• 3 interviews • 5 reports
F	Case F has a digital platform around their VPP, offering four types of service building on this platform for a broad range of stakeholders.	• 3 interviews • 13 press releases • 11 reports
G	Case G uses software to offer VPP services, such as energy pooling and access to energy markets.	• 1 interview • 8 press releases • 4 reports

(Author's own illustration)

II.2 Framing struggles in emerging ecosystems: Frames of chemical recycling and ecosystem relationships

II.2.1 Notes on publication

The following academic article titled “Framing struggles in emerging ecosystems: Frames of chemical recycling and ecosystem relationships” was written by myself as single author.

As corresponding author I submitted the article to an important and respected journal in business administration (B) according to VHB’s Publication Media Rating 2024, section Sustainability Management in August 2024.²

Earlier and shorter versions of the article including the research idea, research design and initial results were presented at influential international conferences with competitive submission processes and double blind peer review:

- Bähr, K. (2022). Actors’ Values and Interests in Sustainability-Oriented Ecosystems. 7th New Business Model Conference (NBM 2022) - Sustainable Business Model Challenges: Economic Recovery and Digital Transformation, 23-24 June, Rome/ITA.
- Bähr, K., Fliaster, A. (2022). Technology Frame Incongruence in Digital Ecosystems. Strategic Management Society 42nd Annual Conference (SMS 2022). Innovative Strategies for an Open World, 17-20 September, London/UK.
- Bähr, K., Fliaster, A. (2023). Technology Frame Incongruence in Digital Ecosystems. 3rd Organization Theory Winter Workshop, 2-3 February, Oslo/NOR.

² The submitted article went under review in September 2024. After review, it was invited to be revised and resubmitted. At the time of publication of this dissertation, the article is still unpublished.

II.2.2 Academic article

Abstract: This research explores the impact of frame congruence and incongruence on ecosystem relationships within an emerging ecosystem. Ecosystems, composed of diverse actors, often develop differing perspectives or "technology frames" regarding the implications of emerging technologies, influencing how actors interact and collaborate. While previous research has focused on technology frames within organizations, there is a gap in understanding how these frames operate at the ecosystem level, particularly in shaping inter-organizational relationships. This study addresses this gap by analyzing 500 documents from 271 ecosystem actors to examine how frame congruence and incongruence affect collaboration and conflict within the context of chemical recycling. Chemical recycling, a technology that converts plastic waste into substances akin to crude oil, serves as the focal point due to its potential yet controversial role in advancing the circular economy. The study finds that congruent technology maturity frames do not necessarily prevent conflict, nor do incongruent technology maturity frames inherently cause conflict. However, a substantial finding is that congruence in circular economy fit frames strongly influences collaboration, with incongruent circular economy fit frames posing substantial barriers and leading to conflict. These findings contribute to the broader understanding of ecosystem emergence, by explaining how different technology frames can either facilitate or hinder collaboration within ecosystems. This study emphasizes the need for further research into how framing processes shape the emergence and development of ecosystems, particularly in the context of sustainability transitions.

Keywords: Collaboration, conflict, ecosystem emergence, frame, network, recycling, technology.

Abbreviations: CE, Circular economy; CEF, Circular economy fit; Nongovernmental Organization NGO; TM, Technology maturity

Introduction

Ecosystems are an essential research field of technology-enabled change that transcends industry borders (Rindfleisch et al., 2020). When an innovative technology with disruptive

potential emerges, actors may develop distinct perspectives (Kumaraswamy et al., 2018). Since many different actors populate ecosystems (Adner, 2013, 2017), these actors may develop different ideas regarding what the upcoming technology means for the ecosystem and its value creation. For instance, some actors associate technology with benefits and others rather with challenges (van Burg et al., 2014). Moreover, actors may seek to influence others' perceptions of technology (Gurses & Ozcan, 2015). As a result, those perceptions of technology, called technology frames (Orlikowski & Gash, 1994), may also affect firms' ecosystem behavior.

Although the concept of the technology frame has been widely used in research on the implementation of (digital) technologies inside organizations (e.g., Kennedy & Fiss, 2009; Maitlis & Christianson, 2014; Spieth et al., 2021), technology frames have hardly been considered in any depth in the ecosystem literature (Kumaraswamy et al., 2018; Raja et al., 2024). Against this background, scholars encourage future research "to broaden the unit of analysis to multiple levels of sensemaking, such as intra-organizational and inter-organizational aspects and sensegiving" (Penttilä et al., 2020, p. 218). Frame incongruences, which are "important differences in expectations, assumptions, or knowledge about some key aspects of the technology" (Orlikowski & Gash, 1994, p. 180), have been identified as a source of problems (Young et al., 2016). Consequently, Lundberg et al. (2022) argue that "firms must establish sufficiently aligned frames, contexts and technology within and across firm-boundaries" (p. 999).

One explanation for the adverse effects associated with incongruent frames is resulting conflicts. In general, conflicts have received little attention in research on interorganizational relationships (Lumineau et al., 2015) and only recently is interest on conflict in ecosystems growing (Jones et al., 2021). Moreover, even in network research, conflictual relationships, also known as negative ties, have received relatively little attention (Everett & Borgatti, 2014; Labianca, 2014). Hence, it seems promising to explore the co-occurrence of frame incongruence and relationships (collaboration and conflicts) in an emerging ecosystem in the face of technological change in order to better understand incongruence's connection with ecosystem relationships. On the other hand, some advocate that incongruence could also have a positive impact as it might "stimulate not only creativity in new product development but also knowledge generation and learning, the renewal of corporate capabilities, and the development and exploitation of resources" (Spieth et al., 2021, p. 28).

Besides, ecosystems as a whole and the emergence of new ecosystems in particular are still a relatively new field of research with many unanswered questions (Polese et al., 2021). Particularly in the context of the sustainability transition, it is important to better understand how framing, frames and legitimation support the creation of new meanings (Snihur et al., 2022). It is of particular interest to engage with existing companies, as they embed the commitment to support the emergence of a new ecosystem in their current business activities and ecosystem relationships (Thomas et al., 2022). Thus, the study of communication, including the topics and frames created by actors during ecosystem emergence, provides a good opportunity to better understand how managerial agency influences ecosystem emergence (Taillard et al., 2016). Qualitative data seem particularly suitable for a detailed understanding of such ecosystem emergence discourses (Roundy et al., 2018).

Therefore, in this research paper, frame incongruence and ecosystem-level relationships are addressed by posing the research question *How do frame congruence and incongruence, respectively, shape ecosystem relationships in an emerging ecosystem regarding chemical recycling?* Chemical recycling, or feedstock recycling, is an umbrella term for several technologies that convert plastic waste into substances similar to crude oil by breaking down polymers into monomers (Ragaert et al., 2017). The maturity level of these technologies ranges from lab tests to commercial applications (Solis & Silveira, 2020). Recently, interest in these technologies is growing again due to the potential contribution they could make to the circular economy (CE) transition (Garcia & Robertson, 2017; Jeswani et al., 2021; Rahimi & García, 2017). Yet, high energy requirements, costs, efficiency issues, and competition with mechanical recycling are posing challenges and hindering social acceptance (Lee et al., 2021).

To explore frame (in)congruence in the context of chemical recycling, 500 documents of 271 ecosystem actors are analyzed by applying qualitative content analysis and network visualization. The findings show that congruent technology maturity (TM) frames do not prevent conflicts and incongruent TM frames do not cause conflict. Different patterns emerge regarding circular economy fit (CEF) frames. There is an obvious preference for collaboration with actors that share the dominant technology fit frame. Incongruent CEF frames become an obstacle for collaboration and bring conflict.

Theoretical background on ecosystem emergence, framing, and technology frames

The origins of the ecosystem perspective lie in the 1990s and 2000s, when various authors explored the complementarity, interdependence, and modularity of value creation (Adner, 2006; Adner & Kapoor, 2010; Moore, 1993, 2006). In the meantime, several ecosystem types, such as business ecosystems, innovation ecosystems, platform ecosystems, entrepreneurial ecosystems, and knowledge ecosystems, have been discussed (Baldwin et al., 2024; Gomes et al., 2021; Shi et al., 2023). Such ecosystems arise in the context of sustainable (e.g., Nylund et al., 2021; Xin et al., 2023) or circular innovations (e.g., Kanda et al., 2021; Trevisan et al., 2022). It becomes clear that the concept of ecosystem is used in several loosely related literature streams (Aarikka-Stenroos & Ritala, 2017; Thomas & Autio, 2020). In this paper, ecosystems are defined as “collaborative arrangements” that emerge due to technological innovation that allows firms to “combine their individual offerings into a coherent, customer-facing solution” (Adner, 2006, p. 99). This definition takes into account that ecosystems “do not include only the actors that are directly or indirectly connected to a network, but also the actors, technologies, and institutions that are interdependent with less formal and looser manner” (Aarikka-Stenroos & Ritala, 2017, p. 27). Research on innovation ecosystems focuses on the interdependence of actors in innovation efforts (Adner & Kapoor, 2010; Ganco et al., 2020) and the role of complementarities (Jacobides et al., 2018; Kapoor & Agarwal, 2017).

Depending on the chosen definition and the different subtypes of ecosystems (innovation ecosystem, digital ecosystem, and platform ecosystem), the boundaries of an ecosystem are drawn differently. This means that the group of actors considered participants of the ecosystem differs. There is usually one or more companies at the center of an ecosystem (e.g., Adner, 2017; Daymond et al., 2023; Lingens et al., 2021; Moore, 1993). In addition to the leader–follower perspective, ecosystems can be analyzed in terms of actors’ role in value creation. This results in four roles of value proposition provider/producer that bundles components, as well as suppliers (Adner, 2006; Iansiti & Levien, 2004; Kapoor, 2018), customers (Dedehayir et al., 2018; Frow et al., 2016; Iansiti & Levien, 2004; Moore, 1993), and complementors (Dedehayir et al., 2018; Kapoor & Agarwal, 2017; Ozalp et al., 2018). Complementors supplement the central value proposition with additional offerings in the form of further products and services that can be bundled together by customers to enhance the value proposition. This bundled value proposition creates more value than the original offering of the producer/service provider.

Hence, actors in ecosystems are linked by two central mechanisms: interdependence and complementarity (Kapoor, 2018).

Ecosystem relationships between actors are shaped by orchestration processes (Blackburn et al., 2023; Lingens et al., 2022). These ecosystem relationships result in “different groups of partners” (Williamson & De Meyer, 2012). Due to the resulting subgroups, only some, not all, actors are related. Likewise, actors steer the strength of their engagement. Therefore, Williamson and De Meyer (2012) compare ecosystem relationships to a club with different membership forms. Although ecosystems support innovation activities (Xie & Wang, 2020), they are also associated with high complexity (Iansiti & Gregory, 2006; Ngongoni et al., 2022). Complexity is caused by the number and diversity of actors involved (Aarikka-Stenroos & Ritala, 2017; Adner, 2017; Axelsson et al., 2014). Furthermore, as many ecosystem business models rely on innovative technologies (Iansiti & Gregory, 2006; Ozalp et al., 2018), another source of complexity is technological progress and new applications, which changes actors’ roles and uncertainty (Dattée et al., 2018; Rong et al., 2013; Sandström, 2016).

Technological development changes the ecosystem and its actors (Beliaeva et al., 2019; Beltagui et al., 2020). In particular, emerging technologies confront actors with the choice of participating in innovation activities for the upcoming technology or keeping on with older technologies in established ecosystems (Adner & Snow, 2010; Reisinger, 2022). Therefore, disruptors who introduce innovative technologies into existing ecosystems must convince established players of the technology’s benefits and attract collaborators. Hence, recently, there has been a growing interest in understanding ecosystem emergence focusing on how ecosystems are born (Daymond et al., 2023; Fang et al., 2021; Hannah & Eisenhardt, 2018; Thomas et al., 2022). During ecosystem emergence, modularity is an important prerequisite to enable complementary (Baldwin et al., 2024). Governmental bodies and public research funding may support the development of interfaces and open standards that pave the way for modularity, as well as ecosystem interdependency and complementarity (Kuan & West, 2023).

The emergence of ecosystems is particularly relevant for business practice, as ecosystems offer opportunities for innovation and business performance but also create high uncertainty (Daymond et al., 2023). For instance, initial resource constraints push firms toward ecosystem co-creation when developing new value propositions (Pushpanathan & Elmquist, 2022). Fang et al. (2021) show how hackathons hosted by platform owners, as examples of temporal gatherings, raise awareness of emergent ecosystems among potential complementors by

enabling sponsorship, social learning, knowledge exchange, and social coordination. If the interdependent actors develop shared intentions, ecosystem emergence is driven forward (Taillard et al., 2016). Several processes such as value discovery, collective governance, platform resourcing, and contextual embedding happen during ecosystem emergence (Thomas et al., 2022). Discursive legitimation processes (framing, sensemaking, positioning, recognizing) and performative legitimation processes (strategic action, value realization, adoption, intervention) create the ecosystem identity by providing contextual embedding and building legitimacy during ecosystem emergence, building on the theory of collective action and institutional theoretic arguments (Thomas & Ritala, 2022). In their framework of ecosystem legitimacy emergence, Thomas and Ritala (2022) describe these activities as discursive legitimation processes that include engagement in conversations and production of written materials. To build legitimacy is challenging as new technology might make incumbents' existing businesses obsolete (Ansari et al., 2016). Hence, a discontinuous or disruptive technology can shake up the web of interdependent ecosystem relationships and roles (Burford et al., 2022; Dedehayir et al., 2018). This explains why technological development plays a central role in understanding ecosystem innovation and emergence (Ozalp et al., 2018; Wareham et al., 2014).

Due to the described complexities and uncertainties, actors need to make sense of emerging technologies. Generally, "sensemaking is about the ways people generate what they interpret" (Weick, 1995, p. 13) and is understood as "meaning construction and reconstruction by the involved parties" (Gioia & Chittipeddi, 1991, p. 442). Sensemaking is a recurring activity that produces frames (Cornelissen & Werner, 2014; Maitlis & Christianson, 2014). Orlikowski and Gash (1994, p. 178) define technology frames as "that subset of members' organizational frames that concern the assumptions, expectations, and knowledge they use to understand technology." Kaplan and Tripsas (2008) explicate that technology frames influence how actors compare and evaluate technologies, containing their interpretation of technologies. Frames reduce complexity by highlighting some aspects and neglecting others (Kaplan, 2008; Kaplan & Tripsas, 2008; van Burg et al., 2014). Thus, actors strive for plausibility during complexity reduction and might pay less attention to accuracy (Weick et al., 2005).

Congruent frames exist when multiple actors have matching perceptions of technology (Orlikowski & Gash, 1994). Frame congruence is associated with homogeneous behavior patterns and enables positive economic effects, such as reduction of transaction costs,

implementation duration, and conflicts (Azad & Faraj, 2008; Young et al., 2016). Conversely, incongruent frames emerge when actors evaluate the same technology differently (Young et al., 2016), resulting in “conflicting views” (Saarikko et al., 2020). Incongruence occurs in ecosystems due to the described complexity of actors and technology. For example, researchers “observed limits regarding the understanding of innovation throughout the ecosystem. While the SMEs in this ecosystem are highly dependent on one another, [...] the perception of what constitutes innovation differs substantially” (Radziwon & Bogers, 2019, p. 6). Incongruent technology frames are particularly problematic when undetected or ignored.

Characteristics of technologies influence framing and, thus, offer insights for understanding incongruence. Since technology characteristics change, frames may also develop according to the dynamic understanding of framing (Bojovic, 2022; Raffaelli et al., 2019). For example, actors that frame technology with high maturity refer to its current performance, while actors framing an immature technology focus on future potentials (Hoppmann et al., 2020). Additionally, de- and reframing processes arise because specific actors intentionally create frames and build institutions (Elbanna & Linderoth, 2015; Minkkinen et al., 2022; Murphy et al., 2021; Strike & Rerup, 2016). For example, actors undertake political activities to mobilize others in their interest to establish a dominant frame (Kaplan, 2008). If the dominant frame remains rigid and the actors fail to integrate incongruent frames of different actors, inefficiencies might result (Olesen, 2014). Hence, during ecosystem emergence, technology frames are contested because “the frames of different groups often come into conflict” (Kaplan, 2008). Therefore, in what follows, the patterns of ecosystem relationships, in particular collaboration and conflict, and technology frame (in)congruence are explored.

Methods

This study analyzes the emergent frames and ecosystem relationships of actors regarding chemical recycling. There are several reasons why this setting is promising: chemical recycling technologies trigger divergent interpretations (Lee et al., 2021). The public discourse on chemical recycling allows analysis of communicated technology frames and different actors participate in this public discourse. Chemical recycling or feedstock recycling is an umbrella term for several chemical processes that produce substances from plastic waste with similar chemical properties to crude oil by breaking down polymers (plastics) to monomers (Ragaert et al., 2017). The various technologies are still at very different stages of development, from

laboratory tests to prototypes and initial applications on a commercial scale, despite the fact that some of them have been the subject of research for several decades (Solis & Silveira, 2020). Interest in the development potential of these technologies is growing again, particularly due to increasing challenges such as landfill waste, resource scarcity, and plastics recycling requirements in the context of the CE transition (Garcia & Robertson, 2017; Jeswani et al., 2021; Rahimi & García, 2017). However, some stakeholders argue that potential benefits are offset by even greater challenges. In particular, the use of resources (high energy consumption of chemical processes, high costs, process efficiency, and competition with established environment-friendly mechanical recycling processes) and the resulting lack of social acceptance stand out (Lee et al., 2021). Consequently, supporters of chemical recycling need to address this “information gap and misconceptions” through their framing and collaboration activities to enable the emergence of an ecosystem around chemical recycling technologies (Lee et al., 2021). This emerging ecosystem in the context of chemical recycling consisting of actors, their framing, and their relationships is explored in more detail.

The research design follows a mixed methods approach combining in-depth qualitative analysis of publicly available documents with explorative network visualization (D’Andreta et al., 2016). The identification of relevant ecosystem actors and suitable publicly accessible documents was carried out in several steps and was designed in line with name generation and name interpretation techniques from social network research (Borgatti et al., 2018; Fliaster & Sperber, 2020). An initial list of actors involved in the discourse on chemical recycling and thus engaged in the ecosystem’s emergence was generated. The starting point was a search query in Lexis Nexis Uni with the search value “chemical recycling” for news between October 2022 and September 2023. This search query resulted in 120 news items, which helped to identify the first actors. As the regional focus is on Germany, actors without significant business activities in Germany were excluded. To add further actors to the actor list, listed German companies, German political parties and political associations, as well as publicly funded chemical recycling projects were examined for relevance. For the listed companies (DAX; MDAX; SDAX; TechDAX), a search was carried out using the company name and the keyword chemical recycling in German and English. The same search was carried out for German political parties using the list of the Federal Election Commissioner from October 2023 with 120 entries. Additionally, there has been a search for publicly funded projects in the Environmental Innovation Program for “chemical recycling.” This resulted in a manual check of the 56 projects found on the basis of the project page, and desk research into the actors

involved. After this initial identification of actors, the company documents found were analyzed for indications of further relevant actors. These additional actors were then added to the list of actors. For these actors identified in the second round, the search query was again carried out with the company names and the chemical recycling keyword in German and English. Overall, the study's database includes 271 actors and 500 documents (Table II.2-1). Due to the described approach, 39 actors are included who do not publicize their own corporate communication on chemical recycling (no documents) but are mentioned in the analyzed documents of other actors.

Table II.2-1: Overview ecosystem actors and data sources

<i>Actor category</i>	<i>Number of actors</i>	<i>Number of documents</i>
EN Environmental NGO	8	12
F Firm	155	283
FI Firm initiative	2	3
G Governmental organization	6	9
IA Industry association	36	94
M Media outlet	24	35
PP Political party	6	10
R Research institute	31	52
TA Trade association	2	1
TS Trade show	1	1
<i>Whole ecosystem</i>	271	500

(Author's own illustration)

MAXQDA was used for the qualitative content analysis, combining deductive and inductive approaches (Azungah, 2018). The qualitative content analysis concentrated on information regarding name interpretation from a social network perspective (Borgatti et al., 2018; Fliaster & Sperber, 2020). There are two levels of analysis: the level of the actor (node) and the level of the relationship between actors. The individual actors' perspectives on chemical recycling were analyzed in line with seminal work on technology frames (Orlikowski & Gash, 1994; Young et al., 2016). Appendix A provides an overview of the different frames and exemplary quotes from the analyzed documents. Next, technology frame maps that illustrate the key concepts and their causal interrelationships were created (Ghobadi & Mathiassen, 2024).

Considering the insights gained regarding activities during framing (Kaplan & Tripsas, 2008), six possible and distinct relationship types were identified. Regarding cooperative relationships

(positive ties), four different types were distinguished: (1) a positive referential or mentioning of another actor; (2) a joint membership relation (especially in industry associations and firm initiatives); (3) a joint publication to shape the public discourse; and (4) collaborative project partnerships. Another type (5) was then defined during the qualitative content analysis for corporate equity relationships because this type of relationship emerged as an additional category. Moreover, potential negative relationships were taken into account (−1). These conflictual relationships were signaled, for example, by public criticism of the actions or attitudes of other actors (e.g. criticism of the verifiability of the information provided—“none of the companies we focus on in this report have publicly disclosed how they calculate emissions, making independent verification of their claims impossible,” D204). Appendix B summarizes all of the relationship types and provides examples of quotes from the data.

All of the network relationships that could not be assigned to any of the explained characteristics are missing. If one actor provided information on some relationships but not regarding other actors, it was assumed that there is no relationship to them regarding chemical recycling (0, empty cell). If one actor provided no information on any relationships, this was highlighted as information on relationships not available (n/a) because it was unclear if the actor simply did not disclose any information about its relationships with other actors or did not engage in relationships regarding chemical recycling (54 actors). The 39 actors that are included who do not have any corporate communication on chemical recycling (no documents) cannot have outgoing relationships. For the sake of clarity and simplicity, media, political parties, and governmental actors were aggregated into actor groups in the network visualization (during the qualitative analysis the frames and relationships were identified for the actors, not the actor groups). There is no information on outgoing relationships on 93 actors, while there is information on 702 directed relationships from 145 actors (684 undirected ties). The information is combined to form a directed network matrix based on qualitative data that includes 238 actors.

To understand how technology frames and relationships are connected in an emerging ecosystem, the next step was to look at them through exploratory network visualization with the aim of uncovering patterns (Clarysse et al., 2014). The software UCINET 6 (Version 6.778) was used for the network visualizations and analysis (Borgatti et al., 2002). Table II.2-2 provides a descriptive overview of the network relationships and frames. Each relationship can take the shape of one of the six presented ecosystem relationship types. Each actor can express

up to two technology frames (TM and CEF). In addition to the relationship type, the (in)congruence of the frames of the connected actors can also characterize a tie between two actors. If two actors share the same frame, the relationship links actors with congruent frames. If two actors express different frames (e.g. one actor holds a high TM frame, while a partner voices a low TM frame), their relationship connects partners with incongruent frames. Finally, if the frame of one or both is not known due to missing data, it remains unclear whether the relationship links actors with congruent or incongruent frames. This results in six possible relationship types with each having three forms of frame (in)congruence to which all relationships can be allocated, i.e., a total of 18 possibilities per frame (TM, CEF) for the 702 identified relationships; Table II.2-2 shows that information on 160 (23%) and 137 (20%) relationships, respectively, is incomplete, which means that (in)congruence is unclear. The majority of relationships have been observed between actors with congruent frames (54%, 75%), while there are also relationships between actors with incongruent frames (24%, 6%).

Table II.2-2: Number and proportion of (in)congruent frames and relationships

	<i>Frame congruence</i>						<i>Unclear (one or both frames unknown)</i>					<i>Frame incongruence</i>						
Relationship type	-1	1	2	3	4	5	-1	1	2	3	4	5	-1	1	2	3	4	5
TM frame	11	139	9	95	112	10	4	83	7	25	36	5	3	65	11	40	44	3
% of all†	2	20	1	14	16	1	1	12	1	4	5	1	0	9	2	6	6	0
% of ±	3	37	2	25	30	3	3	52	4	16	23	3	2	39	7	24	27	2
702†	376 (54%)±						160 (23%)±					166 (24%)±						
CEF frame	0	191	22	136	161	15	4	79	5	18	28	3	14	17	0	6	3	0
% of all†	0	27	3	19	23	2	1	11	1	3	4	0	2	2	0	1	0	0
% of ±	0	36	4	26	31	3	3	58	4	13	20	2	35	43	0	15	8	0
702†	525 (75%)±						137 (20%)±					40 (6%)±						

Notes: TM = technology maturity; CEF = circular economy fit;

† sum of all ecosystem relationships (702);

± sum of (in)congruent or unclear relationships per technology frame type

(Author's own illustration)

For the sake of completeness, the correlation between the two frames and the number of documents was analyzed. No correlation was found (see Appendix C).

Findings

The first part of the findings focuses on the content of the technology frames regarding chemical recycling. These frame dimensions emerged from the qualitative content analysis, which was loosely based on the questions of what chemical recycling is, and why and how actors should use it (Orlikowski & Gash, 1994; Saarikko et al., 2020; Young et al., 2016).

The most prominent distinction regarding what chemical recycling is refers to its maturity level (see Figure II.2-1). I refer to this dimension as TM framing. On the one hand, there is broad agreement on the basic classification of chemical recycling as a group of technologies that use chemical processes to break plastics back into monomers or shorter chains. This includes, for instance, pyrolysis and gasification processes, and enables new products to be manufactured from the outputs of these processes. On the other hand, while some actors regard chemical recycling technologies as mature, others actors argue that they are underdeveloped or developing technologies.

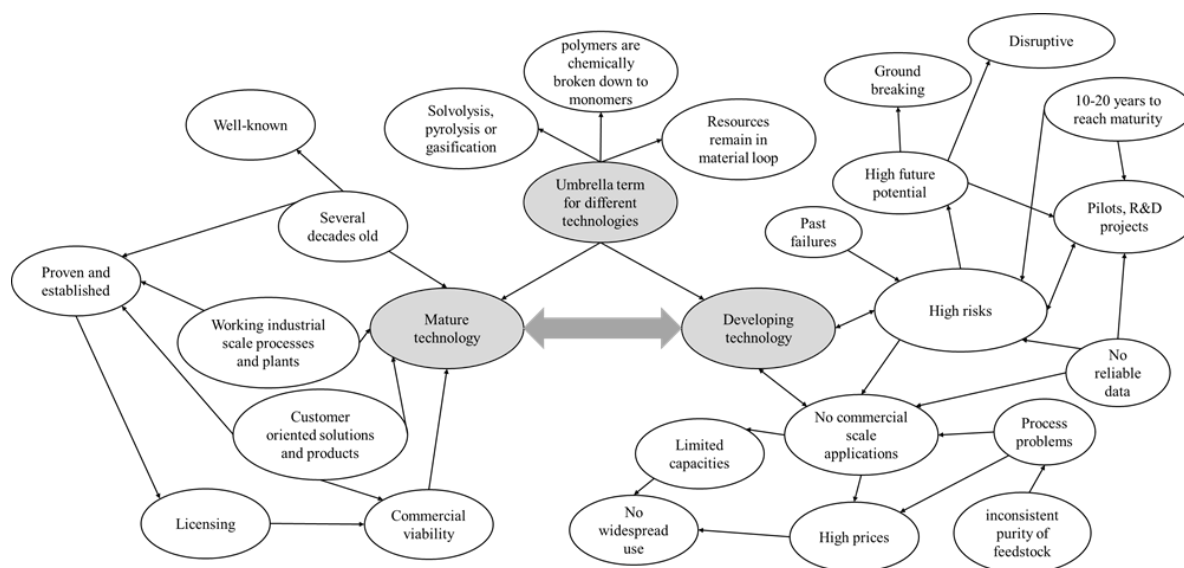


Figure II.2-1: Technology maturity frame map
(Author's own illustration)

Actors that frame chemical recycling as mature argue that these technologies are several decades old and, hence, their theoretical and practical use is well known, which shows that chemical recycling processes are proven and established (high TM framing). For instance,

Research Institute R04 argues in the context of textile recycling that “both gasification and pyrolysis are tried and tested and common processes in practice in which petrochemical raw materials are obtained.” Actors with this high TM framing highlight operating industrial-scale processes and plants that offer customer-oriented solutions and products. These customer solutions and products, in combination with sales of chemical recycling licenses, provide commercial viability according to the actors that express this high TM framing. For example, Media Actor M04 explains that “chemical recycling is already state of the art today.” Similarly, Industry Association IA09 mentions that the “level of technical maturity is considered to be very high.”

This high TM framing is to be distinguished from the low TM framing, which describes chemical recycling as a developing technology. Technologies in the early stages of development are associated with high risks due to great uncertainty (no reliable data), past failures in the last decades of ongoing development, and huge investment needs in pilot plants, research, and development. For instance, Environmental Nongovernmental Organization (NGO) EN2, Industry Association IA03, and Media Actors M05 and M09 stress that chemical recycling involves “immature and high-risk technology.” Due to the high risks and the unresolved process problems, such as the inconsistency of input materials, actors with this low TM frame argue that there are no commercially operating plants, only very limited existing capacities, and high prices that prevent widespread use. Environmental NGO EN5 states: “There are currently no operational plants of significant scale available to recycle plastic to new plastic.” At the same time, however, the high risks are also associated with great future potential as justification for the high investments in research and development. For example, Environmental NGO EN6 explains that, “in future, [...] chemical recycling could offer solutions for multi-material products, provided the technology is further developed.” This statement is in line with the framing of Firm F073: “chemical recycling processes are an opportunity for the future of plastics recycling.”

The next frame dimension focuses on the question of why chemical recycling should be used. The classification of this second frame dimension is described as CEF framing as it contains whether chemical recycling can contribute to recycling and thus the CE, as this is the most important justification for chemical recycling (see Figure II.2-2). A high CEF framing expresses that chemical recycling is understood as an additional form of recycling and can therefore contribute significantly to the implementation of the CE. A low CEF framing, alternatively,

means that chemical recycling technologies are incorrectly referred to as recycling, questioning if these technologies can be considered recycling at all.

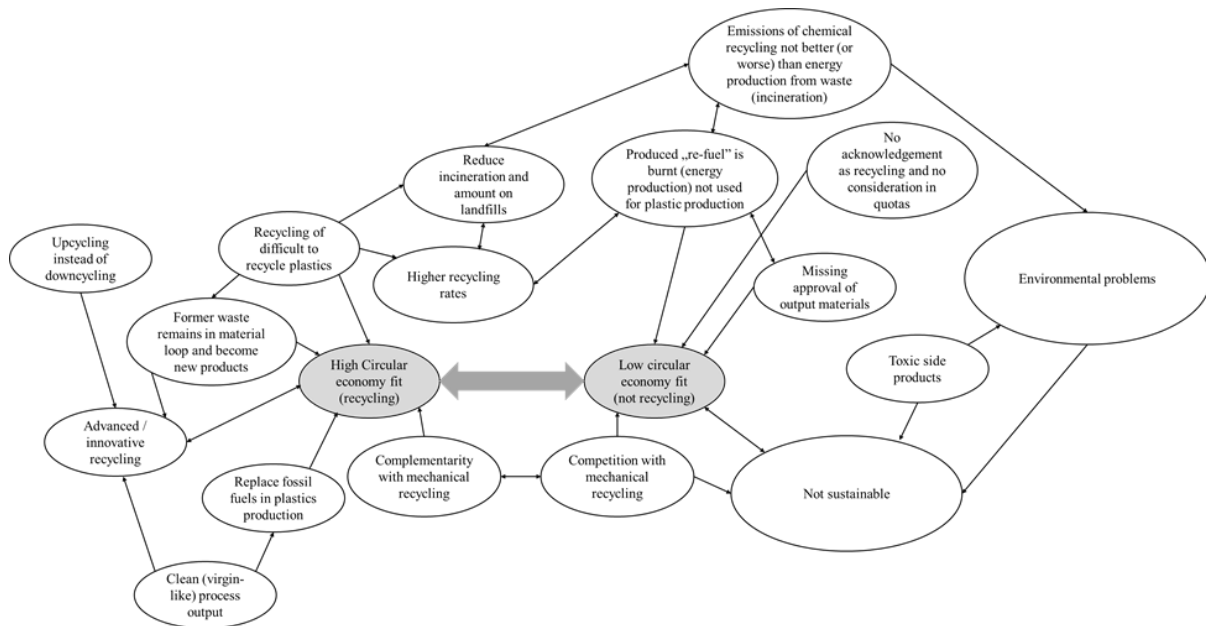


Figure II.2-2: Circular economy fit frame map
(Author's own illustration)

A high CEF framing expresses the actors' belief that chemical recycling is indeed an innovative and advanced form of recycling that complements existing mechanical recycling processes. For example, "[F004] and [F005] aim to develop a sustainable chemical recycling solution along the value chain for currently hard to recycle plastic streams." Hence, actors argue that this complementarity is achieved because chemical recycling processes are able to tackle formerly difficult or impossible to recycle plastics that went to landfills or were burned for energy production (incineration). Firm F033 explains accordingly: "Chemical recycling primarily involves plastic waste that would have been used for energy recovery or landfilled. It complements mechanical recycling, accelerating a circular economy by yielding food-grade recycled plastic." This complementarity results in the advantage that more plastic materials (former waste) remain in material loops and become new products. Chemical recycling processes are praised for producing very clean process outputs that are able to replace fossil fuels in plastic production; as Firm F014 puts it, chemical recycling "also increases the availability of 'clean' recycled plastic which can be used back in food packaging."

Actors that created a low CEF frame of chemical recycling refuse the label of recycling outright. They argue that “chemical recycling” is no sustainable contribution to recycling because it competes with established environmentally friendly mechanical recycling processes regarding well-sorted material streams. The output quality of chemical recycling processes becomes better with better-quality input. The well-sorted material streams can be recycled with mechanical approaches. Hence, chemical recycling provides little additional advantages. Furthermore, chemical recycling processes cause environmental problems due to their energy consumption and toxic process residues. Firm F069 concludes: “Therefore, the only way to protect the climate and resources is to give preference to MR [mechanical recycling] in a direct comparison.” In theory, outputs of chemical recycling processes might replace fossil fuels, but actors with a low CEF framing highlight that approval of these output materials for sensitive applications is still missing. For example, Firm F050 states: “In practice the material must be approved for use—and today no material from chemical recycling has this kind of approval for drug packaging.” This missing approval is causing the emergence of other, less-preferable uses such as for energy production or as fuel for aircraft. Hence, Firm F130 stresses: “Independent experts therefore do not regard pyrolysis as a subspecies of recycling, but as a variant of incineration.” These uses for chemical recycling output are not considered recycling in the proper sense because the material leaves the loop and the bound carbon dioxide is released into the atmosphere.

The following section takes a closer look at the connection between actors’ frames and ecosystem relationships via their visualization. By coding the qualitative database, it was possible to transform it into network information. For this purpose, all available information was assigned to an actor or a relationship.

Figure II.2-3 shows all 702 relationships among the 238 actors that could be identified from the available data. Only isolated actors are not illustrated. Actors are isolated if they did not themselves disclose any relationship in the context of chemical recycling and if no other actor has a relationship to them. These isolates arise because the original selection criterion was engagement with chemical recycling and not information on relationships. Finally, the relationships shown are directional, i.e., the arrow at the bottom right from TA3 to F055 indicates that the actor Trading Association 3 provided information on a relationship with Firm 55. However, Firm 55 did not disclose any relationships, so no arrows emanate from this node.

This original “complete” network forms the basis for all subsequent representations, which are created by emphasizing and reducing selected features.

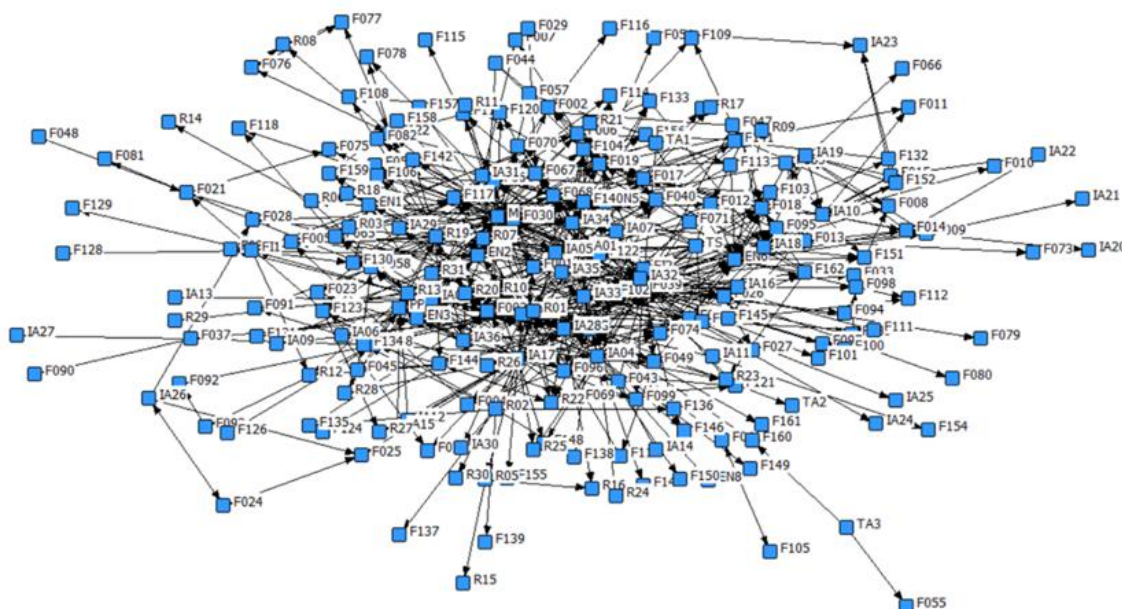
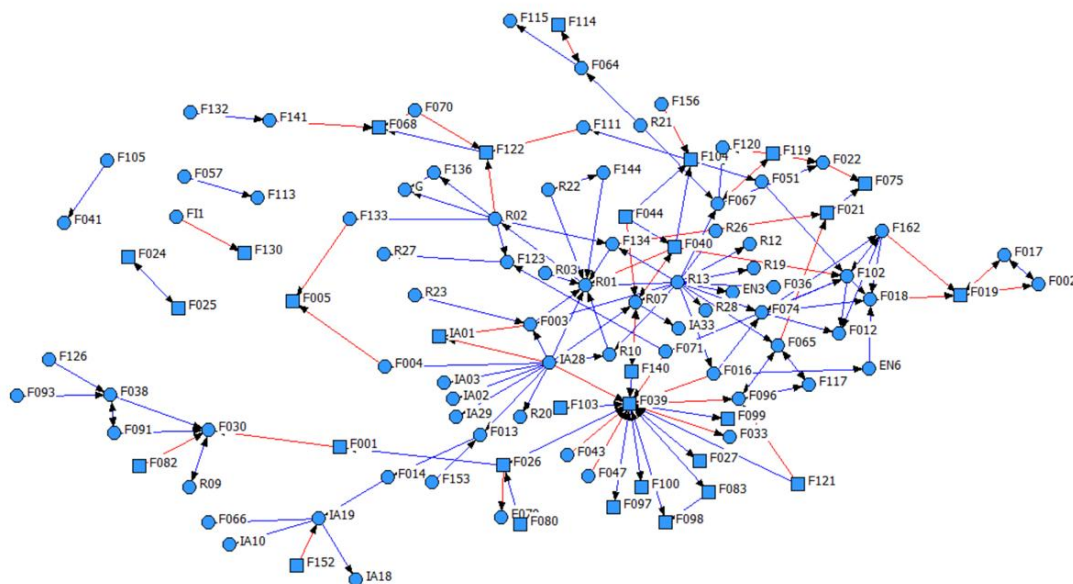


*Figure II.2-3: Network of all ecosystem relationships without isolates (actors without any relationships)
(Author's own illustration)*

First, the frame (in)congruence is examined with respect to the TM frame. However, additional characteristics of the actors and relationships were emphasized. The two manifestations of the TM frame described earlier are expressed by two different symbols (high and low). A circle shows that an actor understands chemical recycling as a technology that is still under development (low TM), while a square shows that an actor described chemical recycling as a mature technology with existing application possibilities but less development potential (high TM). The coloring of the lines indicates whether the two connected actors match in their frame (blue, congruence) or not (red, incongruence). Actors depicted as a triangle do not express a clear frame. The upper part of Figure II.2-12 (Appendix D) shows all network relationships. Actors without a known frame were removed in the next step. Only those actors who expressed a clear frame in their public communication were considered for the following steps (lower part of Figure II.2-12). While no statement on (in)congruence can be made for 160 of the 702 directed relationships, 166 ties connect actors with incongruent TM frames and 376 ties connect actors with congruent TM frames. The following section focuses on the two extreme forms of

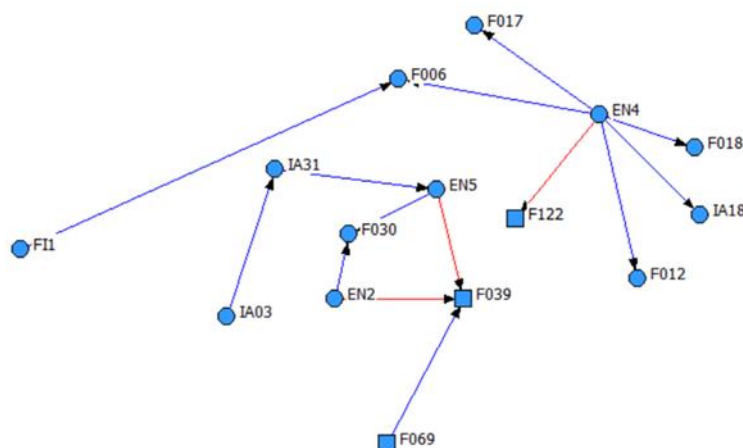
relationship under consideration (collaboration: joint projects and equity joint ventures; negative relationships: criticism and conflict).

Figure II.2-4 shows the collaboration relationships between all actors that have expressed an identifiable TM frame. These are 122 directed ties between actors with the same TM frame (blue) and 47 directed ties between actors with different TM frames (red). Figure II.2-5 shows the relationships that were interpreted as conflictual. There are three relationships between actors with different TM frames (red) and 11 relationships between actors with the same TM frames (blue).



Notes: ●: Low technology maturity (TM) frame: framing chemical recycling as developing technology; ■: High TM frame: framing chemical recycling as mature technology; blue line: relationship within group (actors with congruent TM frames); red line: relationship between groups (actors with incongruent TM frames); figure shows only joint project and acquisition relationships (collaboration)

*Figure II.2-4: Technology maturity frame (in)congruence and collaboration relationships
(Author's own illustration)*

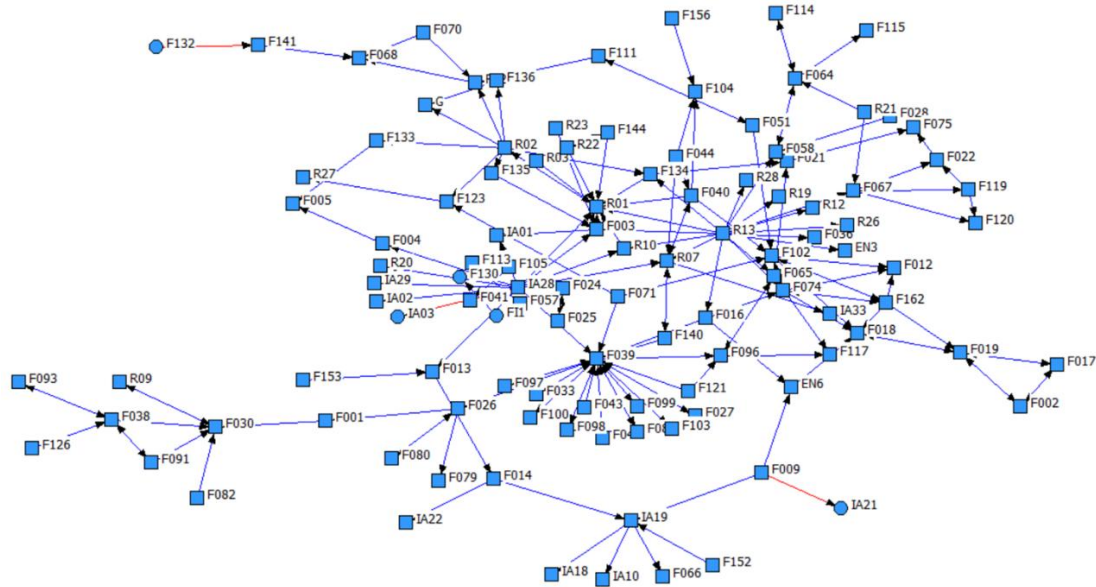


Notes: ●: Low technology maturity (TM) frame: framing chemical recycling as developing technology; ■: High TM frame: framing chemical recycling as mature technology; blue line: relationship within group (actors with congruent TM frames); red line: relationship between groups (actors with incongruent TM frames); figure shows only negative relationships (conflict)

Figure II.2-5: Technology maturity frame (in)congruence and ecosystem conflict

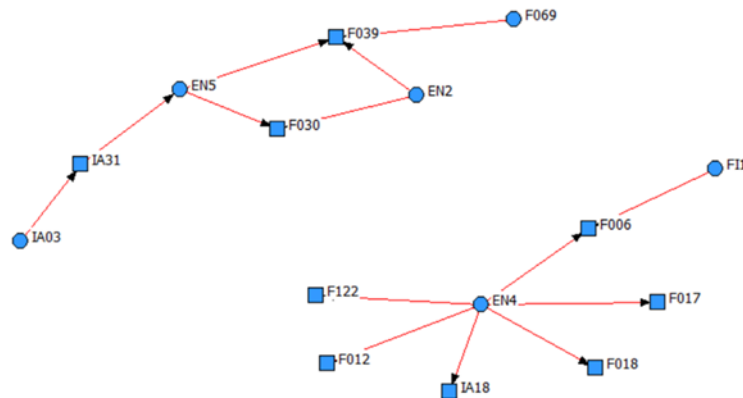
(Author's own illustration)

The same steps were undertaken for the CEF frame. The forms of the nodes in turn express the respective CEF frame of the actors. A circle now stands for the fact that the actor does not perceive a fit between chemical recycling technologies and the CE, thus, does not understand the technologies as recycling (low CEF). A square represents the opposite CEF frame (fit and perception as recycling; high CEF), while the triangle signals that no frame could be assigned (Appendix E, Figure II.2-13, upper part). Just like before, actors without a known frame were neglected (triangle). Thus, 526, or 75%, of the directed relationships shown are between actors with the same CEF frame (blue) and only 36 (6%, red) of the directed relationships connect actors with incongruent CEF frames. Again, special attention was paid to the two extreme types of relationship—collaboration and conflict—in order to prepare a comparison. Figure II.2-6 shows all collaborative relationships between actors that expressed a CEF frame. It becomes obvious that there are only three ties between actors with incongruent CEF frames (red) and 176 directed ties between actors with the same CEF frame. The pattern is similarly clear when the spotlight is on conflicts (Figure II.2-7). In this case, only 14 conflictual relationships between actors with incongruent CEF frames remain (red lines).



Notes: ●: Low circular economy fit (CEF) frame: framing chemical recycling as technology with little CEF (not recycling); ■: High CEF: framing chemical recycling as technology with CEF (recycling); blue line: relationship within group (actors with congruent CEF frames); red line: relationship between groups (actors with incongruent CEF frames); figure shows only joint project and acquisition relationships (collaboration)

*Figure II.2-6: Circular economy fit frame (in)congruence and collaboration relationships
(Author's own illustration)*



Notes: ●: Low circular economy fit (CEF) frame: framing chemical recycling as technology with little CEF (not recycling); ■: High (CEF): framing chemical recycling as technology with CEF (recycling); blue line: relationship within group (actors with congruent CEF frames); red line: relationship between groups (actors with incongruent CEF frames); figure shows only negative relationships (conflict)

*Figure II.2-7: Circular economy fit frame (in)congruence and ecosystem conflict
(Author's own illustration)*

A comparison of these four network maps and the corresponding information reveals interesting patterns. There are more relationships between actors with congruent frames than between actors with incongruent frames (Figure II.2-8).

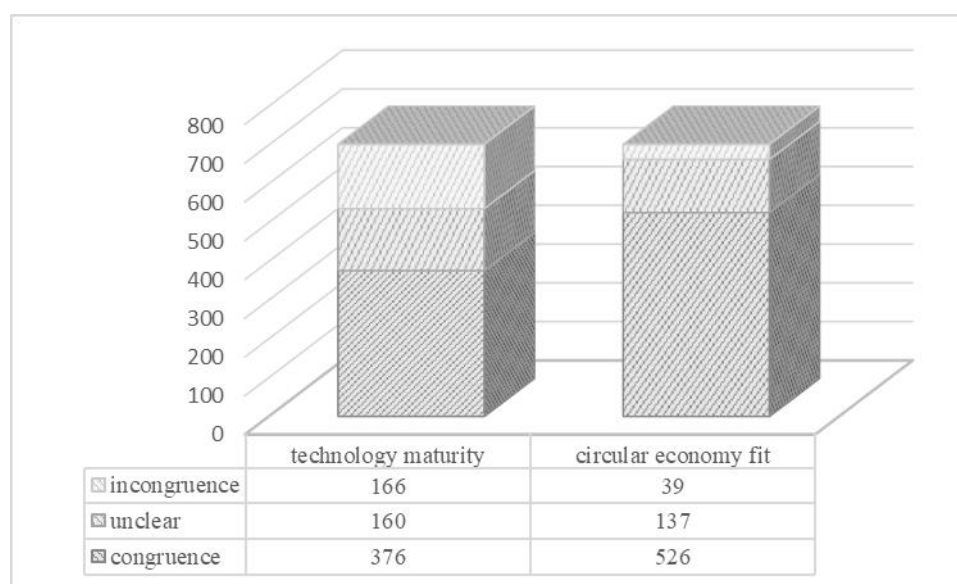


*Figure II.2-8: Proportion of relationships of actors with congruent and incongruent frames
(Author's own illustration)*

Nevertheless, the patterns found differ fundamentally with regard to the two technology frames under consideration and their connection with the type of relationship. Regarding TM frames, it becomes apparent that congruent and incongruent frames are present in both collaboration and conflictual relationships (Figure II.2-9).

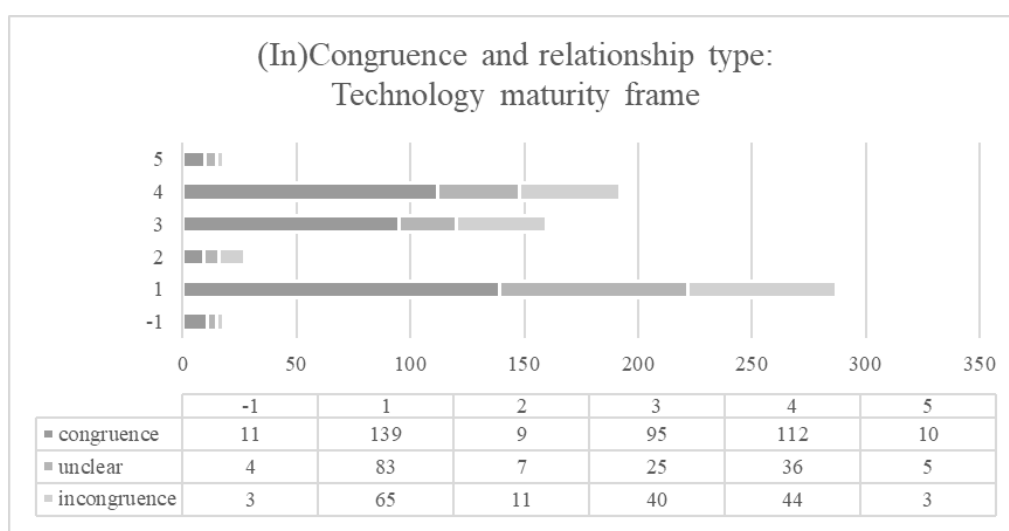


Figure II.2-9: Technology maturity frame (in)congruence and ecosystem relationship type
(Author's own illustration)

A different pattern emerges with regard to CEF frames. It is noticeable that incongruent CEF frames are the exception in collaborations, while all identified conflict relationships between actors with known frames can be traced back to incongruent CEF frames (Figure II.2-10).

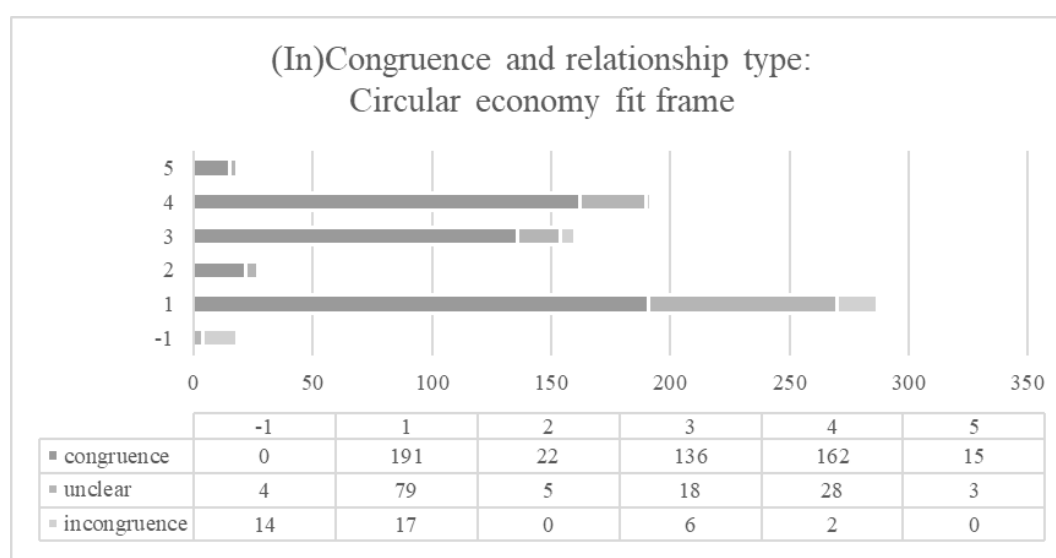


Figure II.2-10: Circular economy fit frame (in)congruence and ecosystem relationship type
(Author's own illustration)

Figure II.2-11 summarizes the observed patterns regarding TM frame (in)congruence and CEF frame (in)congruence. The data show that actors have a slight preference for collaboration with

actors who share the same TM frame (congruence). Nonetheless, congruent TM frames do not prevent conflicts as the majority of actors that are linked by conflictual relationships also share the same TM frame. Likewise, incongruent TM frames do not prevent collaboration despite the slight preference for congruence. This means that there are many examples of collaborating actors with incongruent TM frames. This fits with the observation that incongruent TM frames do not cause conflict because a majority of actors with a conflicting relationship share the same TM frame instead of expressing incongruent frames.

Different patterns emerge regarding CEF frames. There is an obvious preference for collaboration with actors that share the same dominant CEF frame and congruence in CEF frames might prevent conflicts because there is no conflictual relationship between actors that share the same CEF frame. At the same time, incongruent CEF frames become an obstacle for collaboration and seem to be linked with conflict. In the following section, the results described so far are placed in the context of the scientific literature, interpreted, and critically scrutinized.

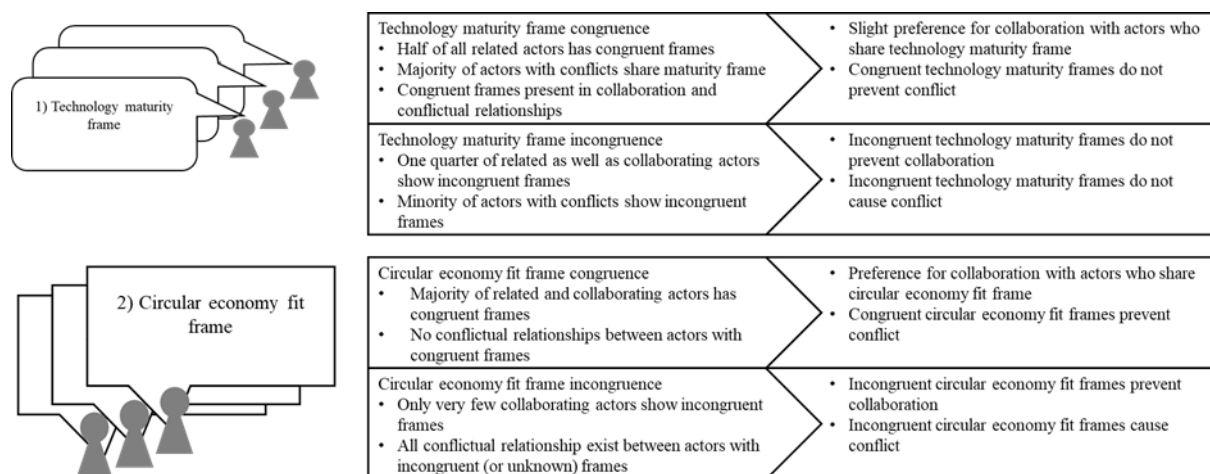


Figure II.2-11: Patterns of frame (in)congruence and ecosystem relationships
(Author's own illustration)

Discussion

The discussion points out two different underlying mechanisms that can be used to explain the two relationship patterns. Actors with incongruent TM frames might actively strive for diversity of the underlying knowledge and the associated opportunity to learn from each other. This explains why relationships with incongruent TM frames materialize across all relationship types. The situation is completely different with regard to CEF frames. In these cases, there

seems to be a preference for working with like-minded people and actors publicly criticize those who think differently. With regard to this purpose-driven frame, the findings show how the incongruent frames clash. In the following, this explanatory approach is further detailed and underpinned with theoretical arguments.

In earlier qualitative research regarding TM frames it has been theorized that actors' perception of technology maturity changes their point of reference regarding performance evaluation (Hoppmann et al., 2020). A high maturity of the internal used technology has been linked to a focus on the present performance and a low maturity of internal used technology leads to a focus on future potentials. This theoretical argument helps to interpret the results described. As highlighted in Figure II.2-1, chemical recycling is an umbrella term for several technologies with various maturity levels. Hence, actors communicate their TM frame in relation to chemical recycling but, at a hidden level, their framing is linked to a distinct technology. Considering this from communication hidden level could resolve supposed incongruities. More importantly, there is also disagreement regarding the classification of the maturity level of specific technologies because, for example, although there are applications that have existed for some time, there are different assessments of the further development potential for other fields of application. In conjunction with the results of Hoppmann et al. (2020), this could mean that even the same technology could be assessed by some of the actors on the basis of current performance, while others price in future potentials. This different point of reference might result in incongruent TM frames that, however, do not exhibit any conflict-causing incompatibility.

Rather, it may be assumed that a diverse knowledge base is available in the collaborative projects on chemical recycling that promotes the exchange of knowledge. As knowledge diversity in firms can improve firm performance (Chen & Liang, 2016), this kind of knowledge diversity resulting from incongruent TM frames might support instead of hinder ecosystem emergence. While no measure of success (either at the project level or at the ecosystem level) was considered in this study, the patterns observed suggest that there are indeed some forms of incongruent frame that bring potential for mutual learning, increased creativity, and innovation performance (Spieth et al., 2021). Since cultural similarity in combination with explicit knowledge transfer explains breakthrough innovation (Wang et al., 2024), the presence of a dominant frame regarding CEF underpins this take. A congruent CEF frame could create a

perception of shared values that could overcome the potential problems of incongruent TM frames and enable knowledge exchange.

The explanation for identified patterns in relation to CEF frame (in)congruence is based on other theoretical arguments. This form of frame incongruence is an example of how one actor group emphasizes the benefits (high CEF), while the actors with a low CEF frame focus on the challenges and threats. Such a threat framing has been linked to a reduction of knowledge exchange activities (van Burg et al., 2014). The finding that only a very few actors with the low CEF frame engage in collaborative projects on chemical recycling is in line with the known relation between threat- or challenge-based frames and a lower engagement in knowledge exchange.

Furthermore, the findings detail our understanding of dominant frames and contestation (Kaplan, 2008; Olesen, 2014). While the high CEF frame may be interpreted as the dominant frame of ecosystem actors, the conflict behaviors of actors with low CEF frames are examples of contestation. According to Olesen (2014), it is important for framing actors to realize and address opposing frames because if they are dismissed without proper confrontation, inefficiencies and inertia may arise. The findings show how, in regard to incongruent CEF frames, primarily environmental NGOs engage in conflict regarding the frames of selected firm actors, while these firms do not react to reciprocate via the observed channels (visible by the direction of the ties). Against the background of past research, the one-sidedness of the observed conflicts could pose a challenge for the further development of the ecosystem, as Olesen's (2014) results indicate that incongruence can persist over longer periods. The situation described in the findings section, in which the criticizing actors talk about the other actors (conflict) instead of working together with them on solutions (collaboration), seems particularly susceptible to persisting incongruence.

Finally, the analysis of the frames in the emerging ecosystem regarding chemical recycling extends Thomas and Ritala's (2022) idea that discursive legitimization processes take place. Discursive legitimization processes seek to create shared meaning and cognitive legitimacy. While Thomas and Ritala (2022) differentiated among four processes that have been ascribed to specific ecosystem actors (framing, sensemaking, positioning, and recognizing), they admit that "discursive legitimation often involves the interaction of legitimating actors, and as such, as we will note, they may participate in several of these processes" (p. 523). This study does not differentiate between the various value-creation-oriented ecosystem roles, as these have not

yet emerged completely in the context of chemical recycling. Nevertheless, the analyzed data show that more than just a few orchestrators are actively involved in framing, and that many other actors also intervene in ongoing ecosystem framing through their communication of frames once they have gained their initial understanding. In addition, the role of external actors, such as governmental actors, nongovernmental environmental actors, the media, and political actors, goes far beyond mere external recognition. Rather, these actors actively shape sensemaking in the emergent ecosystem through their own framing. This may be due to the fact that sustainability is such a socially relevant topic that actors cannot be regarded as external, which is why they actively engage. This engagement in discursive legitimation processes may also be triggered because external actors are already intervening (e.g. through external funding, legal definitions, standards), and thus engaging, in performative legitimation processes, even though the ecosystem is still at a relatively early stage of development. Under these circumstances, intervention causes these actors to develop an increased interest in the further progress of the ecosystem and thus, de facto, they become ecosystem internal actors. In any case, the findings underline that the considerations of Thomas and Ritala (2022) represent a good starting point, but that more puzzle pieces are still missing for a deeper understanding of the complex processes surrounding framing and legitimacy emergence in ecosystems.

The large number of actors who do not participate in framing processes via the analyzed channels of company documentation (available documents) indicates further interesting mechanisms. It could simply be too early in the development phase of the ecosystem, which would explain why so many players are not communicating their own frame. However, since these actors without a known frame can be found in all relationship types, there are probably other mechanisms at work. Potential disruptive innovations pose a risk to established business models, processes, and ecosystem relationships (Burford et al., 2022; Dedehayir et al., 2018; Fraser & Ansari, 2021). Therefore, during this phase of the potential emergence of a new ecosystem, it could be a strategic decision not to participate in the outlined framing struggles. This neutrality may avoid offending partners and unsettling customers in the old ecosystem and at the same time exploit opportunities in the new ecosystem. In the example of chemical recycling, this could apply to logistics and collection service providers, machine manufacturers, and operators of sorting processes. These actors are already important players in the existing system, but can also contribute to the value co-creation of chemical recycling. The possible competition between the emerging ecosystem and an existing ecosystem as a reason for

strategically refraining from participating in framing struggles for established actors may be addressed in more detail by future research.

Practical implications – futures of chemical recycling

A combination of the two frames (TM and CEF) described earlier can give insights regarding possible futures of chemical recycling. First, the combination of high TM and low CEF attributes only minor improvement potentials to chemical recycling. Furthermore, the technologies are not considered recycling in a proper sense. Actors with this combination of frames see no future for chemical recycling. The combination of low CEF and low TM means that chemical recycling is a potential CE technology. Actors with this frame combination emphasize that there are still high uncertainties regarding the chemical recycling technologies and that these technologies do not currently contribute to sustainability. Actors with the third combination, which shows high CEF and low TM, welcome design of the legal framework as well as public and private investments to support the further development of chemical recycling technologies. Actors of the last group combine a high TM frame and a high CEF frame. They expect a high-tech CE solution and focus on commercial applications and upscaling investments. For the actors directly involved in the ecosystem as well as political decision-makers, this insight into possible visions of the future in harmony with the relationship patterns actually found can inform future behaviors. High-tech CE, which is currently the most likely solution due to its complementarity with the existing system (Bauwens et al., 2020), may not be the most sustainable one and the findings of this study help to understand how actors with nondominant frames engage in framing and ecosystem relationships to voice concerns regarding the sustainability of chemical recycling.

Limitations and future research

Further avenues for future research arise from the limitations of the present study. The main limitation of the presented findings is the weakness resulting from the chosen approach. First of all, the data are based on freely accessible documents. This neglects other more direct forms of communication, both digital and personal, such as messages on social media, videos, speeches, and phone calls or meetings between the people involved (incomplete data). In addition, the understanding of the unknown frames remains limited, as shown in the discussion

(no frame vs. decision to avoid engagement in ecosystem framing). Thus, now that this explorative study has shown that interesting patterns between relationships and frames occur in emerging ecosystems, future work could address this weakness through qualitative and quantitative designs that, for example, directly capture, through interviews or surveys, the technology perception and resulting framing as well as the relational behavior of the actors in question. Furthermore, it should not be forgotten that the data are qualitative, despite occasional quantification to illustrate the network relationships. The transfer of the rich qualitative data into quantitative information used for network visualization comes with the disadvantage that nuances can no longer be fully embodied, as only a limited number of categories can be meaningfully represented in the networks. The detailed presentation of intermediate results (e.g. tables with code examples) and description of the analysis steps is intended to ensure transparency. Besides, in the presentation of the results, emphasis was placed on a balance between qualitative and quantitative information. In the future, more quantitatively oriented network studies could test whether the proposed patterns also occur in a statistically significant manner.

Future research could also examine other current and past frame discourses on controversial technologies such as artificial intelligence or nuclear power, to explore whether the patterns found regarding ecosystem relationships can be replicated in other contexts. The second frame in particular (CEF) is highly context-dependent. There is an opportunity for research to further abstract and thus support its transferability to other contexts.

Because the aim of this exploratory study was to explore patterns of frames and relationships in the emerging ecosystem around chemical recycling, broader consequences of these patterns and dynamic developments over time were neglected. These neglects imply a variety of open questions. For example, does it make a difference whether (in)congruent relationships are one-sided or two-sided? The effects on the further development of the technology and the ecosystem were also only touched upon. Are diverse or homophilous clusters more successful in technology development? Which of these clusters are more influential in framing? As ecosystem emergence is a process, longitudinal approaches may provide further interesting insights.

Conclusions

The findings show that actors have a slight preference for collaboration with actors who share the same TM frame (congruence). Nonetheless, congruent TM frames do not prevent conflicts and incongruent frames do not cause conflict. Likewise, incongruent TM frames do not prevent collaboration. Different patterns emerge regarding CEF frames. There is an obvious preference for collaboration with actors that share the dominant CEF frame and congruence minimizes the emergence of conflicts. Incongruent CEF frames become an obstacle for collaboration and come with conflict.

From a theoretical perspective, the present study contributes to several research streams. First, regarding the technology frame literature, the study underpins the theoretical idea about there being a potential positive effect of frame incongruence with promising empirical observations that suggest that knowledge transfer happens between actors with incongruent TM frames. The numerous collaboration relationships between actors with incongruent TM frames in combination with matching CEF frames could offer a new explanation for the positive effect, which is in line with the findings of Wang et al. (2024) on knowledge transfer and cultural diversity in innovation ecosystems. Second, this study answers the multiple calls to examine technology frames more systematically at the ecosystem level (Raja et al., 2024; Snihur et al., 2022; Taillard et al., 2016). Particular attention is paid to frames, framing processes, as well as contestation and conflict in the emergence of ecosystems around the controversial technologies of chemical recycling. Since research interest in this early phase has only recently increased (Polese et al., 2021; Thomas et al., 2022; Thomas & Ritala, 2022), the study expands the knowledge base by integrating the technology frame theory with the ecosystem relations perspective.

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Table II.2-3: Appendix A: Coding examples and manifestations of technology maturity framing and circular economy fit framing

Frame	Manifestation	Exemplar quotes
<i>Technology maturity (TM)</i>	High TM frame	“[F027] has already entered first components from chemical recycling into series production.” (F027) “[F030] developed a [brand name] recycling process, which converts plastic waste into a valuable substance called [brand name], which serves as a feedstock to produces new plastics. [brand name] has been incorporated into more than 10 products and packaging on the European market” (F001) “[chemical recycling brand name] is a proven solution to the complex problem of plastic waste” (F114) “serial production” (F121) “Proven chemical recycling technology: [F142] is a chemical recycling technology company that uses pyrolysis to convert all types of waste plastic into their original building blocks for reuse.” (F142) “This plant will be based on an existing proven and fully commercialised chemical recycling technology already in operation at its existing manufacturing plant” (F159) “Technologies for the chemical recycling of plastics have now reached a high level of technological maturity and represent a better alternative than incineration” (R06)
	Low TM frame: Developing technology	“Chemical recycling, which turns previously unusable plastics into raw materials for new plastics, is an interesting option, but is still a dream of the future.” (F049) “In this respect, chemical plastic recycling has the potential to contribute to solving the global plastic problem. However, the technologies are not yet mature enough to recycle plastic waste to the extent required.” (F063) “In the next step, [F064]'s [brand name] technology will be further developed into a profitable industrial-scale process by 2026/27 [...] In addition, the plan is to launch the first [brand name] licenses on the market in 2023/24, which represents an important next step towards a circular economy and chemical recycling in the industry.” (F064) “According to an internationally valid evaluation scheme, [chemical recycling process name] in the form of the [plant name] pilot plant is assigned a Technological Readiness Level (TRL) 6/7 out of 9. This makes it one of the most modern and advanced applications in the world.” (F065) “We also continue to work on improving chemical recycling technology and solutions.” (F133) “Nevertheless, further research and development work is required for the development of chemical recycling processes and, above all, for the combination of mechanical and chemical recycling” (IA04)

		“At the basis of technology development for chemical recycling, basic research remains important, such as fundamental studies on the energy balance of the carbon cycle.” (IA28) “Mechanical recycling, for example, is rated TRL 9, whereas chemical recycling, in which the polymers are depolymerized back to the monomers, is rated TRL 4 (laboratory test setup).” (R04) “There is still a lot of potential for research and development in chemical recycling processes.” (R13)
<i>Circular economy fit (CEF)</i>	High CEF frame: considered recycling	“With the help of chemical recycling, fossil resources can be replaced by recycled material from plastic waste.” (F016) “This reduction is enabled by a new type of recycling process known as chemical recycling” (F121)
	Low CEF frame: NOT (yet) considered recycling	“Due to low material recovery rates, energy requirements and CO₂ emissions, thermal decomposition-based chemical recovery methods do not enable a true circular approach for plastic waste. Therefore, techniques such as pyrolysis and gasification should be classified at a lower level in the waste hierarchy than other recycling methods and must be classified as recovery. Output molecules of chemical recovery are used at the onset of plastic value chain, and should thus not be classified as recyclates.” (EN2) “Even after chemical recycling, pharmaceutical packaging would be difficult to reuse because the material was in contact with drugs and we do not know how they interact with the materials used for packaging. [...] In theory perhaps, but in practice the material must be approved for use – and today no material from chemical recycling has this kind of approval for drug packaging.” (F050) “Chemical recycling can be a solution to incineration, as the LCA of [F039]’s pyrolysis shows, but should under no circumstances be recognized as a recycling process in order to exclude competition with mechanical recycling” (F69) “The many variants of pyrolysis - also known as chemcycling or chemical recycling ... Independent experts therefore do not regard pyrolysis as a subspecies of recycling, but as a variant of incineration” (F130) “Chemical recycling processes should be driven by a genuine need to turn old plastics into new products with transparent reporting as to what these operations yield. They should not be motivated by a desire to claim that “recycling” is occurring without meaningful production of raw material.” (IA21)
<i>Chemical recycling futures</i>	I) No circular technology: No implementation	“The advantages of chemical recycling - virgin quality and greater tolerance of impurities - do not come close to outweighing the disadvantages of this technology. Therefore, the only way to protect the climate and resources is to give

	preference to mechanical recycling in a direct comparison.” (F069)
II) Potential circular technology: No support due to better options	“It is clear that chemical recycling can only play a marginal role in a sustainable circular economy, if at all. However, as it is a technology that can only be realized on a large industrial scale and at great investment expense, there is a risk that it will ultimately slow down other important developments towards an environmentally friendly circular economy. [EN2] therefore warns against political promotion of or investment in chemical recycling - the risks of this technology clearly outweigh the opportunities.” (EN2) “The aim is to ensure that more plastics can be recycled, which is of course a major advantage. The disadvantages are that the energy required for this process is so enormous that it is still not practical to use chemical recycling on an industrial scale. In addition, it is still unclear how dangerous and environmentally harmful the disposal of chemical treatment aids is - solvents and catalysts unfortunately do not dissolve in the air after use” (F126) “Investments in these uncertain and non-environmentally friendly technologies are not worthwhile. Research in the chemical industry should focus on the recycling-friendly design of plastics. Processors should plan their products according to the Reduce, Reuse, Recycle principles. Politicians should not put plastic-to-plastic chemical recycling processes on the same level as mechanical recycling. Research funding should focus on reusable, design, sorting and mechanical recycling technologies.” (IA03) “According to [EN2], investments in these technologies are not expedient and could even jeopardize an environmentally friendly circular economy.” (M09) “Scathing criticism of chemical recycling from [EN2], [EN1] and others. [...] Investment should be reserved for those organizations that volunteered to improve understanding” (M12)
III) Circular Niche: Developing circular technology: Public and private research funding	“possible state funding for chemical recycling technology must always be in line with the EU's climate and circular economy policy and only for projects that produce new plastics as the end product of the chemical process” (EN1) “[F125] sees potential applications for chemical recycling related to its own business activities, particularly for organic waste from insulants and coatings, as well as for mixed plastic waste and packaging, and is involved in corresponding research and development projects” (F125) “To continue investing in chemical recycling, [F133] is developing technical feasibility studies with companies specialized in conventional and alternative technologies. These studies seek to evaluate and compare technologies for

IV) High-tech
circularity:
Scaling up and
commercial
application

chemical recycling in order to promote plastic recycling in all regions where [F133] operates.” (F133)

“[F162] plans to construct a \$25 million pilot plant in the US to prove the technology, before progressing to full-scale commercialization” (F162)

“Similarly, when fully funded chemical recycling can uplift the value of the recyclates and make them fit for regulated sectors such as food-contact applications. Investing in the adequate infrastructure and new innovative technologies should, therefore, continue [...] Chemical recycling technologies are still at an early stage and further R&D development and scale-up demands more investment.” (IA19)

“In addition to time, this requires more investment, targeted research and expertise. And the abandonment of stubborn either/or positions.” (M02)

“Policymakers are called upon to provide standardized criteria for sustainability assessment and to promote investment in the construction and operation of pilot plants. These can then provide the data for mass, energy and carbon balances, which - prepared according to a standardized model - are a prerequisite for the formulation of regulatory measures on the way to a circular economy. In principle, the different technologies must be compared with competing recycling routes and in the context of long-term changing system conditions. In addition to the technical perspective on chemical recycling, the systemic view of climate- and resource-friendly recycling of plastics should not be neglected.” (R13)

“[F059] licenses its technologies and provides its equipment to customers looking for plastics recycling solutions.” (F059)

“We look forward to working with [F064] to deploy this technology [chemical recycling] at scale” (F114)

“Moving forward, the partners will evaluate further cooperation to broaden the waste material pool and increase recycled volumes” (F119)

“We are pleased that we can now implement this pioneering project with [brand name]. We are convinced that, together with our partners, with chemical recycling we are taking a major step towards a functioning recycling cycle for plastic waste” (F121)

“These planned capital investments by [F068], as well as [F122]'s off-take agreements, represent both companies' largest commitment to date to advance and scale global advanced recycling capabilities” (F122)

“Plastics manufacturers want to invest more than 7.2 billion euros in the expansion of chemical recycling plants in Europe by 2030.” (IA01)

(Author's own illustration)

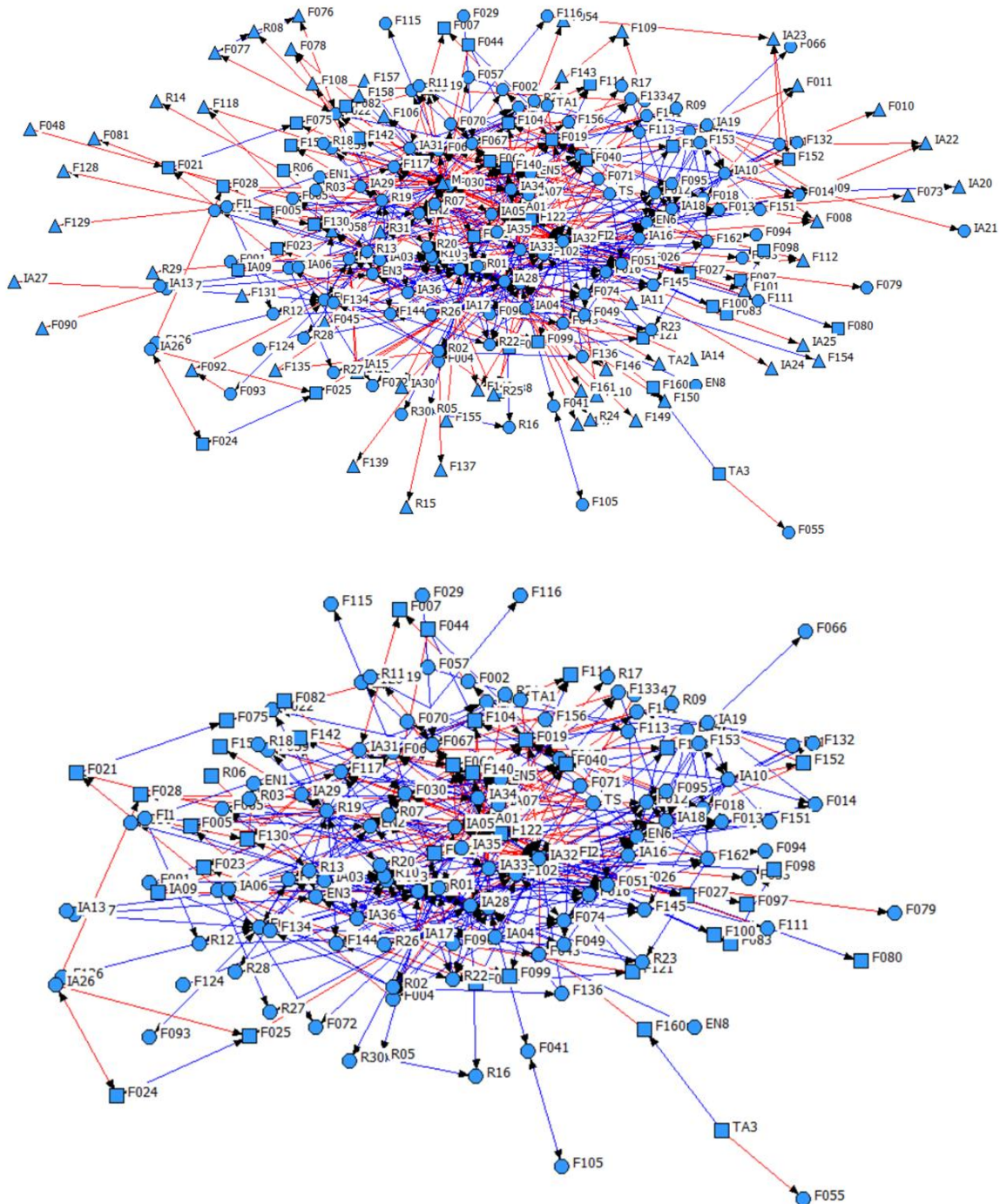
Table II.2-4: Appendix B: Coding examples of relationships (attributes of relations)

<i>Relationship type</i>	<i>Value</i>	<i>Exemplar quotes</i>
Collaboration I: Equity joint ventures (M&A, direct investments)	5	“[F022] acquired a minority stake in [F075] in 2020” (F022) “In September 2020, [F039] acquired a stake in [F026] as part of its [chemical recycling project name] and guarantees the purchase of the thermolysis oil produced both in its own plants and in the plants of its contractual partners.” (F026) “The acquisition of [F038] by [F091] is a milestone for closed-loop recycling. [F091] will fully support [F038]'s current licensing, disposal and mechanical recycling business, which is developing very well, and will complement it by introducing large-scale chemical recycling of plastic waste in Germany.” (F091) “[F104], a global leader in the chemical industry [...] today announced that they have signed an agreement to invest in [F156], a company specializing in a unique solvent-based recycling technology for low-density polyethylene (LDPE)” (F156)
Collaboration II: Joint projects	4	“[F111] is delighted to announce that as part of its commitment to advancing a circular economy, [it] has partnered with [F051] to develop an efficient chemical recycling process to convert flexible PU foams to the original polyol raw material.” (F111) “The recycling of this post-consumer waste is subject of a cooperation between [F123], [F071], [F102] and [F039] [...] The chemical recycling process [...] to be developed as part of this cooperation must be economically and ecologically sustainable and at the same time meet [F039]'s high product quality requirements.” (F071) “This groundbreaking solution was enabled by a cooperation between [F119], [F120], [F022] and [F067] that have successfully managed to chemically recycle ... manufacturing waste on an industrial scale back to plastic raw material” (F119) “The strengthening of [F122] and [F068]'s partnership is another example of how [F122] is working to build momentum around breakthrough advanced recycling technologies” (F122) “[F162] and [F019] launch partnership for products made from advanced plastics recycling” (F162)
Joint publications	3	“This document is supported by the following companies and institutions: [F039], [R01], [F049], [F131], [F102], [F12], [F005], [F132]” (F12) “[IA01]-[IA02]-position on chemical recycling” (IA01) “The dialog process was initiated and moderated by [IA01]. The recommendations for action were contributed by [R17], [R18], [R19], [R20], [R21], [R07], [R10].” (IA01)
(Joint) membership	2	“Together with 40 leading global brands and retailers, we are a proud member of the [IA10]. We are involved in all

		workstreams, including packaging design, EPR (Extended Producer Responsibility) and chemical recycling.” (F153)
Mentioning (positive)	1	“On the part of [G1], chemical recycling is considered to be raw material recovery and therefore also recycling in accordance with the Circular Economy Act.” (F102)
		“Whether [F039], [F003] or [F051] - the major chemical companies are currently researching possibilities for plastics recycling and are already testing on a pilot scale.” (TS)
Conflict: Mentioning (negative)	-1	“[F128] suggests that chemical recycling is superior to mechanical recycling. The term itself is a joke: [G2] rightly does not recognize the chemical process as genuine recycling.” (FI1)
		“[IA31] is sounding the alarm on the grave misinterpretation of facts and scientific evidence on pyrolysis laid out in [EN5]’s recent report” (IA31)
No known relation	N.d.	No documents from actor available (missing information – conclusion: the actor does not communicate any information on chemical recycling but may be named by other actors)
	N.a.	Documents available but no information on relationships available (missing information – conclusion: the actor does not communicate its chemical recycling relationships but may be named by other actors)
	0	Relations that have not been coded with other codes when at least one other relation has been found in the data (assumption: the actor communicates chemical recycling relationships, if there is no information, there is no relationship)
(Author’s own illustration)		

Table II.2-5: Appendix C: Correlation values between codes of public engagement, technology maturity frame, and circular economy fit frame

	<i>Public engagement (number of documents)</i>	<i>Technology maturity frame</i>	<i>Circular economy fit frame</i>
<i>Public engagement (number of documents)</i>	1		
<i>Technology maturity frame</i>	-0,05593432	1	
<i>Circular economy fit frame</i>	0,041778272	0,04608754	1
(Author’s own illustration)			



●: Low technology maturity (TM) frame: framing chemical recycling as developing technology; ■: High TM frame: framing chemical recycling as mature technology; ▲: no TM framing available; blue line: relationship within group (actors with congruent TM frames); red line: relationship between groups (actors with incongruent TM frames)

The upper part of the figure shows all network relationships. The lower part of the figure only shows network relationships between actors whose framing was evident from the data (removal of ▲).

Figure II.2-12: Appendix D: Frame (in)congruence regarding technology maturity frame and ecosystem relationships

(Author's own illustration)

II.3 How companies move to circularity: Adjusting external collaboration and internal reorganizing

II.3.1 Notes on publication

The following academic article titled “How companies move to circularity: Adjusting external collaboration and internal reorganizing” was co-authored by my supervisor Professor Dr. Alexander Fliaster and myself. The detailed division of tasks can be found in the authorship declaration.

The published version of record is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited. How to cite this article: Fliaster, A., and K. Bähr. 2025. “How Companies Move to Circularity: Internal Reorganizing and Adjustment of External Collaboration.” *Business Strategy and the Environment* 34, no. 7: 8450–8469. <https://doi.org/10.1002/bse.4347>.

As corresponding author I have submitted the article to an important and respected journal in business administration (B) according to VHB’s Publication Media Rating 2024, section Sustainability Management in January 2024. The article has undergone peer review in spring 2024 and a revised version has been invited for resubmission. The version included in this dissertation is the originally submitted version of the article.

An earlier and shorter version of the article including the research idea, research design and initial results was presented at an influential international conference with a competitive submission processes and peer review: Fliaster, A., Bähr, K. (2023). How companies move to circularity: Adjusting external collaboration and internal reorganizing. *39th EGOS Colloquium 2023 – Organizing for the Good Life: Between Legacy and Imagination*, 6-8 July, Cagliari/ITA.

II.3.2 Academic article

Abstract: Firms in various industries strive to narrow, slow down, and close resource flows, moving towards a circular economy (CE). We theorize that the transformation of established companies towards CE includes two critical interconnected dimensions – adjustment of external collaboration relationships and internal reorganization. We conducted a qualitative study in the plastics industry to explore them empirically. Our analysis indicates that established firms adapt their external collaborations in four ways: companies modify the criteria of partner selection and the strength of dyadic relationships, add new partners and roles in the value chain, and consolidate the external collaboration network. These collaboration adjustments are accompanied by three key facets of internal transformation – reorganizing of permanent and temporary organizational structures and processes. Finally, our study provides new insights into the interplay of the intra- and interorganizational dimensions of the shift toward the CE.

Keywords (6): circular economy, collaboration, innovation, interorganizational relationships, reorganizing, sustainability

Abbreviations: I Interview, D Document, SDG Sustainable development goal, CE Circular economy, CSR Corporate social responsibility, R&D Research and development, F French, G German

Introduction

"Plastics without a circular economy and sustainability have no future" (Interview 13)

"This internal... transformation of an organization from linear to circular is a challenge that we are only just beginning to grasp" (Interview 15)

"To be successful in the circular economy, the entire value chain must work together. Otherwise, it will not work. ... I always have to keep the overall system in mind and try to optimize the overall system together" (Interview 22)

Grand challenges, particularly the Sustainable Development Goals (SDG) of the United Nations, sparked a powerful need for change at various levels (George et al., 2016). From the management perspective, the circular economy (CE) that reframes waste as a resource and redesigns material loops (Geissdoerfer et al., 2017) is increasingly seen as an essential innovative approach to address these goals since at least two of those sustainable development goals (SDG 11 and 12) directly refer to waste. Nevertheless, recycled secondary materials still account for only 7.2% of material consumption across all sectors in the context of the global economy (Circle Economy, 2023).

As the transformation towards CE is a relatively new phenomenon, knowledge on the "experiences and other struggles" of firms pioneering in CE implementation is still limited (Piila et al., 2022). In particular, previous studies argued that the shift towards CE makes interorganizational collaboration necessary (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022) and has a positive effect on CE implementation (Schögggl et al., 2023). However, while research on CE is burgeoning (Kirchherr et al., 2023), much remains to be understood about the mechanisms of how industrial organizations can build new collaboration patterns towards achieving circularity. Furthermore, while scholars stress that organizational structure can support or hinder CE implementation (Assmann et al., 2023) and established firms must "reconfigure" their activities to implement CE (Khan et al., 2020a), past research directed only scant attention toward exploring the reorganization of internal CE-related processes (Eisenreich et al., 2021) and organizational structures (Eikelenboom & de Jong, 2022).

Moreover, while previous studies found that internal organizational processes and competences affect the characteristics of external collaboration networks (Reck et al., 2022), the links between firms' internal organizing towards CE and the external collaboration relationships are still underexplored (Aarikka-Stenroos et al., 2022; Kleine Jäger & Piscicelli, 2021; Suchek et al., 2021). Hence, our study theoretically and empirically addresses these three shortcomings. The overarching research question of how companies transform towards CE is central to our study. More precisely, we explore how established firms of the plastics industry reorganize internally and externally toward achieving circularity.

First, we briefly summarize the theoretical background and previous empirical findings on circular-oriented collaboration and internal organization. Then, we describe our data collection and analysis. The findings section consists of four parts. Initially, we show the plurality of observed CE strategies and CE-related innovation. Subsequently, the resulting internal

reorganizing and adjustment of external collaboration is presented in detail. The last part of the findings section focuses on the interplay of internal reorganizing and adjustments of external collaboration. Our paper provides several contributions to current research on organizational transformation and collaboration towards CE. Most importantly, in addition to augmenting the literatures on intra- and interorganizational modes of organizational CE-transformation, we enhance research by identifying interdependencies of internal reorganizing and external collaboration.

Theoretical background

CE transformation refers to firms that move away from a linear economy and implement circular initiatives in their business activities (Asgari & Asgari, 2021; Uhrenholt et al., 2022). For firms, this transformation entails two major change arenas (Frishammar & Parida, 2019). On the one hand, companies have to introduce modifications internally, adapting their organizational structure, processes, and capabilities (Assmann et al., 2023; Bocken & Geradts, 2020; Chizaryfard et al., 2021). On the other hand, companies have to strategically develop and adjust collaborative relationships with other actors (e.g., business ecosystem partners) within their external environment (Kuhlmann et al., 2023) – a challenge that has been discussed in the literature as 'CE collaboration' (Aarikka-Stenroos et al., 2022; Calicchio Berardi & Peregrino de Brito, 2021; Gebhardt et al., 2022). In contrast to previous research, which often treated these two big arenas of organizational transformation as isolated from one another (Zollo et al., 2013), we theorize that for the shift towards CE, both of them – internal reorganizing and adjustment of external collaboration – are likely to be necessary and have to be performed by organizations in a coordinated manner.

Recent studies have addressed several internal aspects of the organizational shift towards CE and, more broadly, sustainability. In particular, scholars investigated circular strategy and culture (Bertassini et al., 2021; Blomsma et al., 2019), organizational design and dynamic capabilities (Bocken & Geradts, 2020; Khan et al., 2020b; Köhler et al., 2022), and corporate activities related to CE opportunities and circular business model transformation (Frishammar & Parida, 2019; Khan et al., 2020a). In the following, we focus on one of the core characteristics that essentially affects almost all aspects of organizational life – internal organizing. In doing so, we draw on recent works that have already made efforts to bring internal organizing into connection with the CE shift. For example, Bocken and Geradts (2020) described the

involvement of top management, the introduction of autonomous and separated units, and the tailored innovation processes as enablers of sustainable business model innovation. Furthermore, Khan et al. (2020a) recommend that "firms that want to pursue CE business opportunities should include CE in the organizational structure" (p. 1491). However, there is still a lack of knowledge about concrete organizational measures that support CE and their connection with external collaboration.

Companies can choose between four coordination mechanisms to promote the shift towards CE: make, ally, buy, or do nothing (Hansen & Revellio, 2020; Tuladhar et al., 2023). Collaboration, that is, the 'ally' mode, refers to interorganizational relationships aimed at "voluntarily helping others to attain a common [...] or a private goal" (Castañer & Oliveira, 2020, p. 994). Organizational and sustainability scholars advocated that there are several reasons why collaboration plays a crucial role in CE (Gebhardt et al., 2022; Kleine Jäger & Piscicelli, 2021). Usually, firms initiate CE collaboration to enable resource flows among business partners (Aarikka-Stenroos et al., 2022) and develop or improve services and products (Fluchs et al., 2022; Lichtenthäler & Neligan, 2023). For instance, CE studies revealed that limited internal capabilities and resources increase the need for collaboration, and flexible internal structures have been found to facilitate collaboration (Brown et al., 2018). Further research also revealed other facilitators of interfirm CE collaboration, such as sustainability-oriented internal decision models, collaborative skills, industry-related CE expertise, the ability to bear uncertainty and complexity (Kleine Jäger & Piscicelli, 2021), and dynamic capabilities (Khan et al., 2020b; Köhler et al., 2022). Therefore, firms have to recognize their needs regarding CE collaborations (Brown, Baldassarre, et al., 2021; Brown, Von Daniels, et al., 2021) to select partners and align with them (Calicchio Berardi & Peregrino de Brito, 2021; Kleine Jäger & Piscicelli, 2021; Pedersen et al., 2023; Tuladhar et al., 2023).

Despite this burgeoning work on organizational transformation towards CE, there is still a dearth of research on the interplay of internal reorganizing and adjustment of external collaborations. Previous works advocated, for instance, that "the journey toward CE starts with (re)designing the product, which leads to the transformation around which all other changes in the organization and supply chain collaborations are then arranged" (Aarikka-Stenroos et al., 2022, p. 332), but fall short in addressing those organizational changes in-depth.

Data collection and data analysis

For our study, we chose the qualitative research design as it is advantageous in areas of nascent, not well-established theory (e.g., Graebner et al., 2012). The empirical setting of this study includes companies that currently face challenges related to the circularity of plastics. We followed the theoretical sampling approach (Foley et al., 2021; Glaser & Strauss, 1967), conducting collection, coding, and analysis of data concurrently so that the developed themes and dimensions guided us to decide “what data to collect next and where to find them, in order to develop ... theory as it emerges” (Glaser & Strauss, 1967, p. 45). For example, initial interviews signaled the need to collect additional enriching views from recycling companies and industry consultants. We collected data on firms from Germany and France as they are two of the three countries with the biggest plastics industries in the European Union (Plastics Europe, 2021). As we focus on transformation, we addressed incumbent companies with at least ten years of existence since we assumed those incumbents to experience a need to adapt existing collaboration patterns and well-established internal routines to make the move towards circularity (Steiber & Alänge, 2021; Tuladhar et al., 2023).

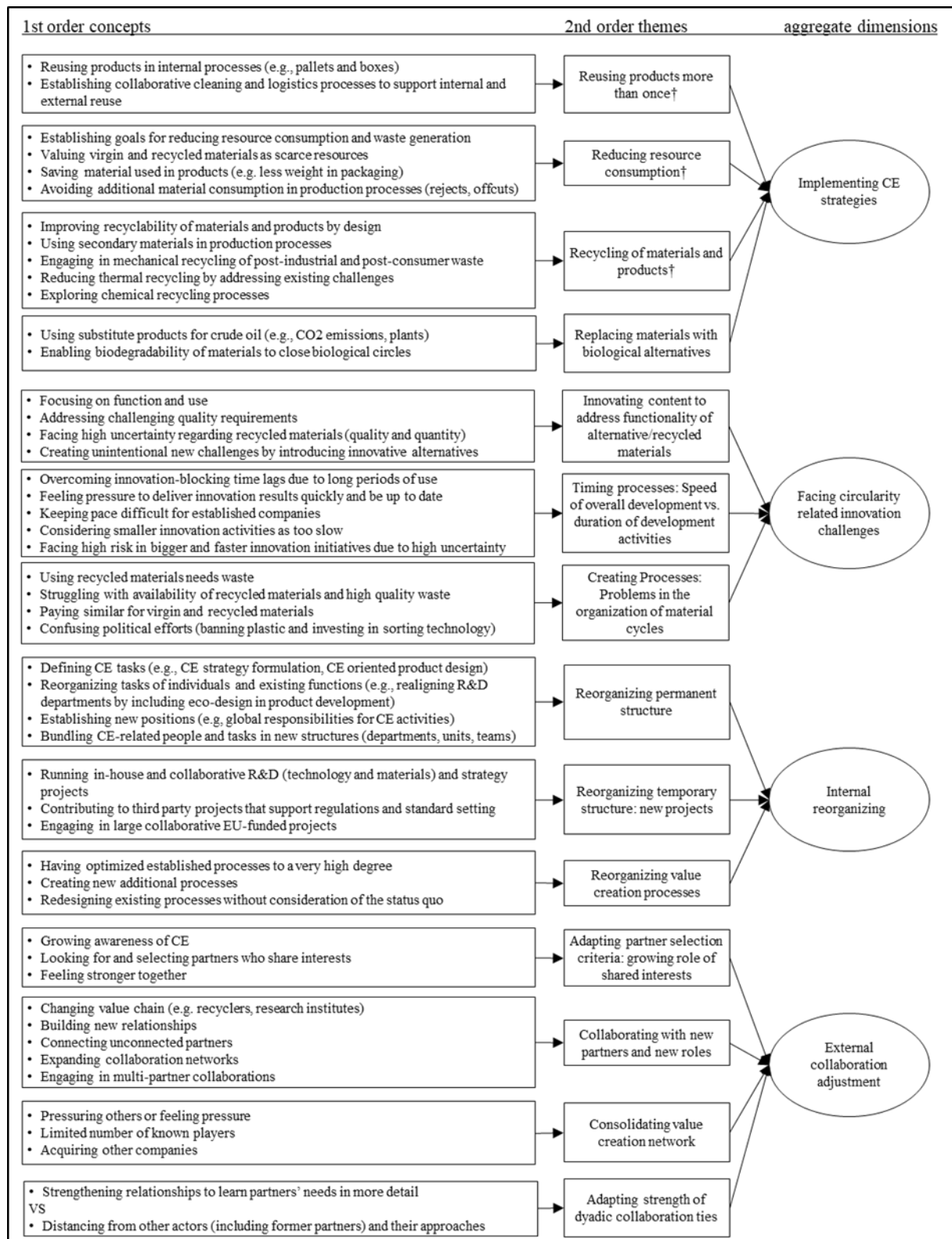
Additionally, we considered empirical data from previous works, which found that, for instance, German companies demonstrate very different speeds and scale of CE transformation (Fluchs et al., 2022; Lichtenthäler & Neligan, 2023). Hence, we focused on companies already making innovative contributions to the CE in plastics or plastic packaging. We checked press releases, corporate reporting, web pages, and media coverage on companies' CE innovation initiatives to find them. Most sampled companies have received awards or certificates for their efforts (e.g., D³⁵¹, D187, D210). While the interviews were the primary form of qualitative data, we intensively engaged in data triangulation to enrich context knowledge and increase trustworthiness (Flick, 2018; Nag & Gioia, 2012). In doing so, we collected and analyzed over 200 publicly available documents (see Appendix 1).

We developed the interview protocol based on design principles for semi-structured interviews (Adams, 2015; Rowley, 2012) and previous empirical work on CE collaboration (Leising et al., 2018). Both authors and a trained graduate student (a native French speaker who wrote her master's thesis under our supervision) conducted the interviews. Eighty-five interview requests were sent out in two waves. In the first wave, we contacted thirty-one companies and conducted

³ In the following, the data sources are indicated by D for document and I for interview.

eleven interviews between June and August 2022. The second interview period ran from February to October 2023. Fifty-four companies were contacted, of which fifteen requests were successful. We received two refusals, and one interview did not happen despite our initial acceptance of our invitation. We conducted 25 semi-structured interviews with 26 top and middle managers (Adams, 2015; Ma et al., 2021). To achieve theoretical saturation (Glaser & Strauss, 1967), we continued data collection until we could not find non-redundant information among the interview participants and confirmed the developed themes and dimensions (Nag & Gioia, 2012). We recorded and transcribed all interviews (see also Appendix 2).

We began our data analysis with the first interview round, steadily supplemented insights, and developed the emerging framework via the newly added interviews. We used MAXQDA 2022 © and first conducted an inductive open coding to identify topics from informants' perspectives (Corley & Gioia, 2004; Gioia et al., 2013). In the second step, we compared codes to build superordinate categories representing researcher-focused themes (Corley & Gioia, 2004; Gioia et al., 2013; Nag & Gioia, 2012). The analysis of the interviews from the first round followed a purely inductive approach with a focus on internal organizational design and related external CE collaboration. Subsequently, we considered the three emergent dimensions in the literature review on CE collaboration and included them in the interview guidelines for the second interview round. We reread interviews several times, discussed emergent themes (Gioia et al., 2013; Lincoln & Guba, 1985), and compared insights with theoretical arguments (Locke, 2002). In addition to the data triangulation, we took several other steps to ensure the rigor of our research. Both authors engaged in data analysis to reinforce the credibility of our findings (Bähr & Fliaster, 2023; Gioia et al., 2010). We also deployed several procedures, such as checking transcripts for obvious mistakes (Creswell, 2014) and managing interview transcripts, published articles, reports, and other collected documents using a software program (Corley & Gioia, 2004). The resulting Data Structure (Figure II.3-1) shows informant-based first-order codes, researcher-centric second-order themes, and general, overarching theoretical dimensions.



† R labels from CE literature (Bocken et al., 2016; Kirchherr et al., 2017; United Nations Environment Programme, 2023); Abbreviations: Circular Economy (CE), Research & Development (R&D)

Figure II.3-1: Data structure
(Author's own illustration)

Findings

The plurality of CE strategies and CE-related innovation challenges

CE generally includes narrowing, slowing, and closing loops, also known as reducing, reusing, and recycling (Bocken et al., 2016). Such CE initiatives or strategies are often described with "R"s ranging from typologies containing three or four Rs (e.g., reduce, reuse, recycle, recover) up to ones that include nine or even more distinct approaches (Barreiro-Gen & Lozano, 2020; Kirchherr et al., 2017; United Nations Environment Programme, 2023; D37, D71). The situation is complicated further by the fact that the individual strategies are not free of overlap (Bocken et al., 2016). Therefore, our first research objective was to understand what CE means for our sample companies (see Figure II.3-2).

Following previous works (e.g., Bähr & Fliaster, 2023; Weber et al., 2019), as we proceeded further with data collection and analysis regarding CE strategies, we did not assemble 1st order categories into 2nd order themes inductively. Instead, we were able to assign them to different predefined themes (i.e., different "R"-strategies drawn from the recent CE literature) (Bocken et al., 2016; Kirchherr et al., 2017; United Nations Environment Programme, 2023). This procedure allows us to systematize novel data "without reinventing the well-ridden wheels" (Gioia et al., 2013, p. 21). Our data show that the CE strategies of the investigated companies are diverse and divided into four thematic areas.

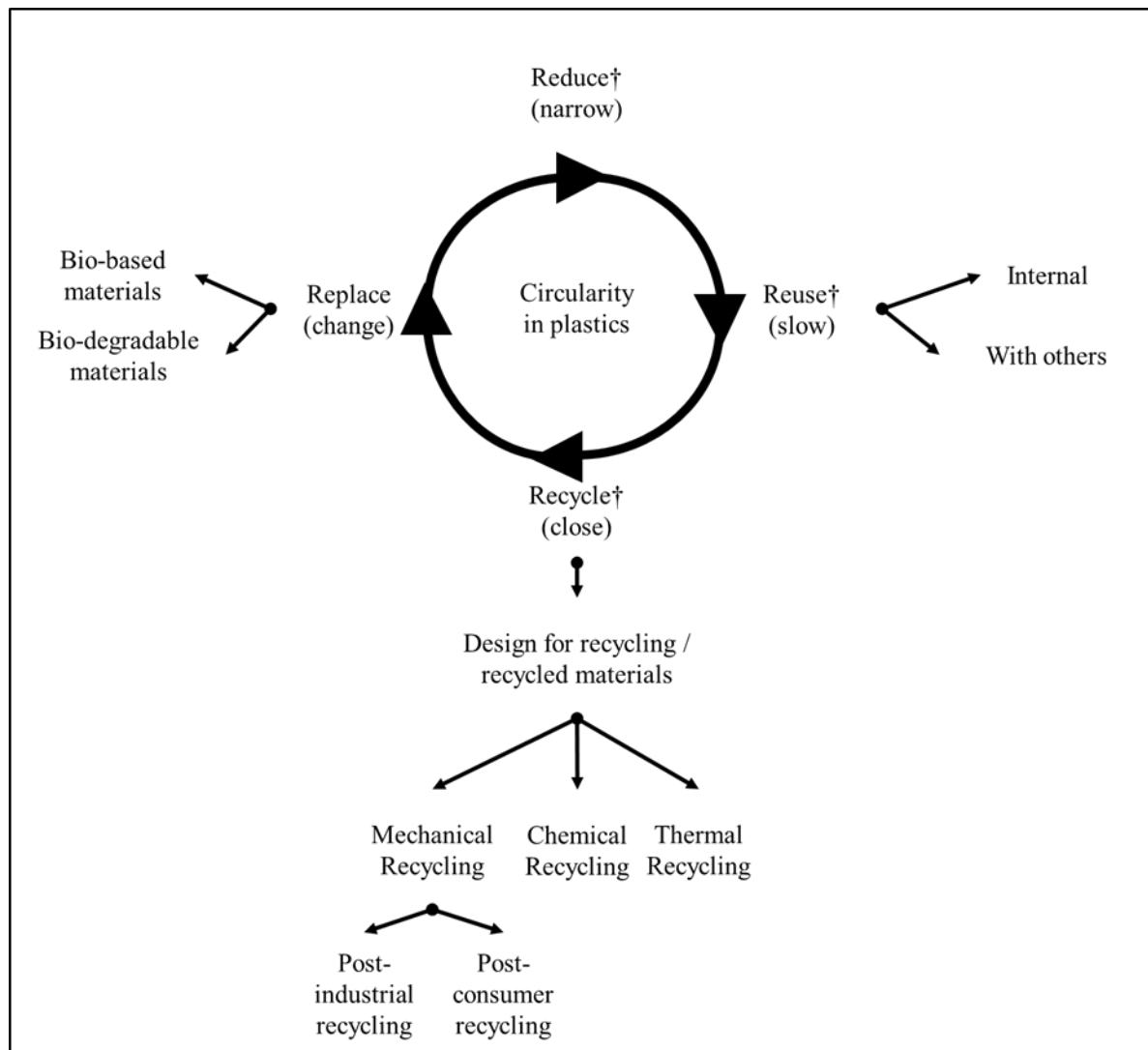
The first strategy, reduce, aims to use fewer resources and produce less waste. It includes making existing production facilities more efficient to save resources and energy (D4, D38, D177) and using less material while maintaining full functionality (D17, D60, D169). Firms have pursued this strategy for many years, also for economic reasons (D39, I19, I23). The second strategy, reuse, refers to repeated or prolonged use of products and the resulting slowing down of cycles. Several respondents stated that pursuing smaller internal initiatives marks the mere beginning of CE transformation (D40, I4, I23) before firms initiate more complex reuse approaches in collaboration with external partners (D186, I6, I18, I22).

Recycling includes approaches that aim to close cycles by design for recycling to improve the recyclability of materials and products (I16, I19, I23) and the use of secondary materials, such as recyclates (I8, I13, I22) or using waste gas for plastic production (D1). Mechanical recycling is the most widespread approach to producing recyclates, in which granules are created from homogeneous mono-material plastic waste by washing, crushing, and melting processes. Mechanical recycling approaches can be differentiated according to the type of waste used. Several companies in our sample have a long tradition of so-called post-industrial recycling

(D37, D148) in which production waste is fed back into the production process (I4, I15, I20). These processes are less demanding than post-consumer recycling because the characteristics of the materials are known, and only small amounts of foreign substances contaminate them. Post-industrial recycling is distinguished from post-consumer recycling, which uses waste collected from end consumers as input material (D11, D22, D73). The processing of post-consumer waste creates significantly higher challenges since neither the materials nor their prior uses are known (I3, I8, I21).

Furthermore, several respondents mentioned “thermal recycling,” i.e., energy production from waste, as it applies to some materials that sorting processes cannot correctly identify or that cannot be recycled mechanically (I3, I5, I15). Some companies are exploring chemical recycling processes, especially for materials unsuitable for mechanical recycling, or using the output of chemical recycling processes in applications where mechanically produced recyclates are prohibited due to product safety concerns (I6, I12, I23). Chemical recycling is an umbrella term for several chemical processes that produce substances from plastic waste with similar chemical properties to crude oil (Ragaert et al., 2017; D40). These processes are still being developed (D1, I24, I25).

The fourth “R” strategy we found in our sample is related to enabling biological flows. We label this strategy as replace. This strategy includes the use of CO₂ emissions (D130) or bio-based materials such as corn, sugar cane, sugar beet, rapeseed, or palm oil, as well as the biodegradability of substances through composting processes (I6, I16, I19). Usually, bio-based plastic shows the same properties as conventional plastic (D26, D33) and cannot automatically enter biodegradation. Some companies have successfully created bio-based plastic and enabled biodegradability but still see these approaches as niche solutions for unique applications (I20, I21, I23).



† R labels from CE literature (Bocken et al., 2016; Kirchherr et al., 2017; United Nations Environment Programme, 2023)

Figure II.3-2: Pluralism of circularity strategies in plastics
(Author's own illustration)

We found that implementing these CE strategies causes essential innovation challenges for the companies. Our data reveal that these challenges refer to the innovation content and process. First, the total need for innovation, e.g., re- and upcycling (I11, I13, I20), is growing as various industries with distinct material streams use plastics (I14). In particular, firms must innovate to meet quality requirements (functionality of alternative/recycled materials), as some companies cannot easily use recycled materials. For instance, regulation determines the (non)use of recyclates due to product safety issues in food and pharmaceutical industries or fire protection of technical plastics (D107, D199, D209).

Regarding the research and development (R&D) process, its speed and duration came to the fore as fundamental challenges. Innovation activities in many industries aim at rapid progress. However, due to the CE shift, the targeted long period of use tends to delay innovation (I20). Furthermore, redesigning existing interdependent business models and their underlying technological base is a substantial challenge that takes time (I25, D149, D171). For instance, developing approaches to chemical recycling takes years (I5, I15), and innovation projects frequently take longer than initially planned (I19). The mentioned disadvantages of recycled materials are the complexity and costs of recycling processes compared to the production of virgin materials (D199). One respondent explained that recycling includes "too many individual steps to get something back from the collected waste. You can only do that by reducing these steps. But you compete against an optimized product with fully automated mass production" (I20). Some companies engage in various parallel development activities (I25) and anticipate that projects might fail (I19) or orient their development activities towards the strictest regulation (I18) to reduce risk. Other firms postpone development activities or invest in other regions because uncertainty regarding future approval procedures and regulation is considered too big (I23, I25). One interviewee stated, "some developments have already been blocked... someone else will do it. Or no one" (I25).

The organization of material cycles is also challenging because of conflicting loops and the "limited availability" of resources (plastic waste). The OECD currently estimates that, due to economic development, plastic production will triple by 2060 (OECD, 2022). Hence, the growing use of recycled materials cannot satisfy the industry's demand (I14, I21) without enhanced quality (Schmidt & Laner, 2023). While CE generally includes narrowing, slowing, and closing loops (Bocken et al., 2016), concerning plastics waste, political efforts focus predominantly on reducing plastics and narrowing loops (Turning the Tide on Single-Use Plastics, 2021) and, thus, companies feel these interfere with their innovation efforts providing fewer incentives for firms' R&D investments in slowing and closing loops (I3). There are also conflicts of interest between the various stakeholders due to conflicting loops. For example, one packaging producer explained, "an innovation that significantly reduces the weight of packaging [narrowing] is of no interest to the recycling industry [closing]" (I24).

In addition, it is increasingly difficult for small and medium-sized plastic-producing companies to purchase recycled materials on the market (I8, I17, I21) as larger companies absorb significant shares of available capacities to meet quota regulations on recycled materials in

production (I13) and thus, reduce freely available quantities through exclusive contracts with collectors and recycling companies (I25). To address the challenges, industrial companies in our study combine internal reorganizing with adjusting external CE-related collaboration.

Internal reorganizing

Figure II.3-3 contains central aspects of internal reorganization, adjustment of external collaboration, and their interplay. Concerning the former, we found that internal reorganizing combines three approaches: transforming permanent structures, temporary structures, and value creation processes. Reorganizing the permanent organizational structure relates to a realignment of R&D and the creation of new CE responsibilities. The embeddedness of CE in the corporate structure illustrates its increasing importance (Bocken & Geradts, 2020; Khan et al., 2020a). Organizational design solutions include creating a CE position for the first time (I6, I16, I19, I24, I25), reorganizing tasks of organizational functions (e.g., R&D, sales) to free up sufficient time resources for the fulfillment of new CE-related tasks (D147, I17, I23), as well as bundling of existing CE-related functions in new departmental structures, business units, or coordinating entities, such as committees and working groups (D112, I11, I17). As a result, the circular-oriented reorganization of the permanent structure leads to more centralization and specialization (Damanpour, 1991) (D70, D148, I25). For example, one firm introduced several new units:

"A completely new department was created, mainly for strategic product management. Product management is now in charge of dealing with [CE-related] tasks. ... A new business unit has been created in recent years. This unit is now responsible for ... compounds. It directly results from sustainability considerations and CE efforts" (I12).

Another interviewee explained,

"we need a ... network function that tries to establish cooperation via the various stakeholders, to achieve cooperation, because the whole issue [CE] definitely cannot be solved alone ... a cross-departmental function that can act and operate independently and then strategically initiate actions or activities in a structured manner" (I24).

Noteworthy, the reorganization of internal R&D comes along with additional innovation contents mentioned above, e.g., the use of recycled materials, eco-design, and design that

enables reselling, refurbishing, and remanufacturing after the initial use ends (I6, I12, I18). Besides, reorganizing R&D supports the management of CE-oriented projects (D112, I19, I25) and the accompanying reorganization of processes (D75, I23, I24).

In addition to reorganizing the permanent structure, companies also reorganize their temporary organizational structure by bundling activities in new projects to enable CE implementation. This observation aligns with previous research that found that CE implementation activities include introducing new CE projects (Piila et al., 2022) representing temporary organizational design (Burke & Morley, 2016). Firms in our study start several in-house R&D (D178, I2, I17) and strategy projects (D3, D72, D147) with CE relevance. These projects go hand in hand with firms' increased willingness to invest financial resources in CE (D5, D37, D122) and the availability of (supra-) national research funding (D147, D162). Second, in addition to technology-oriented projects, companies also carry out new market-related activities, e.g., by commissioning studies and polls on waste and resource flows and consumer preferences to expand the organizational knowledge base (D2, D91, D196). Other new initiatives are stronger firms' engagement in industry and trade associations to influence public discourse and contribute to standard setting and regulation on national and supranational levels (I3, I17, I19).

Finally, our data analysis reveals that firms adapt value-creation processes. This transformation is challenging because firms have optimized production processes for many years. Consequently, highly efficient organizational routines in the linear setting are becoming obstacles to new circular solutions. Hence, the requirement is, for instance, that recycled materials used as a replacement must perform at least as well as the replaced virgin materials (I9). To substitute virgin materials with recycled materials, the involvement of the R&D department in procurement processes is growing because recycled materials are less standardized and more demanding in processing, resulting in a growing need for expert know-how and additional test processes (I16, I19, I22). Such processes were not necessary for conventional materials (I20).

Furthermore, additional administrative processes emerge in the context of R&D due to the certification of new circularity-oriented process technologies and materials (D78, I4, I20). The relevance of R&D also grows for sales processes because using recycled materials in products requires the (R&D) staff to explain new technical specifics in more depth (I16, I23).

Regarding the innovation challenges mentioned above, our data shows that while established, thoroughly optimized production processes no longer offer easy improvement potentials

('narrowing loops'), new CE processes are still less efficient (I4, I8, I16). Thus, instead of incremental improvements, firms strive to develop and adopt new processes (I5, I12, I13) through a CE-based redesign. For example, I15 explained that as the company began to sell not only films but also granules, "adding the compounding component to these processes was a lot more complicated than expected ... had to supplement or change several activities for the compounding business to operate smoothly."

What's more, we found that redesigning internal processes for circularity is most challenging when accompanied by the need to coordinate with other actors along the value chain. For instance, I22 explained: "A big deal is that we develop [recycled] materials together with recyclers and also strive to develop processes together with recyclers [who] ... improve the [recycled] material for us." This explanation also highlights how the internal reorganizing of processes triggers external collaboration (see below).

Adjusting external collaborations

We identified four main arenas of change concerning interorganizational CE collaboration. First, our respondents stressed that with the shift towards CE, the firms adapted their criteria for the selection of collaboration partners: As the general awareness of CE increases (I10, I11, I21), CE pioneers increasingly look for and collaborate with partners who share similar interests in CE and sustainability (D148, I23, I17). For example, as observed by I13, some customers "pay extreme attention to this [CE and sustainability], make their entire product range [sustainable]. For example, their cleaning agents are organic; hence, they also use environmentally friendly circular-oriented packaging to go with it". Firms also signal their growing CE awareness and, thus, attractiveness as collaboration partners by introducing CE-oriented labels and trademarks (D32, D96, D164).

Furthermore, companies introduce two main changes regarding their collaboration portfolio. Reorganized internal processes trigger collaboration with new and different partners and roles. Plastics in the context of CE means "a completely different value chain, completely different players" (I5), and thus, firms establish "exchange with other partners, company associations, completely other stakeholders" (I7). For example, I15 noted that "regarding possible investment partners in chemical recycling capacities ... you always have to look for partners who handle enough waste to operate such a plant. ... These are usually the waste disposal companies".

Current partners may also introduce formerly unconnected value chain actors by hosting meetings with different partners, such as machine manufacturers (I23). Likewise, firms' representatives from R&D departments participate in trade fairs and engage in industry projects and associations to build networks and initiate new collaborative relationships (D80, D103, D167). I17 explained: "An institute approached me and asked if we could do a joint project. The person from the institute met me in a [CE-oriented] committee. It is a [new] project about recycled materials. You get to know each other in those networks".

Particularly regarding suppliers, implementing CE creates new partnerships with companies whose core competence is recycling processes (I16, I19, I23). One respondent explained: "Regarding standard [virgin] materials, of course, it is also the case that the purchasing department somehow dictates and says: 'Listen, if you use the standard materials, then we have one, two, three preferred suppliers. So, please do me a favor and try to get along with them. Try to find the right material.' ... But we are not talking about standard materials, we are talking about recycled polypropylene ... And the suppliers who deliver such recycled polypropylene are not the standard polypropylene suppliers" (I19).

Moreover, shifting toward CE firms cannot rely solely on bilateral collaboration but frequently approach the entire supply chain (I11, I15, I17). For example, one interviewee listed the collaborating partners: "We as a film-packaging manufacturer, the food manufacturer, the waste disposal company, and the chemical company. So, this is definitely a collaboration along the entire value chain" (I12). Similarly, another respondent declared: "In the case of the CE, bilateral relationships are no longer sufficient in most cases; instead, collaboration via the supply chain must be defined somewhat more broadly. Otherwise, it will not be successful" (I17). In addition, firms also begin collaborating with institutions they did not consider in the past, such as national (D88, I19) and foreign universities (D98, I14). The importance of universities and research centers is increasing, e.g., by providing information on complex CE processes, upcoming trends, and current developments (I24).

Moreover, we found that companies also intervene to consolidate their value-creation networks. For instance, some firms acquire other companies and strengthen their circular innovation capabilities (I24, D4, D156) and their position within the ecosystem through vertical integration (I16, I18, I20). Additionally, customers with substantial market power, e.g., well-known brands and retail chains, can either steer the overall system towards CE and motivate others into joint CE activities or undermine the transition (I13, I21, I23).

Finally, our data reveal that firms adapt the strength of dyadic collaboration ties in both directions. Tie strength is one of the significant attributes of interfirm networks that refers to the closeness and intensity of interorganizational relationships. Recent studies showed that ‘strong ties,’ that is, repeated, trustworthy, and intensive interactions between firms, encourage joint problem-solving, mutual learning, and inter-organizational knowledge sharing (e.g., Reck et al., 2022; Reck & Fliaster, 2022). On the one hand, our data reveals that collaborative relationships have become more critical for the firms; one respondent even described the modern chemical industry as "a world of partnerships" (I2). Companies in our sample communicate more to understand the needs of partners (I5, I20, I23), explain the consequences regarding the use of recycled materials (D68, I20, I19), enter detailed bilateral agreements (D39, I15, I23), and jointly develop processes and materials (I19, I20, I22). Furthermore, organizational actors create additional ties between already affiliated partners, as several parties with specific expertise join the exchange, e.g., R&D and CSR (I25). The more intensive collaboration also results from the complexity of the CE transition and the distribution of the necessary knowledge among different actors. I20 observes, for example:

"As [plastics] manufacturers, we partly determine what is possible. ... The customer's purchasing department does not have the expertise and does not know what is possible regarding materials. Ultimately, they only know that it is possible to use recycled materials".

On the other hand, management of tie strength is not a unidirectional activity since firms not only strengthen but also weaken or even cut partnerships completely. The latter happens, for instance, when companies discover that their partners have a different understanding of what CE is all about (I1, I13). In addition, companies distinguish between partners they see as responsible and non-responsible regarding the corporate attitude toward sustainability (I4, I9) and adapt their relationships accordingly.

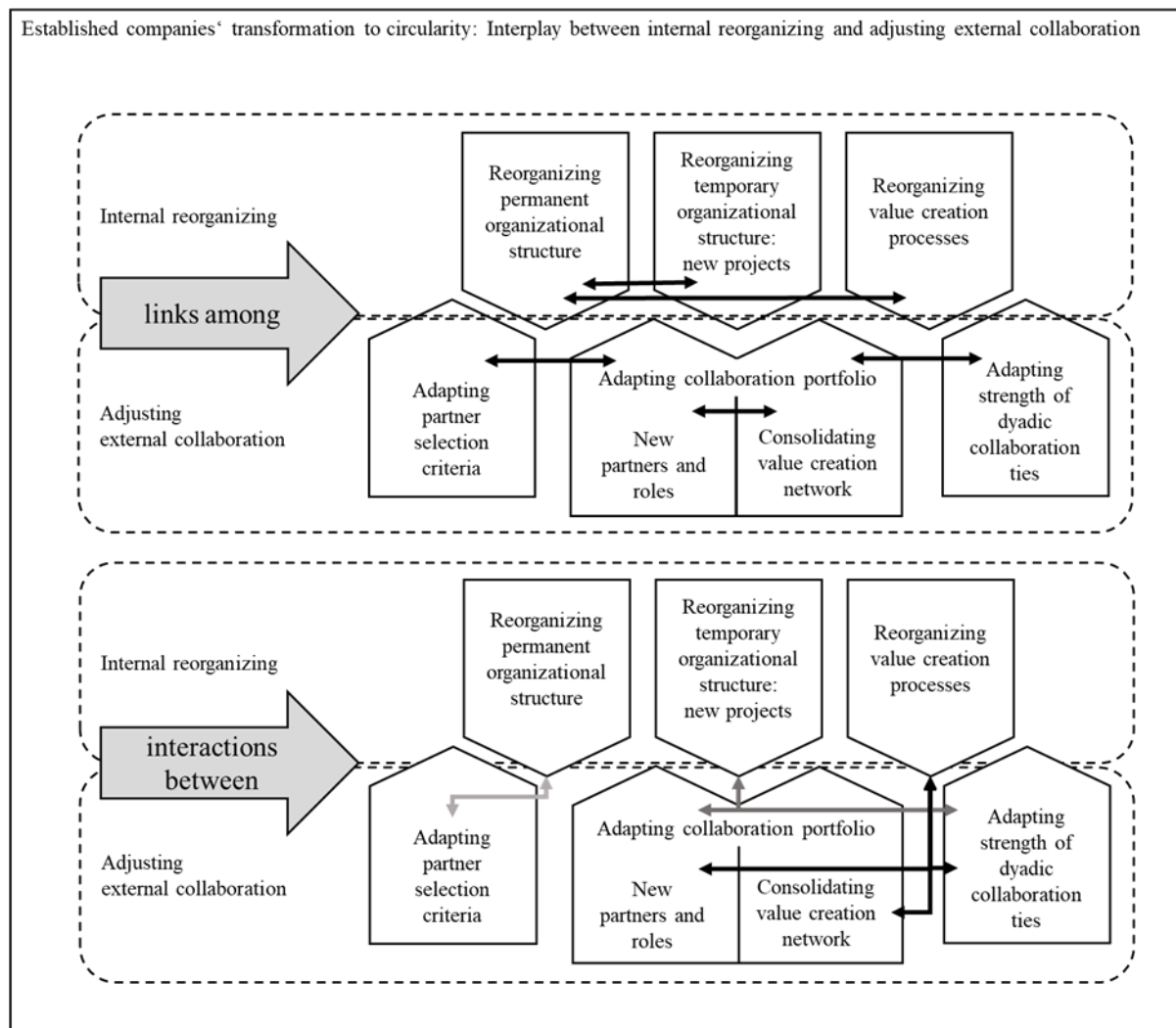


Figure II.3-3: Established companies' transformation to circularity as interplay of internal reorganizing and adjustment of external collaboration
(Author's own illustration)

The interplay of internal reorganizing and adjustments of external collaboration

Our analysis also shows that companies strive to synchronize internal reorganizing efforts with adjusting external collaborations to tackle CE-related challenges. Based on the collected data, we theorize that there are two distinct modes of interplay – (a) the links among different elements of internal organizing or elements of external collaboration activities and (b) the interactions between internal and external elements (see Figure II.3-3).

Links among internal reorganizing: New and distinct positions, units, and departments created as entities within the permanent structure support the creation of temporary projects by bridging the gap between permanent and temporary organizational structures. A notable example

involves personnel in the recently instituted units actively participating or taking responsibility for temporary projects due to their growing CE proficiency (I12, I17, I23). This expanding expertise further bolsters the identification of necessary and feasible process reorganizations. Companies in our study effectively manage the sophisticated tasks of restructuring the value creation processes through thorough and consistent coordination within cross-functional and inter-organizational project groups (I15, I19, I24). Hence, new temporary structures (e.g., CE projects) enable the reorganization of value-creation processes.

Links among external collaboration adjustment: The modified selection criteria for collaboration partners, such as shared interest or CE expertise, pave the way for adapting the collaboration portfolio. These novel criteria are the foundation for identifying and engaging with suitable partners, e.g., at trade fairs or CE networking events (D103, D167, I17). Establishing collaboration between formerly unrelated companies also closely connects with the augmented consolidation of the value creation network and the adaptation of network relationships' strength. Notably, the new CE-oriented suppliers may also foster more profound collaboration when compared to traditional suppliers such as global chemical corporations (I16, I19, I23). One respondent explicates:

"Dealing with a medium-sized recycler is, of course, different. I can, which is very nice, build a direct relationship very well. I can develop materials and processes together, and I am not just a small number in the face of a multinational billion-dollar corporation" (I22).

The interplay between internal reorganization and adjustments of external collaboration: Our analysis revealed that reorganizing the permanent organizational structure facilitates the search for collaboration partners with congruent sustainability interests (I17, I23, I24). Emerging units bundle internal expertise, signal the company's involvement in CE initiatives, and present a more distinct and accessible identity to prospective external collaborators. Moreover, the freshly established units explicitly shoulder internal and external CE-related collaboration responsibility. This responsibility includes tasks such as identifying suitable partners. They progressively build up the knowledge needed to obtain the labels and certificates, such as RecyClass and Cyclos Certifications, that signify the firm's commitment to CE initiatives to external actors and to interpret labels and certificates (I19, I20, I24).

Furthermore, our data underscores the pivotal role of permanent sales staff in initiating customer-related projects (D29). Supported by emerging internal temporally limited project structures, firms also participate in cross-company, cross-industry, and cross-national

collaborative R&D projects (I5, I17, I19). For instance, one firm "set up an interdisciplinary team for a circular model for a customer ... where all these players, both internal and external, that are required to implement the model meet regularly for two years" (I15). Such market- or customer-focused collaborative R&D projects "are mostly about how we can convert existing products into circular products" (I23). The temporary projects reinforce established partnerships and forge new collaborative links between previously disconnected actors (I19, I23, I24). For instance, one interviewee stated that one of the company's largest customers, currently working with an American university, invited the company to join this CE project (I14).

Finally, the reorganization of internal processes catalyzes firms to adjust their external collaborations, thereby resulting in changes in the portfolio of collaboration partners (D37, D120, D126). To establish closed loops within the CE, firms must approach and partner with new actors like waste collectors, recyclers, and consumers (I16, I29, I23). In numerous organizations, we have identified a mutually reinforcing and synergistic interplay between the internal reorganization of value-creation processes and the establishment of new CE collaborations. The internal reorganizing of processes propels firms into novel partnerships. For instance, plastic goods manufacturers attract new clients looking for recycled plastic products. Moreover, expanding a company's value creation processes to encompass recycling initiatives necessitates unique collaborative interactions with business organizations that specialize in plastic waste collection and sorting. Vertical integration also consolidates partnership networks as internal processes may substitute interactions with external partners.

Discussion

Theoretical Contribution

CE is vital in the organizational and societal transition towards sustainability (Kirchherr et al., 2023). In this context, our qualitative study addressed the research question of how incumbent companies in the plastics industry transform towards CE. Our new empirical insights open promising avenues for discussion. First, our research shows that several business companies are trying to implement circularity. These implementation activities are broad, including strategies such as replacing, recycling, reducing, and reusing (see Figure II.3-1). Hence, we conclude that the organizational shift towards CE does not represent what scholars critically labeled "sustainababble" (Engelman, 2013, cited in Kirchherr et al., 2023, p. 1). Instead, we

observed real and complex organizational activities aiming at the delinearization business processes and value creation supporting circular disruption (Blomsma et al., 2023; Neligan et al., 2023).

Second, our research demonstrates that the corporate shift towards circularity is multifaceted and challenging. In sum, moving towards CE, companies have to implement innovations that are different in degree (incremental versus radical), in form (product/service/process/business model innovations), and in type (technical versus administrative, i.e., organizational innovations) (Arekrans et al., 2023; Crossan & Apaydin, 2010). To master it successfully, firms must manage innovation in various arenas to develop new products, introduce new manufacturing processes and organizational design changes, and transform relationships with business ecosystem partners.

Third, companies are confronted with several challenges as they generate and implement innovations. Our data indicate, for instance, that two challenges seem to be the most critical ones, especially as they currently coalesce. On the one hand, companies face manifold external uncertainties on the move towards circularity. In addition to market- and customer-related ones that are typical for many radical innovations (Crossan & Apaydin, 2010), regulatory uncertainties (Engau & Hoffmann, 2011), for instance, regarding approval procedures and quotas regarding the use of recyclates, also must be taken into account by firms that develop and implement CE strategies.

On the other hand, our study found that the transition towards CE is challenging because, in the past, industry incumbents have spent significant amounts of time and resources to bring linear value creation to perfection. The companies we analyzed have competed in the plastic industry for several years; to survive in this competitive business environment, those companies had to make substantial efforts to optimize their processes, nurture core organizational capabilities, and establish valuable partnerships with suppliers and customers. Ironically, the past formula for success seems to become an increasing impediment to progress. Hence, we conclude that the current transformation towards circularity requires promoting organizational change in face of uncertainty and has to be managed strategically.

Further important insights refer to the organizational type of innovation at our study's core. On the one hand, we found that to implement circularity, companies in the plastics industry undertake several activities regarding both their internal functioning and their collaboration with external partners. Concerning internal organizing, past research argued that organizational

design can be a hurdle or an enabler to firms' CE transition (Assmann et al., 2023; Bocken & Geradts, 2020; Khan et al., 2020a). Previous studies also indicated that business model innovations for circularity frequently require redesigning departmental structures, units, and tasks, for instance, creating separated and autonomous units (Bocken & Geradts, 2020). Our study enriches these insights, showing that moving towards circularity entails three distinct facets of internal transformation – reorganizing permanent and temporary organizational structures and intra-organizational value creation processes. Regarding external collaboration, our study draws on previous works that advocate that implementing CE strategies increases the need for companies to collaborate (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022). Our analysis augments this literature by revealing that established firms adapt their external collaborations in four ways: industry incumbents modify partner selection criteria and the strength of dyadic relationships, add new partners and roles in the value chain and consolidate the external collaboration networks.

Finally, our study provides new insights into the interdependencies concerning internal and external reorganizing associated with corporate CE transition. While most previous CE studies addressed these two areas as isolated, we found two types of interplay exist: the interactions among and between the internal reorganization and the adjustment of external collaboration patterns. For instance, our analysis shows that reorganizing permanent internal structures can support CE projects (a temporary form of organizing; Bakker et al., 2016; Lundin & Söderholm, 1995). Two explanations help to shed light on this observation. First, some major CE projects, e.g., for new circularity processes like chemical recycling, run for extended periods. Such fundamental projects are usually operated in companies in a centralized manner (Argyres et al., 2020). Hence, redesigning the permanent structure is a foundation for establishing temporary but long-term innovation projects that can yield fundamental and far-reaching impacts, ultimately contributing to reorganizing value creation processes (e.g., closing the loops). The complexity inherent in CE necessitates innovations that create comprehensive and transformative impact. In this context, the adoption of pathways that involve both internal reorganization of permanent structures and temporary innovative projects aligns with the objectives of pioneers who strive to address the complex CE challenges in a holistic manner.

Second, we argue that centralizing activities within the permanent CE structure supports goal-oriented learning from various customer projects and seamless knowledge transfer across individual business divisions. The cross-functional composition of project teams plays a pivotal

role in learning and knowledge transfer (D55, D75). In addition to the employees responsible for CE who initially often come from innovation, R&D, or business development units, staff from other corporate areas such as procurement, sales, and production get also involved in CE projects. This involvement of personnel from different departments prevents CE initiatives from taking place in isolation and promotes the CE transformation.

Moreover, our explorative study contributes to an enhanced understanding of how internal restructuring can empower CE collaborations, consequently facilitating the expansion of CE transitions beyond individual company boundaries. CE value-creation processes forge interdependencies between formerly unrelated actors, thereby giving rise to the imperative for collaboration mentioned in the literature (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022). Many CE projects in our study are collaborative, entwining many internal and external actors. The observed changes in organizational structure hold relevance not only for the individual company but also for the resulting CE-oriented ecosystems (Parida et al., 2019). For instance, the novel permanent structure not only facilitates the establishment of new criteria when selecting collaboration partners but also signals interest in CE to future potential external partners and ecosystem actors, signifying the company's commitment and readiness for CE collaboration.

Finally, it is worth noting that the empirical results of our study enrich our understanding of CE dynamic capabilities, more specifically, the reconfiguration of internal and external competences (Bocken & Geradts, 2020; Khan et al., 2020b; Sandberg & Hultberg, 2021; Teece et al., 1997). Our study provides further insights into the approaches established firms take to reconfigure internal organizational structure and value creation processes, as well as their interplay with the adjustment of external collaboration.

Practical implications

Our study also allows for practical recommendations regarding the transition towards CE. First, the detailed descriptions and examples of individual measures that the companies in our sample deploy can contribute to a more profound understanding among organizational decision-makers regarding which internal and external reorganization activities might support CE strategies in their firms. This is also true for fostering the synergistic integration of internal and external elements necessary to achieve successful CE outcomes.

Moreover, our data show that different ways towards circularity might be possible from the firm's perspective. Hence, at the top management level, the decision has to be made on which CE strategies (e.g., reducing, reusing, and recycling) are most appropriate considering the waste hierarchy (e.g., Kirchherr et al., 2017) as well as the given company's competitive strategy, organizational capabilities, and position within the business ecosystem. Notably, this strategic decision faces conditions of market volatility and regulatory uncertainty.

Given these intricate dynamics, companies are well-advised to deploy instruments of strategic planning and foresight, such as, for instance, scenario analysis (Grant, 2022), to develop and implement appropriate circularity strategies. Medium-sized businesses, especially, might have less experience dealing with these strategic tools in the past. As the regulatory, technological, and market environment changes, a more proactive and comprehensive strategic planning could help companies master the multifaceted transition towards CE.

Another important managerial implication of our research insights from the organizational perspective is the need for organizational integration. Our findings demonstrate that to make circularity work, several departments, such as R&D, procurement, sales, and organizational communication, must adapt their activities. Adapting activities across these diverse functions demands a substantial degree of internal orchestration. In light of this, we argue that companies have to make more use of organizational coordination instruments, such as “dialogic coordination practices” that are conducive to integrating “organizational work under conditions of task interdependence and uncertainty” (Faraj & Xiao, 2006, p. 1156). By embracing such instruments, companies facilitate the alignment of activities spanning multiple functions, thus bolstering the prospects of successful CE transformation.

Limitations and future research

The qualitative research methodology used in our study provided several valuable insights. However, like all other research methods, it is not free from limitations that open attractive avenues for further research. The theoretical sampling approach primarily concentrated on pioneers, that is, companies that have made substantial efforts to establish circularity and have made notable progress in de-linearizing their value-creation processes. In doing so, we considered whether the companies had received awards for their CE efforts or engaged in publicly funded R&D projects that featured competitive selection mechanisms. Thus, we

emphasize that additional studies are needed to address “CE laggards,” shed light on barriers that impede the shift towards circularity at the organizational level, and diagnose the reasons for the failure of undertaken circular initiatives. Recent papers have already begun to explore barriers to CE transition (e.g., Bocken & Geradts, 2020). Concurring with Bocken et al. (2023), we advocate that further analysis of barriers would be insightful from both academic and practical perspectives, especially as the practical implementation of CE strategies worldwide is still at an early stage and, in some fields, even declining (Kirchherr et al., 2023).

Second, from the methodological standpoint, the qualitative research design we deployed is particularly suited for exploring novel, under-understood phenomena and allows for theorizing based on “rich and nuanced” data, revealing mechanisms that might be overlooked in quantitative data (Graebner et al., 2012, p. 278). However, we advocate that in addition to qualitative methodologies, further research is warranted to deploy other methods to cover the variety of organizational approaches to CE transition.

More specifically, our study revealed several internal and external organizational initiatives and indicated some external conditions relevant to the transformation towards circularity. As these initiatives are at least partly interdependent, we advocate using research designs that are especially conducive to uncovering interdependencies instead of addressing isolated effects of individual variables. More specifically, to explore CE further, we recommend the deployment of the QCA methodology that has already found its way into strategy research (e.g., Fiss, 2011), sustainability research (e.g., Juntunen et al., 2019) as well as into studies of collaborative interorganizational networks (e.g., Reck & Fliaster, 2022). The QCA methodology builds on configurational thinking to unveil distinct combinations of explanatory factors. Based on our qualitative study, we advocate the logic of “conjunctural causality,” hypothesizing that successful implementation of various CE strategies as the organizational outcome results from different configurations of multiple internal and external factors rather than from the net effects of any of these factors in isolation. We leave this intriguing analysis for future research.

Last but not least, while our study provided some interesting examples, a more profound analysis of alternative collaborative arrangements for CE has not been the central focus of our work. This limitation presents a fertile ground for future research to explore the interplay of internal reorganizing and different forms of collaboration (strategic alliances, joint ventures, ecosystems) and diverse partners (suppliers, customers, research institutes, companies in other industries, and actors from other sectors).

Conclusion

Our paper provides three contributions to current research on organizational transformation and collaboration towards CE. First, we demonstrate that contributing to the CE requires reorganizing internal structures and processes. Second, we shed light on how companies that shift to circularity adjust their external collaboration. Third, in addition to augmenting the literatures on intra- and interorganizational modes of organizational transformation, we also enhance research on CE by identifying several interdependencies of these two fundamental modes. By connecting these research streams, our study also creates a promising avenue for further CE and transformation studies.

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*Appendices**Table II.3-1: Appendix A: Information on data sources*

Organization	Descriptive information on data sources						Interviews
	No of press releases	Pages in business reports	Pages in CSR reports	Website pages	Article pages	Other material pages (e.g., presentation slides)	
1	8	1095	201	-	-	62	1
2	-	1767	-	9	-	-	1
3	3	-	-	2	5	20	1
4	-	-	-	5	-	-	1
5	-	-	-	2	-	-	1
6	4	-	-	6	-	-	1
7	-	-	40	8	-	-	1
8	-	-	-	3	1	-	1
9	-	-	-	3	-	-	1
10	1	-	48	7	-	-	1
11	-	-	-	4	-	-	1
12	-	-	-	5	-	-	1
13	21	-	12	4	-	8	1
14	8	-	56	4	4	1	1
15	3	-	-	3	-	-	1
16	-	152	101	6	-	-	1
17	-	-	-	3	-	9	1
18	7	-	232	5	19	20	2
19	-	-	68	5	6	-	1
20	3	-	-	4	5	-	1
21	-	-	13	6	1	-	1
Other	2	-	-	6	280	-	3
Summary	60	3014	771	100	321	120	25

Abbreviations: Corporate Social Responsibility (CSR)

(Author's own illustration)

Table II.3-2: Appendix B: Information on interviews

Organization type	Position of interviewee †	Descriptive information (duration of recording, volume of transcript, language ‡)
Manufacturer of plastic products	Chief Executive Officer	45 minutes (F), 11 pages (G)
Manufacturer of packaging for the food-industry	Chief Executive Officer	57 minutes (G), 14 pages (G)
Manufacturer of plastic packaging	Chief Executive Officer	49 minutes (G), 15 pages (G)
Manufacturer of plastic packaging esp. films	Chief Executive Officer	45 minutes (G), 11 pages (G)
Manufacturer of plastic packaging esp. films	Chief Technology Officer	59 minutes (G), 14 pages (G)
Manufacturer of plastic packaging	Chief Sales Officer	45 minutes (G), 13 pages (G)
Manufacturer of plastic packaging esp. industrial applications and tanks	Managing Director	46 minutes (G), 13 pages (G)
Manufacturer of plastic electromechanical modules	Shareholder-managing Director	45 minutes (G), 12 pages (G)
Manufacturer of plastic packaging films	Head of R&D	44 minutes (G), 13 pages (G)
Manufacturer of plastic packaging	Head of R&D and Business Development	47 minutes (G), 12 pages (G)
Plastics recycling esp. Compounding and preparation	Head of R&D and Production	29 minutes (G), 9 pages (G)
Manufacturer of thermoformed packaging	Head of Communication	45 minutes (F), 12 pages (G)
Manufacturer of chemical products	Head of Sustainability	53 minutes (F), 15 pages (G)
Manufacturer of plastic packaging	Business Unit Manager Compounds	48 minutes (G), 13 pages (G)
Manufacturer of plastic films	Senior R&D Manager	49 minutes (G), 13 pages (G)
Manufacturer of plastic films	Senior Product Manager	47 minutes (G), 14 pages (G)
Manufacturer of chemical products	Project Manager CE	30 minutes (G), 8 pages (G)
Manufacturer of plastic products in several divisions	Enabler of Sustainable Innovation	54 minutes (G), 13 pages (G)
Manufacturer of plastic packaging	Business Development & Sustainability Leader	46 minutes (G), 13 pages (G)
Manufacturer of plastic packaging	Sustainability & CSR Manager	45 minutes (G), 13 pages (G)
Manufacturer of electrical insulation materials	CE & Sustainability Manager	15 minutes (G), 5 pages (G)
Manufacturer of technical packaging	Business Analyst	
Adhesive transformer	Plant Manager CE	52 minutes (F), 14 pages (G)
	Quality Health Safety & Environment Manager	20 minutes (F), 6 pages (G)
Union of polymers manufacturers	Consultant / Instructor	60 minutes (F), 14 pages (G)
Industry association plant manufacturers	Adviser Environmental & Sustainability Affairs	30 minutes (G), 8 pages (G)

† Sequence of the presented information does not correspond with the numbering of the interviews in the text

‡ (F=French; G= German)

Abbreviations: Circular Economy (CE), Corporate Social Responsibility (CSR), Research & Development (R&D)

(Author's own illustration)

II.4 Customer roles in digital business ecosystems: Different forms of customer contribution in value creation

II.4.1 Notes on publication

The following academic article titled “Customer roles in digital business ecosystems: Different forms of customer contribution in value creation” was written by myself as single author.

This is a post print chapter. The original version is available in *Handbook on Digital Business Ecosystems* edited by Sabine Baumann, published in 2022 by Edward Elgar Publishing Ltd. <https://doi.org/10.4337/9781839107191.00021>

Original citation: Bähr, K. (2022). [Customer roles in digital business ecosystems: different forms of customer contribution in value creation](https://doi.org/10.4337/9781839107191.00021). In: Baumann, S, *Handbook on Digital Business Ecosystems. Strategies, Platforms, Technologies, Governance and Societal Challenges*, 194–211. <https://doi.org/10.4337/9781839107191.00021>

As corresponding author, I submitted the article to the call for chapters for consideration to the *Handbook on Digital Business Ecosystems. Strategies, Platforms, Technologies, Governance and Societal Challenges* in October 2020. The *Handbook on Digital Business Ecosystems* provides a comprehensive overview of current research and industrial applications as well as suggestions for future developments. Multi-disciplinary in scope, the *Handbook* includes rigorously researched contributions from over 80 global expert authors from a variety of areas including administration and management, economics, computer science, industrial engineering, and media and communication. After peer-review, three rounds of revision took place. The revised version was accepted for publication in December 2021. The final version of the chapter in the *Handbook* has been available since April 2022.

The content of this chapter was presented at an influential international conference: Bähr, K. (2022). *Customer Roles in Digital Business Ecosystems: Different Forms of Customer Contribution in Value Creation*. 17. *Internationale Tagung Wirtschaftsinformatik*, 21-23 February, Nürnberg/GER, virtual.

II.4.2 Academic article

Abstract: Customers shape digital business ecosystems with their resource contributions and interactions. This chapter expands the understanding of co-creation in digital business ecosystems. It develops a typology of different customer roles according to their interaction level and their integration of resources. Hence, the central research question is: Which customer roles emerge in digital business ecosystems? This chapter discusses customers as essential resource contributors from a theoretical point of view, illustrated by real-world cases. The level of interaction of the customers in the different roles is characterized as either active or passive. At the same time, integrated resources are differentiated in terms of time, skills, physical resources, and data. The combination of both dimensions allows eight distinct customer roles to be defined: self-service seekers, service graders, content creators, skill sources, product/service providers, co-producers/prosumers, data providers, and data generators. Co-creating customers further question the distinction between consumption and production in digital business ecosystems.

Keywords: digital business ecosystem, customer roles, co-creation, resource integration, customer interaction, real-world cases

1 Introduction

Customers contribute essential resources to value creation in digital business ecosystems (DBEs) and are critical actors that shape such ecosystems in manifold ways. According to the data management platform provider Domo, their contributions reached a new peak in 2020, with Instagram users posting 347 222 stories, YouTube users uploading 500 hours of video, Facebook users uploading 147 000 photos, and WhatsApp users sharing 41 666 667 messages, every minute (domo.com, 2020). Indeed, without such customer contributions, most well-known DBEs would look very different. Interestingly, despite its importance to DBEs, research is only beginning to address and understand digital resource integration (Ng et al., 2019).

A vast body of literature exists highlighting customers' role in value creation (Gummesson et al., 2014; Nambisan and Baron, 2009; Ng et al., 2019) and the challenges involved in managing essential resources outside a firm (Hilton et al., 2013). Yet, only a few articles consider what

customers contribute to value co-creation. In their literature review on the roles and resource contributions of customers in value co-creation, Agrawal and Rahman (2015) additionally find that most studies on customers' contributions are limited to one or two customer roles, and hence, in their paper they call for more research on the different customer roles and their degree of contribution to value co-creation. In particular, literature on the understanding of value creation that overcomes the distinction of customers or firms looking beyond dyadic interactions is still underrepresented (Beatty, 2019; Hollebeek et al., 2018; Fehrer et al., 2018; Åkesson and Edvardsson, 2018). Despite the growing body of literature on customer roles in value co-creation, a systematic link between contributed resources, interaction, and the resulting customer roles in DBEs is still missing. Therefore, this chapter's central research question is: Which customer roles emerge in DBEs according to customers' resource contribution to value creation? In particular, this chapter seeks to develop a framework of the different customer roles according to their co-creation interactions and their co-creation integration of resources.

As customers' contributions have especially more impact in DBEs (Prahalad and Ramaswamy, 2002), it is essential to understand the different roles of co-creating customers. Customers' motives for participating in co-creation activities are generally related to perceived benefits (Nambisan and Baron, 2009) and their evolving experience (Ramaswamy and Ozcan, 2018). However, individual customers may differ in their motives (Åkesson and Edvardsson, 2018) and in their perceptions of the benefits and experience. The coordination of value creation in DBEs exceeds the isolated optimization of products, and confronts managers with new challenges (Parker et al., 2017) due to the need to orchestrate customers' co-creation activities. Co-creation occurs in several ways, and to understand it in the context of DBEs it is vital to identify and differentiate the distinct customer roles, because each role may cause distinct challenges for firms (Rayna and Striukova, 2021).

In reading this chapter, practitioners will become more aware of the different customer roles and may be better able to choose a matching configuration for their DBE to orchestrate their co-creation and resource integration activities. The theoretical contribution of this chapter lies in the further elaboration of the co-creation activities of customers in DBEs, resulting in defining eight ideal types of distinct customer roles.

In the following, this chapter presents the theoretical framework to understand the different customer roles in DBEs by defining the concept of a DBE, while introducing customers as

essential actors, and discussing some exemplary real-world cases to demonstrate these roles in action. It integrates customers' contributions to the value creation of DBEs by developing different customer roles and elaborating potential future research opportunities. The remainder of this chapter is organized as follows. It first presents the theoretical framework by defining the central concepts, discussing past research on customer roles, and introducing two key facets of co-creation: the interaction between customers and the other ecosystem actors, and the resource integration of customers. The derived theoretical framework comprises eight customer roles, which are explained. The chapter then briefly introduces some exemplary cases for illustration purposes and presents case descriptions for the eight customer roles in these real-world examples, as well as an explanation of the resource integration and level of interaction in the respective cases. The central findings are discussed next. The concluding section highlights the contribution this chapter makes to the field, explains the study limitations, and points out some opportunities for future research.

2 Theoretical Framework: Customer Roles in Digital Business Ecosystems

2.1 Defining Digital Business Ecosystems

Thinking about business using the analogy of an ecosystem goes back to Moore (1993, 1996), who suggests:

a company [may] be viewed not as a member of a single industry but as part of a business ecosystem that crosses a variety of industries. In a business ecosystem, companies co-evolve capabilities around an innovation: they work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations (Moore, 1993, p. 76).

Therefore, essential to the concept is, first, the notion that competition takes place between ecosystems across industrial borders instead of among firms in one industry (Moore, 1996). Second, a combination of cooperative and competitive relationships characterizes business ecosystems; also called “coopetition” (Ritala et al., 2016; Bacon et al., 2020). Third, business ecosystems emerge around a focal value proposition (Adner, 2017) that may incorporate innovative products or services and that satisfies customer needs.

Due to progressing digitalization, the DBE concept was developed to account for digital technologies more explicitly. Matopoulos et al. (2012) define a DBE as a system that passes through several evolution phases, organizes itself, and includes a software layer. In their more recent work, Senyo et al. (2019) define a DBE as “a socio-technical environment of individuals, organisations and digital technologies with collaborative and competitive relationships to co-create value through shared digital platforms” (p. 53). Further, DBEs can entail multiple actors besides the focal firm, for example, enterprise partners, end-user customers, and developer customers (Ramaswamy and Ozcan, 2018).

Summing up, the new realms of competition are ecosystems (Moore, 1996), inside which coopetition can emerge (Ritala et al., 2016; Bacon et al., 2020) around the focal value proposition (Adner, 2017). Finally, digitalization adds a software layer or digital platform as a fourth defining element (Matopoulos et al., 2012; Senyo et al., 2019) of a DBE.

In the strategy literature on ecosystems, the idea of value co-creation is embedded in Adner’s (2017) definition, which states that several ecosystem partners jointly co-create the focal value proposition in multiple interactions, resulting in an alignment structure. In a similar vein, the research stream on service ecosystems tends to be concentrated on co-creation from a service-dominant logic perspective, looking at dyads of resource contribution and benefit extraction (Autio and Thomas, 2020). According to Vargo and Lusch (2010), service ecosystems seek to address three aims: (1) to offer co-produced services; (2) to provide services through mutual engagement; and finally (3) the co-creation of value. In this context, Lusch and Nambisan (2015, p. 162) describe co-creation as the “processes and activities that underlie resource integration and incorporate different actor roles.” This definition highlights co-creation as including three elements—actors, resources, and integration—which will guide the remaining theoretical part of this chapter.

2.2 Customers in Digital Business Ecosystems

Business ecosystems incorporate the relationships with and the resources of customers (Vargo and Lusch, 2010; Moore, 1993; Adner, 2017). Participating ecosystem actors try to capture value and contribute to value creation. Therefore, the categorization of producers versus consumers becomes blurry or can even disappear completely (Vargo and Lusch, 2010). Indeed,

some scholars acknowledge this development by replacing the terminology of “businesses” and “customers” with “actors,” resulting in actor-to-actor interactions (Beirão et al., 2017).

Digital technologies have accelerated and amplified this development of more active customer roles (Prahalad and Ramaswamy, 2000), for example by enabling self-service on digital platforms (Mostafa, 2016). The emergent activities of customers now transcend the borders between production and consumption and have been labeled “prosumption” (e.g., Toffler, 1980; Kotler, 1984) if their production activities result in consumption (Ritzer and Jurgenson, 2010). Ramaswamy and Ozcan (2018) also transcend the borders between production and consumption with their concept of digitalized interactive platforms. They argue that ideas for the configuration of digitalized interactive platforms can originate from anywhere in the DBE, and are no longer dependent on the established distinction between production and consumption, or between the producers and consumers of goods and services. Xie et al. (2008) describe prosumption as the value-creation activities of consumers that generate products, followed by the consumption activities and experiences of the same consumers.

Acknowledging that the distinction between consumers and producers can become blurry in DBEs, customers’ roles need to be clarified and further developed. Lappi and Haapasalo (2016) present the idea of different business ecosystem customer tiers: end customers, core service providers, second-tier service providers, indirect stakeholders, and supporting service providers. End customers are the ones who consume the co-created value; therefore, their needs are central to the service providers. The core service providers are customers of the second-tier service providers (Lappi and Haapasalo, 2016). Building on this idea of ecosystem customer tiers, end customers and other types of customers can integrate their resources in the co-creation of value. Besides customer tiers, recent research has also developed the idea of distinct customer roles in value co-creation. For example, Agrawal and Rahman (2015) identify 11 roles, ranging from co-producer to co-tester, based on customers’ responsibilities. Åkesson and Edvardsson (2018) identify four archetypical customer roles in a self-service-based system by differentiating between high and low motivation, and high and low knowledge/skills.

The theoretical perspective of interactive value creation stresses the growing importance of customers due to the affordances of digital technologies. Affordances emerge based on numerous still unrevealed possibilities for new functionalities or efficiency gains (Autio et al., 2018). Ramaswamy and Ozcan (2018) point out that value co-creation in interactions leads to

incomplete offerings and the upcoming distinction between customers as “engaging actors” and focal firms as “organizing actors.”

2.3 Customer Co-creation in Digital Business Ecosystems

The concept of value co-creation is used in several study areas, such as innovation or service management research (Gummesson et al., 2014). Central to value co-creation activities is the interactive value creation between customers and firms (Gummesson et al., 2014; Vargo and Lusch, 2010). Co-creation activities are multifaceted and occur in many different forms: for example, self-service, co-reflection, co-design, and co-recovery (Mostafa, 2016); the co-creation of brand value (Mingione and Leoni, 2020); and co-creation in new product or service development (Hoyer et al., 2010). The activities can span multiple functions from the co-conception of ideas and co-design, to co-production, co-distribution, co-maintenance, and co-disposal (Frow et al., 2015). Still, the co-design of innovation dominates the perception of co-creation and firms tend to underrate other forms of co-creation (Frow et al., 2015). In the following, a broad conceptualization of co-creation activities is applied.

Co-production incorporates self-service, self-service technology, and a higher level of customer activity in resource integration (Hilton et al., 2013). It is usually considered as part of value co-creation (Frow et al., 2015; Lusch and Vargo, 2006), or used as a synonym for it (Payne et al., 2008). Lusch and Vargo (2006) conceptualize value co-creation by describing it as a nested concept. Value co-creation represents the superordinate level, while the co-creation of value and co-production of value represent the subordinate level. Further, they state that the co-creation of value occurs during consumption, whereas co-production “involves the participation in the creation of the core offering itself” (p. 284). Although some authors argue that co-production is not part of co-creation (e.g., Etgar, 2008), this chapter will apply the prevailing definition that both concepts are interrelated and that co-production is one aspect of value co-creation (Frow et al., 2015). In the remainder of this section, the central ideas of the interactions between co-creating actors and resource integration will be elaborated in more detail.

2.3.1 Level of interaction between co-creating customers and focal firms in digital business ecosystems

Grönroos and Voima (2013) describe interaction as the participation of one actor in another actor's activities by physical, virtual, or mental contact. Typically, one actor will orchestrate these interaction opportunities (Grönroos and Voima, 2013; Grönroos and Ravald, 2011). While such interactions enable value co-creation, they may not be sufficient for value co-creation to unfold in practice (Grönroos and Voima, 2013). Direct interaction is described as an active, ongoing coordinated process that includes dialogue and integrating resources from both actors. Indirect interaction is the usage or consumption of the other actor's resources (Grönroos and Voima, 2013). This chapter focuses on direct interaction, with such interaction defined as a coordinated and collaborative process in which both actors integrate resources.

The differentiation between interactions initiated and coordinated by the firm (labeled "passive" from the customers' perspective) and interactions initiated and coordinated by customers (labeled "active" from the customers' perspective) characterizes the customer role. The idea to differentiate active and passive customer roles is not new; for example, Åkesson and Edvardsson (2018) introduce active and passive customer roles and differentiate these roles based on customers' motivation. Grönroos and Voima (2013) differentiate the roles based on two distinct situations. In the first situation, the firm asks the customer to integrate their resources into a collaborative production process. This activity is labeled a passive interaction from the customer's point of view because the customer is following the firm's lead. In the second situation, the customer becomes the integrating actor and initiates the activity (Grönroos and Voima, 2013), which can be understood as an active customer interaction. Customers signal their interaction willingness by their voluntary behavioral actions or by signing up for resource integration activities. These customer-coordinated single transactions are examples of active customer engagement.

2.3.2 Integration of resources by customers in digital business ecosystems

Research on the integration of resources in value co-creation has made some interesting progress over the last few decades, but it is still unclear what ideal resource integration practices and processes look like (Kleinaltenkamp et al., 2012). Vargo (2008) comments on the ongoing discussion on resource integration in value co-creation to stress that customers not only

integrate resources in firms' value-creating activities, but also co-create value themselves by combining the resources of several actors. Customers in this instance can be understood as resource integrators instead of a firm's resource, following the premise of service-dominant logic (Vargo, 2008). This perspective on customers as resource integrators allows a more nuanced understanding of customer roles by acknowledging the different types of resources that customers control or own in DBEs.

In service-dominant logic, it is common to differentiate between operant and operand resources (e.g., Tariq et al., 2020; Plé, 2016; Kleinaltenkamp et al., 2012). Operand resources are tangible and static resources that enable or support actors' activities (Lusch and Nambisan, 2015), while operant resources are intangible, dynamic, challenging to transfer, and affect other resources (Lusch and Nambisan, 2015), for example, knowledge, skill, expertise, and time (Hilton et al., 2013). Technology as a resource has attracted much scientific attention (e.g., Sklyar et al., 2019) due to its ambiguity. Akaka and Vargo (2014) conceptualize technology as an operant resource, as one needs to fully consider its potential to act on other resources; whereas others describe it—for example, in the case of self-service technology—as an operand resource because its value creation is dependent on the operant resources of customers (Hilton et al., 2013). In summary, this shows that the differentiation between operand and operant resources is context-dependent and still developing in the scientific discourse.

The actual types of resources have attracted significantly less attention than the overarching differentiation; although some noteworthy exceptions are the works by Plé (2016) and Agrawal and Rahman (2015). Concerning this chapter's aim to identify and compare the different customer roles in value co-creation, both contributions do not seem especially appropriate, due to the many resource types and the essential overlaps between these types. Therefore, the typology stemming from the presumption literature will be applied here. In this typology, customers contribute four resource types: time, skill, physical resources, and data. The first three resources are based on the seminal work defining presumption (e.g., Toffler, 1980; Kotler, 1984), while the fourth resource, that is, data, emerged later due to the growing importance of digital technologies in the modern world (Rayna and Striukova, 2021). Time and skill are considered typical examples of operant resources (Hilton et al., 2013).

The increasing digitalization of business ecosystems introduces data as a new type of resource and calls for its differentiation from the other three resource types, that is, time, skill, and

physical resources. According to the wisdom hierarchy, data is a lower form of knowledge when referring to its structure and agency (Rowley, 2007). Data is a digital recording of things, events, activities, and transactions, comes without context and interpretation, and is unorganized and unprocessed (Rowley, 2007). In contrast, information is structured data that can be used for a specific purpose (Rowley, 2007; De Mauro et al., 2016). Accordingly, data contains no contextual meaning or usage, whereas information is structured and purpose-bound. In the following cases, the theoretical distinction between data and information may become blurry. However, remembering that information is purpose-bound data, then the reuse of this data for other purposes makes data the more appropriate concept in the context of resource integration in DBEs.

This section has introduced and differentiated active from passive interaction, and argued that there are four resource types that are essential to understanding resource integration in DBEs. Hence, eight ideal types emerge, which are illustrated in Table II.4-1. Active interaction contains, depending on the resource type, the customer roles of self-service seekers (time), content creators (skills), product/service providers (physical resources), and data providers (data). In comparison, the passive interaction level entails service graders (time), skill sources (skill), co-producers (physical resources), and data generators (data). All eight ideal types of customer roles will be illustrated by real-world cases in the remainder of this chapter. The labels of the ideal types were deduced from the cases.

Table II.4-1: Ideal types representing different interactions and integrated resources

Integrated resource	Level of interaction	
	active	passive
Time (e.g., self-service, answering of surveys, grading of content)	Self-service seekers initiate a relationship and actively engage in interaction (individual transaction).	Service graders share their opinion/experience after an invitation (individual transaction).
Skills (e.g., personal skills like creativity, writing, video-making, programming, or singing)	Content creators provide individual parts of self-produced material (transaction), often after an initial registration (relationship).	Skill sources provide content that other actors use for additional purposes.
Physical resources (e.g., real estate, cars, products, 3D-printers, power-generating or energy-storage devices, hardware, technology)	Product/service providers initiate the relationship by registering and initiate the transaction by listing their offer.	Co-producers initiate the relationship by entering into a contract but do not initiate single transactions (ongoing nature), coordination performed by others.
Data (e.g., purposeful self-produced data or local information on traffic jams, preferences, usage patterns)	Data providers initiate the relationship by registering for services and share data on individual events (e.g., running tracks, corona infection, bugs).	Data generators initiate the relationship by registering for services; data generation and communication work in the background.

(Author's own illustration)

3 Exemplary Real-world Cases

According to the theoretical arguments presented, the case selection process aimed to choose DBEs incorporating the value co-creation activities of customers. Further, the selected cases should represent the theoretically deduced categories. This approach follows the idea of a diverse case method (Seawright and Gerring, 2008), which is in line with exploring different roles through case examples (Nylund et al., 2021). The case selection seeks to represent the maximal variance (Seawright and Gerring, 2008) regarding the eight ideal types, building on the introduced dimensions for integrated resources and the level of interaction (Table II.4-1).

DBEs may entail different value creation opportunities, resulting in several value propositions and co-creation activities in the same ecosystem (Ramaswamy and Ozcan, 2018). Hence, the same ecosystem may be an example of two (or more) distinct customer roles; for example, one actor might actively integrate their time and skill in different co-creation situations, because the

same actors can play different roles depending on the specific situation (Åkesson and Edvardsson, 2018).

3.1 Customers' Integration of Time

Customers actively integrate their time to co-create self-service experiences by using self-service technology (Hilton et al., 2013), and therefore they become self-service seekers. ING, a large direct bank, provided around 9.5 million customers with banking services in 2019 without actually possessing any physical service points, making ING the most significant direct bank in Europe (ING, 2020). Its banking services include, for example, money transfers, mobile payments, credit, and insurance services, and are embedded in a DBE comprising various partners of ING, such as Visa, Google Pay, and Apple Pay. However, the most crucial resource in online banking's DBE seems to be the customers' time. Customers actively integrate their time to co-create self-service experiences by instructing their banking transactions; for example, transferring money, buying and selling shares, installing limits. Customers are willing and capable of doing their banking transactions by themselves, which is an essential part of online banking's value creation. The active customers primarily integrate their time (Payne et al., 2008), resulting in a perceived co-created value of better and more timely information, more control, and a higher level of convenience (Hilton et al., 2013). The integration of customers' time during the digital self-service is active because the actors initiate the relationship by becoming customers of the DBEs' offering and by initiating the single transaction; for example, by logging into their online account to buy shares.

Another example of the active integration of time can be seen in Google Opinion Rewards, an application in Google's DBE. Here, mainly end-user customers answer the survey questions of partner firms or developer customers to earn small payments for completing each mini-survey. Customers can use their earnings to pay in the Google Play Store. In September 2020, there were more than 50 million installations of this application on Google Play (Google. com, 2020). Once installed, and after answering an initial survey with personal questions, the application will occasionally send mini-surveys on, for example, watched YouTube content, visited places, or personal habits. Initially, the customer role is active because customers decide to use the application and register to participate in mini-surveys. Here, participation in these mini-surveys is not a by-product, but rather the experience that is co-created. Later on, Google, which will

invite selected customers to participate in specific mini-surveys, initiates the ongoing interaction. So overall the customers initiate the relationship, but later on the firm orchestrates the individual interactions. The customer role becomes less active as the customers follow the invitation to participate in selected mini-surveys. Regarding the contributed resources, the customers mainly contribute their time to answer the survey questions, as there are no specific skills, knowledge, or expertise required to participate. Compared to the following examples of passive time integration, it is interesting that customers dedicate their time very consciously to this activity of answering mini-surveys, and it is not a by-product of other services.

Netflix, Amazon Prime, Wattpad, and many other DBEs orchestrate the integration of customers' time as service graders, resulting in their passive integration of time in value co-creation. This integration of time is passive because it takes place parallel to or after the main activity. The main activity may be watching, reading, buying, or searching the web. Typically, focal firms ask customers to share their opinions/experiences with others. These opinions range from elementary ratings, such as a thumbs up/down (Netflix) or star ratings (Amazon Prime, eBay, Amazon), to recommendations or verbal feedback (Amazon Prime Reading, Wattpad, eBay, Amazon). Regardless of the complexity, the integrated resource is time, because the customers utilize their time for grading the services additional to the main activities.

The usual reader on Wattpad also primarily contributes their time by reading Wattpad stories, rating and commenting on them; thus becoming a service grader. Wattpad, which introduces itself as "The world's most-loved social storytelling platform" (Wattpad.com, 2020), is a DBE that connects 80 million readers and writers globally and is available in 30 languages. Wattpad connects customers (writers and readers) and partner firms (publishers and studios) in its DBE. Readers do not necessarily need unique or specialized skills to contribute to the DBE of Wattpad. Therefore, they also donate their time. Readers begin their interaction through the registration to enable them to enjoy upcoming authors and trending, legal, and accessible stories. Instead of paying money, Wattpad invokes them to rate and comment on stories to help build a fan base. Other actors of the ecosystem, like the focal firm, ask readers to engage in these value-creation activities. Hence, if present, their engagement is labeled passive because, while they initiated the main activity (reading), they did not initiate the co-creating activity (content grading).

3.2 Customers' Integration of Skills

Content creators actively integrate their skills. The Mozilla Firefox browser was built with open-source software with the goal of championing a “healthy” internet. The Mozilla Foundation controls the Mozilla Company. It is a non-profit organization established in 2003 with the stated purpose that everyone should be able to access the internet without any barriers (Mozilla.org, 2020b). It provides a non-profit alternative to commercial offerings (Mozilla.org, 2020a), and collects only data necessary to provide the service, while avoiding using data for other purposes. Several types of content creators contribute differently to value co-creation in the DBE of Mozilla Firefox. When Mozilla introduced Firefox as an innovative alternative to the available commercial browsers, customers engaged closely with them, especially in the marketing activities (Krishnamurthy, 2009). Today, two types of content creators prevail: developer customers and end-user customers (Mozilla.org, 2019). The content creators initiate all their engagement, since Mozilla Firefox is accessible to everyone, even without Firefox community engagement. Consequently, the content creator’s interaction in value co-creation is active. Regarding the resources, the end-user customers integrate their skills by, for example, testing the browser’s new features, answering support questions, and translating and localizing Firefox; for example, enhancing the browsers fit with a specific area. Customers need a certain skill level to execute the co-creation activities (time and physical resources are also necessary, but skill is essential for the contribution). Summing up, in the case of Mozilla Firefox, the customers also actively integrate their skills.

The second example refers again to Wattpad. Here, writers create the stories that are Wattpad’s content. They use their skill, knowledge, and expertise to write a unique and captivating story to share on Wattpad. Because time alone is not sufficient for writing a story and specific skills are necessary, this example represents the integration of skills. The content creator uploads and shares their story with the Wattpad community, and initiates both the relationship and interaction. Therefore, this example represents an active integration of skills.

DBEs that build on machine learning enable customers as skill sources to integrate their skills passively. DeepL, founded in 2017, applies neural machine translation to offer translation services to more than 1 billion customers (Deepl.com, 2020), achieving convincing translation results (Coldewey and Lardinois, 2017). The online dictionary Linguee is the backbone of DeepL and uses web crawling to find translated text pairs. Human translators evaluate text pairs

that are later used for machine learning in neural machine translation, especially to train the neural network (Faes, 2017). Text pairs come, for example, from multi-national organizations that offer professional translations of texts in various languages, such as the European Union (Smolentceva, 2018). Besides text pairs, right from the beginning, Linguee and DeepL have been working with user feedback, which allows the skill sources to comment, correct, or choose the best translations. Both forms of evaluating existing text pairs, and user feedback on their translation requests, build on human language skills. Therefore, the integrated resource is necessary as well as the skill sources' skills. The skill sources do not actively seek the integration of their skills. Also, they do not use translation services specifically to make them better, but rather to receive a specific translation. Therefore, services built on machine learning, such as neural machine translation, enable skill sources to integrate their skills passively while using the core service. Similarly, the speech recognition used by many systems, such as Siri, Alexa, or Cortana, enables skill sources to integrate their language skills to train digital assistants' understanding capacity for the language.

3.3 Customers' Integration Their Physical Resources

In DBEs, actors need some basic infrastructure to enable their participation, and indeed this is usually a necessary precondition (for example, access to the internet, standard devices, and standard software). Hence, this basic infrastructure is not considered an integrated resource for value co-creation in this chapter.

Product or service providers actively integrate their physical resources. Airbnb created a DBE for matching travelers with places to stay around the globe. Airbnb's end customers are travelers looking for local rooms and special events (Airbnb.com, 2020). Airbnb also targets core service providers (Lappi and Haapasalo, 2016) as customers of the DBE, such as hosts. The hosts participate as service providers to end customers, and are at the same time customers of Airbnb who rent out free space in their owned real estate after initially registering as Airbnb hosts. Airbnb supports hosts by providing the digital booking platform and support services, such as insurance for liabilities and property damage, and payment processing. Airbnb charges the hosts a small fee proportional to the reservation. Guests and hosts are motivated by the perceived value (for example, service quality, economic benefits, human interaction, authenticity, and convenience) to engage in co-creation activities (Thaichon et al., 2020). As

Airbnb service providers, the hosts actively contribute to value co-creation in the digital ecosystem by contributing their physical resources (for example, apartments, houses, rooms). Their contribution is active because they initiate their hosting activities with their first registration and then actively manage the hosting process by preparing their place, welcoming guests, and answering questions.

Similarly, product providers actively integrate their physical resources, especially their products, on the eBay marketplace by selling them to eBay's buying customers (eBay Inc.com, 2020b). eBay's DBE consists of the marketplace ebay.com, its local marketplaces, and eBay mobile apps (eBay Inc.com, 2020a), connecting millions of buyers and sellers worldwide. The product providers are individuals, and organizations of all sizes. As any marketplace needs product providers, they play a dual role as sellers of the products and customers of the eBay marketplace. They use the DBE services and pay for these services, ranging from the digital platform to ambassador groups lobbying for the sellers' interests and initiating campaigns shaping critical political issues (eBay Inc.com, 2020b). As product providers actively have to offer products they want to sell, their contribution to value co-creation is active. They primarily contribute physical resources, consisting of new and used products; for example, automobile parts, books, shoes, smartphones, toys, watches, and laptop computers.

Co-producers integrate their physical resources passively in the DBEs' value co-creation. In particular, in the energy sector, innovative DBEs around service platforms (Midttun and Piccini, 2017) such as virtual power plants (VPPs) allow for the integration of decentralized units (Nosratabadi et al., 2017). These offer a high-tech digital platform that enables energy efficiency and energy peer-to-peer sharing (Mahmud et al., 2020). VPPs virtually integrate and control power-generating units, such as photovoltaic, wind turbines, hydro turbines, and energy storage systems (Kasaei et al., 2017). Within this context, energy customers appear both as consumers and as producers of electricity, or so-called prosumers (Dellermann et al., 2017; Olkkonen et al., 2017). They initiate the prosuming of energy (Olkkonen et al., 2017), for example, by acquiring the systems; and mostly, they own energy production units such as solar panels (Olkkonen et al., 2017), or batteries of electric vehicles used to store energy (Mahmud et al., 2020). A VPP aggregator orchestrates the DBE (Nosratabadi et al., 2017) and manages the day-to-day activities. This orchestration results in the ongoing passive integration of prosumers' physical resources in the co-production of local green energy. Some other examples

of co-producers passively integrating their physical resources are cryptocurrencies, and web access via privately owned remote routers.

3.4 Customers' Integration of Data

Data providers actively integrate self-created and owned data into DBEs when they share individual packages of data with all or with chosen actors of the ecosystem. This active integration is built on single decisions to integrate data. It is not a side effect of service use, but rather an interdependent and deliberate activity. Many applications for phones (Runtastic, Strava) and smart devices, such as watches (Apple Watch, Fitbit), or shoes (FeetMe), can track the daily lives of individual actors. For example, Fitbit tracks the number of steps, distance traveled, calories burned, weight, heart rate, sleep stages, active minutes, and location of users (FitBit Inc.com, 2020), and generates a massive amount of data. Fitbit enables customers to share that data by connecting their devices with applications or software to synchronize the data (FitBit Inc.com, 2020). Additionally, it is possible to share some aspects of this recorded data with friends and strangers, but this can also have unintended consequences. One example of how data providers sharing such information can be problematic relates to a famous case involving soldiers using fitness tracking while exercising. They recorded their exercise routes and shared them; third parties, in turn, used the routes to locate the military bases (Hern, 2018). Usually, such data is used to recommend courses or compare exercise results, resulting in exercise experience co-creation from data providers' active data integration.

Passive customer data integration also happens every moment of the day when customers co-create value as data generators. One prominent example is Google Maps. The use of Google Maps for navigation generates rich location data and traffic data, because every user is tracked. The generated data helps to understand and forecast traffic jams (Lau, 2020). A German artist who faked a traffic jam by slowly carrying 99 phones on the street impressively demonstrated how this passive integration of customer data works (Hern, 2020). The information resulting from the 99 phones seemed to signal a traffic jam because they were moving slowly. This integration of customer data is passive because the data generators give their consent by accepting the terms of use of the core service. However, customers may not be aware of this activity as they do not initiate a single transaction to integrate data, such as sharing, uploading, or connecting; instead, the data tracking happens continuously in the background while the data

generators participate in other DBE activities. Table II.4-2 summarizes the presented ideal customer types regarding their level of interaction, the integrated resources, and exemplary cases.

4 Discussion

First, the active integration of resources emerges in two cases (time and physical resources) with economic benefits in the form of either cheaper, more comfortable, and self-controlled services (self-service seekers), or financial compensation (product/service providers). The economic benefits from the active integration of skills and data vary between ecosystems and individual actors. The co-creators in the discussed examples receive no obvious economic benefits, whereas others do; for example, YouTubers may earn money with their content; designers on Spreadshirt sell their designs of several products via the central platform provided by Spreadshirt; beta testers get early and discounted access to products such as video games for giving bug reports and feedback. To summarize, active integration can go hand in hand with economic benefits for resource-owning customers. This discrepancy poses challenges in the organization of value proposition design and value capture in DBEs, which can be addressed in dialogue with resource-owning customers who signal a willingness to make a voluntary commitment or who have an interest in the economic benefits. Vice versa, customers are more likely to signal their willingness to integrate resources if they can observe an attractive value proposition.

Second, referring to Lappi and Haapasalo's (2016) idea of ecosystem customer tiers, the four customer types represent different tiers; for example, self-service seekers, data providers, service graders, skill sources, and data generators might be end customers. Content creators, product/service providers, and co-producers/prosumers seem to refer to core service providers. One possible assumption might be that either integrating physical resources or the active integration of a skill enables customers to become core service providers. Indeed, physical resources and active skill integration are activity-specific resources. Time and data are usually not activity-specific because there may be several other equally good opportunities to use them. Hence, there seem to be fewer opportunities to use activity-specific resources; while at the same time, fewer customers possess these resources. Customers integrating activity-specific resources thus tend to occupy central positions. These customers may act more like traditional businesses (provision of services/products/production, role of economic benefits). Thus, the

actor-to-actor (A2A) interaction seems especially appropriate to characterize DBE interactions (see also Beirão et al., 2017) because it becomes challenging to characterize the interaction as B2B or B2C.

Table II.4-2: Summary of the ideal customer types in this study and some exemplary real-world cases

Type	Exemplary cases	Level of interaction	Integrated resource
Active integration of time → self-service seekers	Self-service platforms, like online banking services and booking kiosks, online FAQs, and discussion forums, feedback systems, like Google Opinion Rewards, YouGov.	Active – Self-service seekers initiate a relationship and actively engage in interaction (individual transaction).	Time – Engaging in self-service, like looking up solutions to one's own problems or answering survey questions, which primarily consumes time.
Passive integration of time → service graders	Netflix, Amazon Prime, Wattpad as a reader, YouTube as a user, Instagram as a user.	Passive – Service graders share their opinion/experience of consumed content with others or the focal firm after an invitation (individual transaction); no initial registration/consent (relationship) necessary (e.g., YouTube).	Time – Service graders need mostly time to consume and grade content.
Active integration of skills → content creators	Wattpad, Firefox, YouTube, Instagram, Facebook, Wikipedia, 3D-printing designs.	Active – Content creators provide individual parts of self-produced material (transaction), often after initial registration (relationship).	Skills – Content creations build on personal skills, like creativity, writing, video-making, programming, or singing.
Passive integration of skills → skill sources	DeepL/Linguee (text recognition and translation), Alexa/Siri/Cortana (speech recognition).	Passive – Skill sources provide content that other actors use for additional purposes.	Skills – Skill sourcing builds on the availability of matching content that has been created using specific skills.
Active integration of physical resources → product/service providers	Airbnb, eBay, Uber, 3D-printing services, peer-to-peer-credits	Active – Product or service providers initiate the relationship by registering and initiate the transaction by listing their offer	Physical resources – Both products and services integrate physical resources, like real estate or cars, products, or 3D printers, of the product/service providers
Passive integration of physical resources →	Virtual power plants, cryptocurrency, THOR network as a passive participant, provision	Passive – Co-producers initiate the relationship by entering into a contract or by registering on mining	Physical resources – Co-producers integrate resources, like power-generating or energy-storage devices, hardware, and energy to

co-producers/prosumers	of private network access points	platforms, but do not initiate single transactions (ongoing nature), with coordination performed by others	mine cryptocurrencies – especially technology
Active integration of data → data providers	Fitbit, German Corona Alert Applications, beta tests	Active – Data providers initiate the relationship by registering for services and share data on individual events (e.g., running tracks, corona infection, bugs)	Data – Data providers integrate purposeful self-produced data
Passive integration of data → data generators	Google Maps, Facebook	Passive – Data generators initiate the relationship by registering for services; data generation and communication work are performed in the background	Data – Data generators create massive data while using services (e.g., local information on traffic jams, preferences, usage patterns)

(Author's own illustration)

Third, it may be questioned whether it is helpful to consider the passive integration of time in value co-creation. According to Grönroos and Voima (2013), the service-dominant logic overemphasizes co-creation. Every value-creating activity can be described as co-creation, because the key elements are the activities of the service providers and customers, which are present in every service experience. Is it possible to differentiate the illustrated co-creation from a typical analog service experience? Regarding the passive integration of time, service graders share their experiences, evaluation, or feedback. First, this behavior is very typical for DBEs. It overcomes specific shortcomings of digital value propositions (for example, missing trust or security) (Flanagin et al., 2014), and enables, extends, and improves the value proposition. Thus, service grading results in value creation beyond the single consumption experience at the DBE level. Second, the grading activity may be part of the consumption experience, but individual consumption can unfold without the grading activity. Therefore, it is not an indispensable component (external factor in service), like being present to get a haircut. The activity of service graders translated to the analog world might be extensive feedback given to the hairdresser to improve the service, or recommendations given to others (for example, word of mouth), resulting in co-creation in innovation or marketing (Frow et al., 2015).

Fourth, the dimensions are not mutually exclusive. Service providers also integrate their time and skills. Content creators also contribute their time and physical resources (for example, devices used for internet access and other specialized equipment). The passive integration of

physical resources in the VPP becomes active if the power-generating unit is a biogas plant instead of a photovoltaic unit, because biogas farmers need to fill the power plant with resources (for example, corn). The resource types, though, are still overlapping (Plé, 2016; Agrawal and Rahman, 2015). Another more detailed possibility to conceptualize resources would be to consider different resource combinations and their impact on the customer roles. Similarly, it could be worthwhile to conceptualize the level of interaction not as dichotomous (active versus passive) but rather as a dimension that captures differences in the kind and differences in the grade of interaction.

Fifth, digital technologies and customers' option to integrate data overcome the challenges of information provision which is necessary for providing individually tailored products and services. Etgar (2008) argues that co-production and information provision are two distinct strategies to achieve customization. He concludes that information provision is inferior to co-production, due to the high risks of mismatching and high transaction cost. In contrast, the discussed examples indicate that digital technologies (for example, automated data collection, possibilities to share data, and communication technologies building on artificial intelligence and chatbots) reduce both the risks and transaction costs by establishing more efficient and effective ways to ensure information provision (Lusch and Nambisan, 2015). Therefore, DBEs enable new forms of resource integration and value co-creation (Keeling et al., 2021).

5 Conclusion

At the beginning of the chapter, the research question was stated as: Which customer roles emerge in DBEs according to customers' resource contribution to value creation? The theoretical deduction of two dimensions (the level of interaction and the integrated resource) with their respective manifestations (active and passive, time/skill/physical resources/data) resulted in eight ideal types, as summarized in Table II.4-1. These were central for the identification and selection of the real-world cases depicted in Table II.4-2. The cases illustrate which resources at which interaction level customers may contribute to value co-creation in DBEs. The four roles characterized by the active integration of resources are: self-service seekers, content creators, product/service providers, and data providers. The roles described as involving customers' passive integration of resources are: service graders, skill sources, co-producers/prosumers, and data generators. The eight customer roles explicitly link customers'

resource integration with their interaction degree, whereas the existing works in the literature (e.g., Agrawal and Rahman, 2015; Lappi and Haapasalo, 2016) do not combine both perspectives.

The eight ideal types of customer roles might support managers in the orchestration of value co-creation in DBEs because they show different options to organize value co-creation depending on the level of customer interaction and the resource type. Additionally, the selected real-world examples illustrate the differences between the customer roles, and support the design of similar customer co-creation opportunities in other settings.

The distinction between data providers and data generators seems especially interesting for future research in the face of growing interest in data security and privacy. The discussion of the appropriate design of the customer role, either as a data generator or as a data provider, dominated the German Corona-Warn-App's development. Finally, customers have become data providers, with the responsibility to actively integrate their data for value co-creation. Future research might address such issues, and focus on the causes and effects of the described customer roles.

The voluntary and active resource integration of self-service seekers, content creators, product/service providers, and data providers needs customers to be motivated to participate in active interaction and resource integration. Often, there is no need for customers to integrate their resources in value co-creation; therefore, they have to acknowledge the emergent benefit to feel motivated (Kleinaltenkamp et al., 2012). Future research might further elaborate on these motivational aspects of active resource integration (Agrawal and Rahman, 2015).

The passive and sometimes involuntary integration of resources can even be value-destroying. Additional extreme forms of passive integration of skill might be seen in the use of available online content, including online platforms such as Napster, kino.to, and SciHub, where content availability is often misused to surpass paywalls or violate property rights. These extreme and adverse forms might result in a co-destruction (Keeling et al., 2021) of value. Therefore, the passive integration of customer skills needs more nuanced attention in future research.

This study is not free from limitations either. Due to the case selection and the small number of cases in each category, there is no guarantee of the representativeness of the chosen cases; although the comprehensive descriptions and explanations try to enable readers to evaluate the cases and reach their conclusions. Some cases may be extreme ones that do not appropriately

represent the corresponding configuration of customers' resource integration and interaction in value co-creation. One example of a potential ambiguous classification is the service provider outlined in the discussion.

Additionally, this work follows a relatively static view of DBEs, where customers integrate their resources into existing value propositions. Of course, customers also contribute to dynamic developments as co-innovators (Agrawal and Rahman, 2015) and can even contribute to changing the existing ecosystem. The changes include creating new value co-creation logics, expanding the existing value proposition, or creating an additional value proposition inside the existing DBE. Future research might look into customer roles regarding ecosystem dynamics.

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II.5 Implementation of smart services in ecosystems

Implementierung von Smart Services in Ökosystemen

II.5.1 Notes on publication

The following academic article titled “Implementation of smart services in ecosystems” was co-authored by my colleague Philipp Laut and myself. The detailed division of tasks can be found in the authorship declaration.

This is a post print chapter of the version of record. The original version of record is available in Smart Services edited by Manfred Bruhn and Kersten Hadwich, published in 2022 by Springer Nature, https://doi.org/10.1007/978-3-658-37346-7_17. Reuse in this dissertation and publication in the specified repository is supported by kind permission of Springer Nature.

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Together, Philipp Laut and I submitted a short version for consideration to the Forum Dienstleistungsmanagement 2022 Smart Services in January 2021. After positive feedback, we submitted the long version in August 2021. The article was accepted for publication in the book series Forum Dienstleistungsmanagement 2022 in the book Smart Services in December 2021. In this book, academics and industry experts discuss the increasing digitalization of smart services. The version of record of the chapter in the edited volume has been available since July 2022.

II.5.2 Academic article

Zusammenfassung: Dieser Beitrag adressiert die Implementierung von Smart Services in Ökosystemen. Zuerst wird der Stand der Forschung dargestellt. Im Anschluss erfolgt eine vergleichende Fallstudie von acht Smart Service Implementierungen in Ökosystemen. Mittels dieser Fallstudien werden zwei Dimensionen zur Systematisierung genutzt und Idealtypen erarbeitet. Auf dieser Grundlage werden schließlich die strategischen Zielsetzungen, die Innovationsintensität und das Innovationspotenzial, sowie die Zusammenarbeit bei der Implementierung von Smart Services in einem Ökosystem analysiert.

1 Einleitung

Smart Services sowie Ökosysteme erfahren sowohl in der wissenschaftlichen Literatur als auch im Unternehmenskontext vermehrt Aufmerksamkeit (Acatech 2018; Töytäri et al. 2018). Hierbei werden beide Themenfelder nicht nur getrennt voneinander betrachtet, stattdessen rückt deren Interaktion zunehmend in den Vordergrund (z. B. Kohtamäki et al. 2019; Sklyar et al. 2019a). Es zeigt sich, dass sich die Charakteristika von Smart Services und Ökosystemen ergänzen, im Sinne der komplexen Komplementarität verstärken und Mehrwert schaffen, der in der Summe den Wert der einzelnen eingebrachten Leistungen übersteigt. Dies wird insbesondere dadurch erreicht, dass Akteure eines Ökosystems unterschiedliche Kompetenzen besitzen und mittels Datenströmen vernetzt sind. Somit erfolgt die Leistungserstellung des Smart Service nicht durch einen einzelnen Akteur, sondern durch *mehrere Ökosystempartner*, welche in die Leistungserstellung aktiv eingebunden sind. Weiterhin können auf dieser Basis zusätzliche Services angeboten werden.

In der *Praxis* finden sich zahlreiche Beispiele für die Zusammenarbeit von mehreren Akteuren in der Leistungserstellung von Smart Services. So vernetzt Uber Technologies Inc. mittels Apps Fahrer und Passagiere miteinander und stellt den Datenaustausch sicher. Auch im Kontext des Smart Homes findet die Integration von Smart Services statt. Hier lassen sich zahlreiche Anbieter von Smart Services finden, deren unterschiedliche Leistungen smarte Komponenten besitzen und miteinander interagieren. So können beispielsweise mittels Google Assistant zahlreiche Applikationen im Smart Home gesteuert werden. Hierunter fallen u. a. die smarten Services von Nest (Wärme-, Luftqualitäts- und Videokontrolle), Philips Hue (Licht) und Siemens (Küchengeräte).

In der Literatur finden sich unterschiedliche *Typologisierungen von Ökosystemen*. Jacobides et al. (2018) gliedern Ökosysteme in die drei Gruppen Geschäftsökosysteme, die sich mit Unternehmen und deren Umgebung beschäftigen, Innovationsökosysteme, die sich auf eine Innovation bzw. neue Wertangebote fokussieren, und Plattformökosysteme, welche die Organisation von Akteuren auf einer Plattform beschreiben. Hierbei wird ersichtlich, dass Ökosysteme äußerst facettenreich sind (Jacobides et al. 2018; Autio/Thomas 2020; Klimas/Czakon 2021). Schwerpunkte der Forschungsliteratur zu Ökosystemen sind die Struktur von Ökosystemen verbunden mit den daraus resultierenden Interdependenzen (Adner 2017; Adner/Kapoor 2010) und Komplementaritäten (Jacobides et al. 2018; Hein et al. 2019), die Kooperation in Ökosystemen (Cenamor/Frishammar 2021; Cozzolino et al. 2021) sowie das Management von Ökosystemen, welches häufig als Orchestration bezeichnet wird (Furr/Shipilov 2018; Lingers et al. 2021). Auch die *Charakteristika von Smart Services* wurden bereits tiefgehend untersucht. So geben Paukstadt et al. (2019) einen detaillierten Überblick über die unterschiedlichen Charakteristika von Smart Services und differenzieren Motive (Technologie- und Marktgetrieben), Geschäftsmodellentwicklungen (Evolution, Disruption und Umsatzanpassungen), Auswirkungen und Nutzenversprechen sowie Unsicherheit und Komplexität.

Betrachtet man die Literatur, die sich sowohl mit Ökosystemen, als auch Smart Services beschäftigt, fällt auf, dass *unterschiedliche Typen von Ökosystemen*, wie beispielsweise Geschäftsökosysteme (z. B. Töytäri et al. 2018), Innovationsökosysteme (z. B. Yin et al. 2020; Wei et al. 2020) und Internet of Things Ökosysteme (z. B. Manzoor et al. 2021) untersucht werden. Hierbei lassen sich vier verschiedene Schwerpunkte identifizieren. Die Theorie beschäftigt sich mit unterschiedlichen Akteuren und Rollen (z. B. Kohtamäki et al. 2019; Anke et al. 2020), Organisationsstrukturen (z. B. Sklyar et al. 2019a; Wei et al. 2020), der Interoperabilität (z. B. Bello/Zeadally 2019; Yin et al. 2020) und der Implementierung (z. B. Töytäri et al. 2018; Sklyar et al. 2019b).

Bei der Betrachtung der Implementierung und der Leistungserbringung von Smart Services in Ökosystemen kann sowohl in der Literatur als auch der Praxis erkannt werden, dass diese in unterschiedlichen Kontexten auftreten. Hierbei ist noch nicht klar, wie das Zusammenspiel zwischen den Charakteristika der unterschiedlichen Ökosysteme, der Smart Service Ausgestaltungen und der Unternehmenssituation die Implementierung sowie die Leistungserbringung beeinflussen. An dieser Stelle setzt dieses Buchkapitel mit der

vorliegenden vergleichenden Fallstudie an und untersucht die *Ausgestaltung der Implementierung von Smart Services*.

Zum Schließen dieser Forschungslücke folgt das Buchkapitel folgendem Vorgehen. Abschnitt zwei gewährt einen Einblick in die Charakteristika von Smart Services und Ökosystemen. Hierauf aufbauend werden die Charakteristika in Bezug auf die Ausgestaltung von Smart Services in Ökosystemen thematisiert. Anschließend stellt Abschnitt drei die Methodik der vergleichenden Fallstudie vor und gibt einen Überblick der betrachteten Fälle. Abschnitt vier präsentiert die Ergebnisse der Arbeit und diskutiert diese. Der Beitrag endet mit einer Zusammenfassung, den Implikationen, Limitationen und Ansätzen für zukünftige Arbeiten.

2 Theoretische Grundlagen

2.1 Einblick in Smart Services

Smart Services stellen, sowohl für die forschungs- als auch die praxisorientierte Literatur ein aktuelles Themenfeld dar. In seinen *Ursprüngen* wird unter Smart Service eine Dienstleistung verstanden, die über rein physische Produkte hinausreicht und in der Folge sowohl Mehrwert für Kunden als auch Kosteneinsparungen für den Anbieter des Service mit sich bringt. Realisiert wird dies durch die Erweiterung der Leistung um Intelligenz, d. h. Bewusstsein und Konnektivität (Allmendinger/Lombreglia 2005). Hierauf aufbauend fokussieren sich Forschende bei der Definition von Smart Services auf die drei miteinander in Beziehung stehenden Aspekte Technik, Individualisierung und Kunden. Im Kontext der *Technik* stehen vernetzte und intelligente Plattformen zur Auswertung der verfügbaren Daten im Zentrum. Die hieraus gewonnenen Erkenntnisse dienen im Weiteren der Individualisierung der Leistung (Wellenstadt et al. 2017; Stöhr et al. 2018; Knorre et al. 2020). Der zweite Aspekt verknüpft die *Individualisierung* mit der sich verändernden Kundenbeziehung. Durch die Individualisierung werden Leistungen kundenspezifisch und situationsabhängig modifiziert. Dies bildet die Grundlage neuer Geschäftsbeziehungen, die sich vorteilhaft auf Kostenstrukturen auswirken können (Wunderlich et al. 2013; Beverungen et al. 2017). Drittens steht der *Kunde* im Zentrum des Smart Service. Hierbei profitiert dieser sowohl von neuartigen Leistungen als auch von bisherigen Leistungen, die um eine digitale Komponente erweitert werden (Frank et al. 2018). Acatech (2018) verknüpft in diesem Kontext die unterschiedlichen Aspekte und definiert Smart Services als „datenbasierte, individuell konfigurierbare

Leistungsangebote aus Dienstleistungen, digitalen Diensten und Produkten, die über integrierte Plattformen organisiert und erbracht werden“ (Acatech 2018, S. 51).

Durch die intelligente Auswertung und Kombination von unstrukturierten Daten wird der beidseitige Mehrwert für Anbieter und Kunden geschaffen (Tombeil et al. 2016). Hierbei kommt Plattformen eine essenzielle Aufgabe zu, indem sie die Möglichkeit zur Veredelung der Daten bieten und die Schnittstelle zwischen Anbieter und Kunde darstellen. In diesem Zusammenhang kommt es zu einer Veränderung der Kombination einzelner Leistungsbestandteile, die nicht länger hersteller-, sondern kundenorientiert geschieht. Dies bewirkt eine Verkürzung von Reaktionszeiten, eine optimierte Kapazitätsauslastung und eine höhere Agilität (Bullinger et al. 2017).

Der Aufbau und die Integration von Smart Services unterteilt sich in die drei voneinander abhängigen Ebenen: Dienstleistungsebene, software-definierte Ebene und vernetzte physische Ebene (Acatech 2015). Basis des Smart Services ist hierbei die *vernetzte physische Ebene*, die technologische Voraussetzungen gewährleistet. Dies wird durch intelligente Produkte und Sensornetzwerke ermöglicht (Porter/Heppelmann 2014; Wellsandt et al. 2016; Bullinger et al. 2017). Mittels der Produkte und Sensoren lassen sich Daten sammeln und übertragen. Auf der *software-definierten Ebene* werden die zuvor gesammelten Daten zusammengeführt, gespeichert, mit externen Daten kombiniert und ausgewertet. Hierbei sind kontextbezogene Algorithmen von entscheidender Relevanz (Bullinger et al. 2017). Im Bereich der *Dienstleistungsebene* erfolgt die eigentliche Erbringung der Leistung. Diese entsteht durch die Kombination aus digitalem Dienst und kundenspezifischer Leistung. Sie kann sowohl automatisiert als auch mittels menschlicher Interaktion erfolgen (Herterich et al. 2016; Tombeil et al. 2016). Die genaue Ausgestaltung der Leistungserbringung ist hierbei stark von der jeweiligen Situation abhängig und kann von digital angereicherten Dienstleistungen bis hin zu rein digitalen Diensten reichen (Wunderlich et al. 2013).

Smart Services *unterscheiden sich von klassischen Dienstleistungen* in mehrfacher Hinsicht. Erstens ergeben sich durch die Erweiterung der Dienstleistung um digitale Technologien neue Anforderungen, wie beispielsweise Kompatibilität, Vernetzung und Kompetenzen sowohl an Kunden als auch an Anbieter (Wunderlich et al. 2013). Zweitens werden Kunden in die Leistungserbringung umfangreicher eingebunden, wodurch eine Kollaboration zwischen Anbieter und Kunde gefördert wird. In diesem Kontext kommt der Ko-Kreation ein entscheidender Anteil zu (Bähr 2022). Drittens treten Smart Services in unterschiedlichen

Umgebungen auf. So existieren Smart Services im Kontext von Geschäfts- und Privatkunden. Neben bilateralen Beziehungen bieten Ökosysteme entscheidende Anknüpfungen für Smart Services.

2.2 Einblick in Ökosysteme

2.2.1 Definition

Die fortschreitende Digitalisierung und die damit einhergehende beschleunigte Evolution von digitalen Ökosystemen bieten Smart Services zusätzliche Anwendungsszenarien. Durch die *Abstimmung verschiedener Akteure*, die multilateral zusammenarbeiten müssen, damit ein *zentrales Nutzenversprechen* entstehen kann, ergibt sich eine *Struktur*, die als Ökosystem bezeichnet wird (Adner 2017). Bereits 1993 äußerte Moore grundlegende Überlegungen zu Ökosystemen. Demnach verbindet ein Ökosystem Unternehmen verschiedener Branchen, die zusammenarbeiten um eine gemeinsame Innovation zu realisieren und damit Kundenbedürfnisse zu stillen, während sie unter Umständen gleichzeitig auch an anderer Stelle im Wettbewerb miteinander stehen. Die Parallelität von Kooperation und Wettbewerb hat sich in der Zwischenzeit zu einem zentralen Aspekt des Ökosystems entwickelt (Bacon et al. 2020). Des Weiteren verlagert sich der Wettbewerb zunehmend von der Ebene des Unternehmens auf die Ebene des Ökosystems (Moore 1996). Digitale Ökosysteme definieren sich zusätzlich durch eine verbindende digitale Infrastruktur, die entweder durch eine Softwareebene (Matopoulos et al. 2012) oder eine digitale Plattform (Senyo et al. 2019) implementiert sein kann.

Ebenso wie Smart Services findet das *Konzept des Ökosystems* zunehmend Beachtung in der Managementforschung (z. B. Khurana/Dutta 2021; Klimas/Czakon 2021; Wang 2021) sowie der Unternehmenspraxis (z. B. Accenture 2020; Wellener et al. 2020; PwC 2021). Klimas und Czakon (2021) argumentieren das Herzstück aller Ökosysteme ist stets die Ko-Kreation eines Nutzens, welcher sich jedoch je nach Perspektive unterscheidet. In Geschäftsökosystemen liegt der Fokus auf dem gemeinsamen Leistungsversprechen, während in einem Innovationsökosystem das Ziel verfolgt wird, gemeinsam eine Innovation zu kreieren. Da eine Innovation sowohl die Erfindung, als auch deren erfolgreiche und nutzenstiftende Anwendung beispielsweise durch eine Markteinführung beinhaltet, sind beide Perspektiven nicht überschneidungsfrei (Klimas/Czakon 2021). Ein Innovationsökosystem beinhaltet somit alle für die Innovationsleistung wichtigen Akteure, Aktivitäten, Artefakte, Institutionen und

Beziehungen, insbesondere auch substituierende und komplementäre Beziehungen (Granstrand/Holgersson 2020).

Die Perspektive der *Plattformökosysteme* misst darüber hinaus der zentralen Technologie, welche die Plattform bildet, eine besondere Bedeutung bei (Jacobides et al. 2018). Diese zentrale Technologie verfügt in der Regel über Schnittstellen und bedingt damit eine zusätzliche gegenseitige Abhängigkeit der Akteure, aber eröffnet auch zusätzliche Vorteile für die Beteiligten (Thomas/Autio 2020). Beispielsweise erreichen unabhängige Softwarehersteller durch die Partizipation an einem Ökosystem überdurchschnittliche Erlöse und eine höhere Chance auf einen Börsengang (Ceccagnoli et al. 2012). Hein et al. (2020) beschreiben digitale Plattformökosysteme anhand der *drei Charakteristika* Eigentumsverhältnisse, Wertschöpfung entweder durch Transaktionen oder die Ermöglichung von Innovation und die Autonomie von Komplementoren. Die Eigentumsverhältnisse einer Plattform, welche die Machtstrukturen im umgebenden Ökosystem bestimmen, können grundsätzlich zentral, geteilt, oder dezentral sein (Hein et al. 2020). Der Fokus dieser Arbeit wird im Folgenden daher auf der kooperativen Entwicklung von Smart Services im Innovationsökosystem und deren Implementierung im Geschäftsökosystemen liegen.

2.2.2 Evolutionsphasen

Ökosysteme durchlaufen ähnlich wie natürliche Organismen einen dynamischen und ständig fortlaufenden Entwicklungsprozess (Meynhardt et al. 2016). Die Idee, dass sich ein Ökosystem weiterentwickelt, geht auf einen natürlichen Lebenszyklus zurück (Zhang et al. 2017). Bereits Moore (1993) etabliert die *vier Evolutionsphasen eines Ökosystems* Geburt, Wachstum, Führung und Erneuerung. Bei der Geburt eines neuen Ökosystems ist die Definition der zentralen Leistung sowie die Zusammenarbeit mit den richtigen Partnern um diese Leistung zu verwirklichen essenziell. Damit das Ökosystem erfolgreich wächst, müssen laut Moore (1993) zwei Bedingungen erfüllt sein. Erstens muss eine größere Anzahl potenzieller Kunden existieren. Zweitens bedarf es eines gut skalierbaren Leistungsversprechens. Sind die beiden Bedingungen erfüllt kann das Ökosystem wachsen, tritt dabei jedoch häufig in einen Wettbewerb mit anderen Ökosystemen. Deshalb sind in der Wachstumsphase weitere Teilnehmer vom Nutzen des Ökosystems zu überzeugen. In Phase drei entwickelt sich aufgrund des bisherigen Erfolgs ein Wettbewerb um die Leitung des Ökosystems und einzelne lukrative Aktivitäten innerhalb dessen. Durch diesen Wettbewerb zwischen den Akteuren gewinnen

Standards und Schnittstellenmanagement an Bedeutung, da der Wettbewerb Innovationstätigkeiten begünstigt. Größere Veränderungen der Umwelt oder radikale Innovationen mit einem disruptiven Charakter können die vierte Phase einleiten. In dieser Phase kann sich das Ökosystem erneuern oder, falls dies nicht gelingt, auch sterben.

In der Literatur existieren mittlerweile *zahlreiche Lebenszyklusmodelle*. Aktuelle Studien, die sich mit der Evolution von Ökosystemen beschäftigen, belegen die grundlegende Idee der fortlaufenden Entwicklung (Zhang et al. 2017; Xiao et al. 2019). Beispielsweise durchläuft ein Serviceökosystem sechs Phasen bevor es eine angepasste Serviceorientierung erreicht, die sich vor allem auch durch eine aktive Einbindung des Kunden in Ko-Kreierungsprozesse auszeichnet (Banoun et al. 2016). Die Evolutionsphase in der sich ein Ökosystem gerade befindet ist damit für strategische Entscheidungen bezüglich der Implementierung von Smart Services von Unternehmen maßgeblich. Im Folgenden wird insbesondere zwischen der Geburt, also der Initiierung eines neuen Ökosystems und einem bestehenden Ökosystem (Wachstum, Führung, Erneuerung) unterschieden.

2.2.3 Rollen und Zusammenarbeit

Ein Ökosystem besteht aus verschiedenen Akteuren, die wiederum *unterschiedliche Rollen* übernehmen, indem sie bestimmte *Aktivitäten* ausführen. Gewöhnlich steht im Zentrum eines Ökosystems ein oder mehrere Unternehmen. Dieses zentrale Unternehmen übernimmt die Steuerung des Ökosystems und wird auch als Leader (Moore 1993), Orchestrator (Furr/Shipilov 2018; Lingens et al. 2021), fokales Unternehmen (Adner 2017), Hub (Iyer et al. 2006) oder Keystone (Iansiti/Levien 2004) bezeichnet. Die anderen Unternehmen stellen aus dieser Perspektive Teilnehmer bzw. Follower dar (Moore 1993).

Neben der Leader-Follower-Perspektive lassen sich Ökosysteme auch bezüglich der *Rolle in der Wertschöpfung* analysieren. Hier ergeben sich die vier Rollen Anbieter, welcher die Einzelleistungen zusammenführt, sowie Lieferanten (Iansiti/Levien 2004; Adner 2006; Kapoor 2018), Kunden (Iansiti/Levien 2004; Frow et al. 2016) und Komplementoren (Dedehayir et al. 2018). Gerade in digitalen Smart Service-Ökosystemen nehmen Kunden durch die Integration von Ressourcen und die Bereitstellung von Daten zunehmend zentralere Rollen ein (Bähr 2022). Die letzte Akteursgruppe, welche in Ökosystemen durch die komplexe Komplementarität von Leistungen auftritt (Jacobides et al. 2018), sind Komplementoren

(Kapoor/Agarwal 2017; Ozalp et al. 2018). Diese ergänzen die zentrale Leistung um zusätzliche Angebote in Form von weiteren Produkten und (Smart) Services, die vom Kunden zu einer Gesamtleistung zusammengeführt werden können (Dedehayir et al. 2018). Diese Gesamtleistung stiftet mehr Wert als das ursprüngliche Angebot des zentralen Unternehmens (Jacobides et al. 2018).

Eine *Plattform* kann sowohl ein Bestandteil eines Ökosystems sein, als auch die Basis des Ökosystems bilden (Iansiti/Levien 2004; Autio/Thomas 2014; Dedehayir et al. 2018). Grundsätzlich ist eine Plattform ein Produkt oder ein Service mit einer fortlaufenden Ergänzung oder Erweiterung durch komplementäre Leistungen (Cenamor/Frishammar 2021) und hat die Funktion Akteure auf zweiseitigen Märkten zu verbinden (Eisenmann et al. 2006). Beispiele für dieses grundlegende Verständnis sind Kreditkarten oder Marktplätze, die Transaktionen zwischen sonst nicht verbundenen Akteuren ermöglichen (Eisenmann et al. 2006). Im Gegensatz zu diesem ursprünglichen Verständnis, zeichnet sich eine digitale Plattform durch verschiedene Ebenen aus (Yoo et al. 2010). Die Ebenen werden als Architektur einer Plattform zusammengefasst und enthalten beispielsweise die physischen Geräte, das Netzwerk, die Services und die Inhalte (Yoo et al. 2010; Parker et al. 2017). Bedeutende Ressourcen einer Plattform sind Software Development Kits, Application Programming Interfaces (APIs), sowie Code-Bibliotheken und Vorlagen (Parker et al. 2017; Hein et al. 2019). Die Ressourcen können genutzt werden um die Innovationskraft des Ökosystems zu steigern, indem sie für andere Akteure freigegeben werden (Yoo et al. 2010; Parker et al. 2017; Hein et al. 2020).

Ein weiterer wesentlicher Aspekt, welcher durch die Eigentumsverhältnisse bestimmt wird, ist Ausgestaltung der *Offenheit des Ökosystems* für andere Akteure. Cenmor und Frishammar (2021) unterscheiden beispielsweise zwischen vier Strategien bezüglich der Bereitstellung von komplementären Produkten und Leistungen. Bei der proprietären Strategie liegen Entwicklung und Vermarktung alleinig in der Hand des Unternehmens. Werden beide Funktionen von externen Komplementoren übernommen, handelt es sich um eine Drittanbieter-Strategie. Daneben ist eine kooperative Aufgabenteilung zwischen Plattformunternehmen und Dritten möglich, bei der das Plattformunternehmen entweder nur die Entwicklung (Outbound) oder nur die Vermarktung (Inbound) übernimmt (Cenamor/Frishammar 2021).

Grundsätzlich benötigen alle am Ökosystem beteiligten Akteure die Fähigkeit Interaktionen durch Innovationsaktivitäten gezielt zu gestalten (Valkokari et al. 2017). Die *Komplexität der Zusammenarbeit* nimmt in digitalen Ökosystemen dabei deutlich zu (Bruhn/Hadwich 2019).

Beim Eintritt eines Plattformunternehmens in ein bestehendes Ökosystem ergeben sich ebenso verschiedene Handlungsalternativen (Cozzolino et al. 2021). Bei der selektiven Kooperation arbeiten etablierte Unternehmen lediglich bei niedrigpreisigen Produkten zusammen. Im Rahmen des gemeinsamen Wettbewerbs kooperieren etablierte Unternehmen bei der Entwicklung eigener Plattformen, um technische Herausforderungen und Wissenslücken zu kompensieren. Der selektive Wettbewerb zeichnet sich dadurch aus, dass Wettbewerb zwischen etablierten Unternehmen und der eintretenden Plattform auf der Ebene des Produktes ausgetragen wird, wohingegen die Ebene der Komponente von Zusammenarbeit geprägt ist (Cozzolino et al. 2021).

Der modulare Aufbau eines Ökosystems ermöglicht noch weitere *Kooperationsstrategien*. Allgemein können sich Akteure entweder auf eine bzw. wenige Komponenten oder das Gesamtsystem konzentrieren (Hannah/Eisenhardt 2018). Akteure, die eine Systemstrategie verfolgen, stehen im Wettbewerb mit anderen Ökosystemen. Im Rahmen einer Komponentenstrategie kooperiert ein Akteur im Ökosystem und konkurriert mit anderen Komponentenanbietern im eigenen Ökosystem sowie mit anderen Ökosystemen. Einige Komponenten limitieren das Wachstum oder den Erfolg eines Ökosystems (Adner 2012). Die letzte strategische Möglichkeit besteht nun darin gezielt solche limitierenden Komponenten zu identifizieren und diese zu besetzen, wodurch komplexe Kombinationen aus Kooperations- und Wettbewerbsbeziehungen entstehen (Hannah/Eisenhardt 2018). Hedman und Henningsson (2015) argumentieren schließlich, dass Technologie im Ökosystem unterschiedliche kollaborative Strategien ermöglicht. Einerseits ermöglicht Technologie den Ausschluss anderer bzw. neu hinzukommender Marktteilnehmer und kann durch die Zusammenarbeit bestehender Akteure zum Aufbau von Markteintrittsbarrieren genutzt werden. Andererseits kann Technologie auch den Weg für neu eintretende Akteure durch gezielte Kooperationen mit ausgewählten etablierten Unternehmen ebnen (Hedman/Henningsson 2015).

In einem sich entwickelnden Smart Service-Ökosystem ist die Frage der *Zusammenarbeit* bei der Implementierung von Smart Services somit ein zentraler Aspekt. *Kooperation* beschreibt grundsätzlich eine Zusammenarbeit basierend auf gemeinsamen Zielen, welche durch übereinstimmende und passende individuelle Interessen und Motive entstehen (Salvato et al. 2017). Unter *Koordination* wird hingegen eine Zusammenarbeit, welche auf Effizienz und Effektivität ausgerichtet ist und somit einen Fokus auf Organisation und Abstimmung aufweist, beschrieben. Gemeinsame Ziele rücken bei einer koordinierten Zusammenarbeit in den

Hintergrund (Salvato et al. 2017). Diese Unterscheidung zwischen kooperativer und koordinierter Zusammenarbeit stellt neben den aufgeführten unterschiedlichen Facetten der Kooperation eine grundsätzliche Unterscheidung bei der Implementierung von Smart Services in Ökosystemen dar.

2.3 Ausgestaltung von Smart Services in Ökosystemen

Aufgrund der vielfältigen Ausprägungsformen von Smart Services, die insbesondere auf den unterschiedlichen Ökosystemen beruhen, ist eine *strukturierte Verbindung zwischen Smart Service und Ökosystem* notwendig. Neuhütter et al. (2016) nutzen zur Eingruppierung von Smart Services einerseits die Leistungsdimension und andererseits die Smart Service-Elemente. Betrachtet man komplexere Smart Services, die in Ökosysteme eingebunden oder durch die Interaktion mehrerer Akteure erstellt werden, nimmt der Koordinationsaufwand zu (Herterich et al. 2016). In diesem Kontext ergeben sich die Ausgestaltung des Smart Service, die verschiedenen Rollen der beteiligten Akteure (insbesondere fokales Unternehmen und Komplementor), die Ausgestaltung der Zusammenarbeit (kooperativ oder koordiniert) und die Evolutionsphase (Initiierung eines neuen Ökosystems oder Einbettung in ein bestehendes Ökosystem). Diese Unterteilung dient im Folgenden der Charakterisierung der Smart Services.

Den Anbietern von Smart Services bieten sich verschiedene Strategien für die Ausgestaltung und Erbringung der Leistung. Ross et al. (2017) sowie Weiß et al. (2018) identifizieren *drei distinktive Strategien* die im Kontext der Smart Services verfolgt werden. Erstens können Unternehmen die *Kostenvorteile* in Form von Effizienz und operativen Prozessoptimierungen sicherstellen. Hierbei werden bisherige Leistungen günstiger erbracht oder es werden im Kontext der Leistungskoordination Vorteile genutzt. Zweitens kann eine Strategie der Kundenbindung und Verbesserung des Kundenerlebnisses formuliert werden. Hier spielen insbesondere die zuvor charakterisierte *Leistungsindividualisierung* und Ko-Kreation die Vorteile aus. Drittens können neue Produkte und neue Dienstleistungen erbracht werden. Dieses zusätzliche Wertangebot kann als *Leistungsdivergenzierung* verstanden werden. Während die ersten beiden Strategien insbesondere bei inkrementellen Innovationen auftauchen, finden radikale Innovationen häufig im Kontext neuer Dienstleistungen Anwendung (Gassmann et al. 2014). Abhängig von der Strategie können Unternehmen die verfügbaren Daten unterschiedlich nutzen. So ist es einerseits denkbar, dass Unternehmen mittels Daten die Kunden in Form von Rabatten an sich binden oder individualisierte

Leistungen anbieten. Andererseits können Unternehmen die Daten ins Zentrum der Leistung rücken (Paukstadt et al. 2020). Neben der Verfolgung einer einzelnen Strategie kann eine Kombination mehrerer Strategien erfolgen. So kombiniert Predictive Maintenance beispielsweise ein neues Leistungsangebot mit kundenspezifischen Anforderungen.

Die Ausgestaltung des Geschäftsmodells interagiert stark mit der gewählten Strategie. Je nach Zielsetzung und Ausgestaltung der Leistungserbringung können unterschiedliche Bereiche des Unternehmens beeinflusst werden. Johnson et al. (2008) identifizieren drei Komponenten, die das Geschäftsmodell beeinflussen. Erstens kann im Kontext der Leistungsanpassung das Wertversprechen verändert werden. Hierbei ergeben sich Potenziale in denen beispielsweise eine Interaktion mit anderen Kunden ermöglicht wird oder die zuvor beschriebene Leistung individualisiert angeboten wird. Zweitens kann die Kostenstruktur angepasst werden. Dies kann z. B. durch individualisierte Preise ermöglicht werden. Drittens können Schlüsselaktivitäten und Ressourcen in den Fokus rücken. So können durch die verstärkte Fokussierung auf Daten interne Prozesse mit digitalen Komponenten ausgestattet werden. Auch können Produkte lediglich durch Software differenziert werden.

Häufig beruhen Smart Services auf der Zusammenarbeit von mehreren Akteuren. Um die Interaktion zwischen den Akteuren zu gewährleisten, spielen *Interoperabilität* und *Kompatibilität* eine entscheidende Rolle. Hierbei fördert die Echtzeitinteraktion den Datenaustausch sowie die Kommunikation. Essenziell sind hierfür gemeinsame Standards, die im Ökosystem genutzt werden und Akteure miteinander verbinden. Somit profitieren auch Akteure die zuvor lediglich durch schwache Beziehungen vernetzt waren (Sklyar et al. 2019b). Durch die Zusammenarbeit des Unternehmens mit Partnern und Kunden kommt es zu einer Kombination von internen und externen Ressourcen (Beverungen et al. 2017; Anke et al. 2020). Ursache für die Zusammenarbeit sind unterschiedliche Anforderungen an Wissen, Erfahrung und Daten (Porter/Heppelmann 2014).

Die Zusammenarbeit ermöglicht darüber hinaus, dass *Akteure verschiedene Rollen* aufgrund technologisch getrennter, wertschöpfender Aktivitäten einnehmen, die in der entsprechenden Art und Weise erwartet werden (Kambil/Short, 1994). Hierbei können solche Rollen sowohl von Organisationen, Teams oder Individuen besetzt werden (Lusch/Vargo 2014). Anke et al. (2020) identifizieren beispielsweise im Kontext von Smart Services die vier Rollen „Projekt Sponsor“, „Digitaler Innovator“, „System Integrator“ und „Service Operator“. Der Projekt Sponsor nimmt in diesem Kontext die Rolle des Initiators und Koordinators ein. Weiterhin

betreibt er den Service und bietet diesen dem Kunden an. Digitale Innovatoren stellen bei der Entwicklung des Smart Services notwendige methodische Kompetenzen zur Verfügung und ermöglichen eine Neugestaltung des Geschäftsmodells. System Integratoren entwickeln die technische Infrastruktur und integrieren bestehende Dienstleistungen und Produkte mit den Smart Services. Service Operatoren betreiben technische Systeme, die für die angebotenen Leistungen benötigt werden. Zur erfolgreichen Integration und Erbringung von Smart Services hat die Literatur festgestellt, dass regelmäßig unterschiedliche Akteure beteiligt sind. So sind neben den Dienstleistern selbst, technische Experten, Daten- und Informationsanbieter, Institutionen und teilweise Wettbewerber aktiv (unter anderem Sklyar et al. 2019b; Anke et al. 2020; Wei et al. 2020).

In Bezug auf diese Ausgestaltung identifiziert Sklyar et al. (2019b) die Balance aus *servicebezogener Zentralisierung und lokaler Kundennähe*. Einerseits ermöglicht die Zentralisierung einen erleichterten Wissensaustausch und den vereinfachten Zugang zu Daten. Dies kann beispielsweise durch ein Cloud System oder ein universell zugängliches Interface geschaffen werden. So werden die benötigten digitalen Ressourcen allen beteiligten Akteuren zu Verfügung gestellt. Andererseits erlaubt die Kundennähe eine flexible Reaktion auf Veränderungen, lokale Präferenzen und individuelle Kundenwünsche (Olivia/ Kallenberg 2003; Sklyar et al. 2019b).

Zusammenfassend kann damit ein Smart Service entweder als *leistungsbezogene Innovation* oder als *strukturelle Innovation* in einem Ökosystem *implementiert* werden. Bei der leistungsbezogenen Innovation liegt der Fokus auf dem Smart Service selbst, beispielsweise durch Differenzierung wie zu Beginn dieses Abschnittes ausgeführt. Bei der strukturellen Innovation liegt der Fokus auf dem Ökosystem. Dies äußert sich beispielsweise in der Ausgestaltung von Rollen und den Rahmenbedingungen für Zusammenarbeit im Ökosystem. Wie ausgeführt, gliedert sich die Evolution eines Ökosystems in Phasen (Moore 1993; Zhang et al. 2017; Xiao et al. 2019). Im Kontext von Smart Services ergibt sich in allen Evolutionsphasen die Möglichkeit Smart Services einzuführen. Einerseits können Smart Services im Rahmen der Geburt als Initiierung eines neuen Ökosystems angesehen werden. Um den Smart Service zu erbringen, kann mit Hilfe anderer Akteure ein neues Ökosystem aufgebaut werden. Andererseits können Smart Services in bestehende Ökosysteme integriert werden.

3. Vergleichende Fallstudie von Smart Service-Ökosystemen

3.1 Methodik der vergleichenden Fallstudie

Die vorliegende Arbeit orientiert sich an der *vergleichenden oder multiplen Fallstudie* (Yin 2018; Eisenhardt 2021). Diese Form der Fallstudie erscheint im Kontext der Smart Service-Ökosysteme besonders geeignet, da es sich bei der Implementierung von Smart Services in Ökosystemen um komplexe Prozesse und Entscheidungen handelt (Gehman et al. 2018). In einem ersten Schritt wurden bestehende Smart Service-Ökosysteme in verschiedenen Branchen identifiziert. Hierzu fand eine Internetrecherche von Schlagwörtern zu Smart Service ergänzt um (Haupt-)Wirtschaftsbereiche entsprechend der Standard Industrial Classification Codes auf Deutsch und Englisch statt. Auf diese Weise konnten 47 Smart Service-Ökosysteme identifiziert werden. Dieses Forschungsdesign ermöglicht es die gemeinsamen Prozesse, welche die Basis von Smart Service-Ökosystemen bilden, herauszuarbeiten, da das gleiche Phänomen (Smart Service-Ökosysteme) sowohl in verschiedenen Branchen, als auch in verschiedenen geographischen Kontexten beleuchtet wird (Eisenhardt 2021). Das Vorgehen wurde weiterhin gewählt um die Generalisierbarkeit der Ergebnisse zu erleichtern (Graebner/Eisenhardt 2004) und um im Rahmen einer theoretisch-konzeptionell orientierten Generalisierung Lücken und Schwächen der dargelegten Theorien zu beleuchten (Yin 2013).

Im weiteren Prozess wurden *acht Fälle* für die qualitative Analyse und den Vergleich gewählt. Die Auswahl der Fälle folgt den vorangegangenen theoretischen Überlegungen und ist damit theoriegeleitet (Eisenhardt 2021) und nicht zufällig oder repräsentativ (Eisenhardt/Graebner 2007). Konkret erfolgte die Auswahl der Fälle nach einer initialen Analyse aller Fälle anhand der Kriterien Evolutionsphase des Ökosystems (bestehendes Ökosystem oder neues Ökosystem) und der Innovationsart des Smart Service (leistungsbezogene Innovation mit einem Smart Service Fokus oder strukturelle Innovation mit einem Ökosystemfokus). Weiterhin flossen die verfügbaren Informationen zu den gewählten Fällen in die Auswahlentscheidung ein. Die detaillierte Analyse auf acht Fälle zu beschränken erscheint sinnvoll, da vergleichende Fallstudien regelmäßig mit vier bis zehn Fällen gute Ergebnisse liefern (Eisenhardt 1989; Eisenhardt 2021). Die Basis der detaillierten Analyse bilden öffentlich zugängliche Informationen zu den Smart Services, den Ökosystemen sowie den zentralen Unternehmen. Hierzu zählen beispielsweise Unternehmenshomepages, Geschäftsberichte und Berichterstattung in der Wirtschaftspresse.

3.2 Fallbeschreibungen

Fall 1: Philips Hue Das smarte Lichtsystem von Philips, welches unter dem Markennamen *Philips Hue* vertrieben wird, erweitert die bestehende Kernleistung der Leuchtsysteme um smarte Serviceelemente. Philips wurde als Unternehmen zur Fertigung von Glühlampen vor mehr als 100 Jahren in Eindhoven in den Niederlanden gegründet. Philips bleibt bei der Erweiterung des bestehenden Produktangebots im Bereich Leuchtmittel um smarte Funktionalitäten der eigenen Kernkompetenz treu. Philips Hue besteht aus mehrheitlich physischen Teilen, welche über Schnittstellen mit smarten Funktionalitäten erweitert und in bestehende Ökosysteme von Partnerunternehmen eingebunden werden. Zu den physischen Teilen, welche das Kernangebot von Philips Hue ausmachen, zählen unter anderem Lampen, Lichtstreifen, Leuchten, und Zubehörteile wie Bridges, smarte Schalter und verschiedene Sensoren. Die physischen Produkte besitzen bereits die nötigen Schnittstellen um smarte Funktionalitäten wie die Steuerung der Leuchtmittel per App, über Sensoren oder per Sprache zu ermöglichen. Darüber hinaus lassen sich die Leuchtmittel über Hue Sync mit anderen medialen Aktivitäten wie Musik hören, Gaming oder Fernsehen verknüpfen. Diese Verknüpfung erlaubt eine intelligente Steuerung der Leuchtsysteme, die sich automatisch an die konsumierten Inhalte anpasst. Schließlich weist das Produktangebot von Philips Hue eine hohe Kompatibilität mit anderen Systemen auf, womit eine Integration in bestehende und neu entstehende Ökosysteme im Bereich Smart Home unterstützt wird.

Fall 2: Siemens MindSphere *MindSphere* ist ein Betriebssystem im Bereich Internet der Dinge (IoT), welches durch die Integration von Fertigungsanlagen und -linien eine Datenbasis sowie darauf aufbauende intelligente Analysemöglichkeiten bietet. Dieses IoT-Betriebssystem zeichnet sich durch Offenheit in drei Bereichen aus. So existieren Wahlmöglichkeiten bezüglich des Cloud Anbieters und des Herstellers maschineller Produktionsanlagen durch die Nutzung von Standards und offenen Schnittstellen. Weiterhin befähigen offene Programmierschnittstellen Nutzer individuelle Smart Services anzupassen. *MindSphere* ermöglicht dabei den Ökosystemakteuren drei Gruppen an Smart Services zu nutzen, selbst zu entwickeln und wiederum auch eigenen Kunden anzubieten. Die erste Gruppe an Smart Services zielt auf die Analyse und Vorhersage von Fertigungsprozessen der vernetzten Anlagen ab. Hierdurch sollen beispielsweise Ausfälle prognostiziert und Reparaturen sowie Ausfallzeiten vermieden werden. Die zweite Gruppe an Smart Services bietet die Vernetzung mehrerer vormals nicht integrierten Anlagen, sowie die Analyse und Optimierung dieses neu geschaffenen Gesamtsystems. Die dritte Gruppe an Smart Services stellt individuelle Erweiterungen der Plattform durch die Adaption oder Neuentwicklung von

Softwareapplikationen dar. Insbesondere diese Erweiterungen ermöglichen das Angebot innovativer Smart Services am Markt. Beispiele hierfür sind das Angebot von Fertigungsstunden als Service oder die kundenindividuelle Fertigung der Losgröße 1. Neben dieser technologischen Plattform im Bereich der industriellen Fertigung, welche das bestehende Ökosystem von Siemens erweitert, kooperieren zahlreiche an IoT Interessierte im Ökosystem MindSphere World um einen gemeinsamen Erfahrungsaustausch über Geschäftsmodelle und erfolgreiche Anwendungen zu unterstützen. MindSphere World zählt aktuell über 150 Mitglieder aus unterschiedlichsten Branchen. Dazu gehören beispielsweise Anlagenhersteller, Banken oder Unternehmen aus dem Bereich Software, Informationstechnologie und Automatisierung.

Fall 3: Smart Forst Stihl Im Fokus der Betrachtung der Smart Service-Implementierung von *Stihl* stehen die einzelnen Applikationen zur intelligenten Bewirtschaftung eines Forstes, welche 2017 im Rahmen des Forst 4.0-Pilotprojektes LogBuch erstmals eingeführt wurden. Den Kern dieser Services stellt die Geolokalisation von Objekten im Forst dar. Nach der Lokalisation können Objekte wie Bäume oder Gehölz mittels Spracherkennung um zusätzliche Informationen ergänzt und in der webbasierten Anwendung gespeichert werden. Die ersten Nutzenpotenziale liegen damit einerseits in der einfachen Datenerfassung, welche durch die Spracheingabe keine manuelle Nutzung des Geräts erfordert und auch ohne Netzzugang möglich ist und andererseits in der übersichtlichen Darstellung der erfassten Informationen beispielsweise auf einer Karte. Die Vision von Stihl beinhaltet die automatische Erfassung von Daten über physische Geräte wie Kettensägen zur Erstellung eines digitalen Zwillings der entsprechenden Forste. Neben der Vernetzung verschiedener Akteure im Ökosystem entstehen so neue Möglichkeiten für die Gestaltung der Lieferketten und Preismodelle. Mit dem Vorbild der Industrie 4.0 werden im Rahmen der Smart Forestry einzelne Anwendungen gestaltet, die jeweils einen Mehrwert durch die Anreicherung von manuellen und maschinellen Arbeitsschritten durch smarte Serviceelemente generieren. Mittlerweile wird LogBuch auch zur Lokalisierung von Grünflächen und Baumbeständen in urbanen Gebieten eingesetzt. Neben LogBuch hat Stihl in der Zwischenzeit weitere ergänzende Applikationen wie die Stihl Holzliste, FOVEA oder Stihl Connected am Markt eingeführt. Insbesondere die Holzliste, welche zur Lokalisierung von Gehölzbeständen per GPS und der Verknüpfung mit verkaufsrelevanten Daten angeboten wird, und FOVEA, welche Holzbestände über Bilderkennung vermessen und erfassen kann, führen die ursprüngliche Vision des LogBuchs fort.

Fall 4: Uber Technologies Inc. Die Ursprünge der heutigen Mobilitätsplattform *Uber* reichen zurück bis ins Jahr 2008. Damals fanden die beiden Gründer kein Transportmittel und formulierten deshalb die Idee die Mobilität zu revolutionieren. Die Mobilitätsplattform hat Stand 2021 monatlich knapp 100 Mio. aktive Nutzer und ist das Zentrum des neu geschaffenen Ökosystems. Herzstück der Mobilitätsplattform stellen zwei Anwendung für Smartphones dar, welche 2009 entwickelt wurden und 2010 in San Francisco in den Markt eingeführt wurden. Die Plattform funktioniert über eine Anwendung für Nutzer und eine separate Anwendung für Fahrer und bietet mittlerweile alleine 15 unterschiedliche Fahrtoptionen für die Beförderung von Personen in mehr als 10.000 Städten an. Der zentrale Service der Uber Plattform ist dabei die möglichst effiziente und nutzenstiftende Vermittlung zwischen Nachfrage und Angebot, beispielsweise durch die Abwicklung von Bezahlendiensten. Das Leistungsangebot geht mittlerweile jedoch weit über die reine Vermittlung von Beförderungsangeboten hinaus, wobei die Lieferung von Speisen und Nahrungsmitteln – auch in Berlin – noch naheliegend ist. Daneben bietet Uber durch zahlreiche eigene Smart Services zusätzliche Sicherheit während der Fahrt. Die ständige Überwachung der Fahrt über Sensorik bezüglich ungeplanter Stops, die Ortung des Fahrzeugs und die Möglichkeit die Fahrt mit nahestehenden Personen zu teilen sind dabei nur einige Beispiele.

Fall 5: OP 4.1 Bei der Plattform *OP 4.1* handelt es sich um ein durch öffentliche Gelder gefördertes Projekt mit der Zielsetzung die Idee der vernetzten Datenströme der Industrie 4.0 auf die Herausforderungen des komplexen deutschen Gesundheitssystems in Bezug auf Prozess- und Patientendaten zu übertragen. Das Projekt strebt damit an, die Beschränkungen durch die noch vorherrschenden Insellösungen von modernster Technologie im Operationssaal zu adressieren und durch eine verbindende Plattform Effizienz- und Nutzenpotenziale zu eröffnen. Um die enormen Herausforderungen des bestehenden Gesundheitssystems bestmöglich zu lösen, zeichnet sich dieses Projekt im Bereich der Smart Health durch die Zusammenarbeit von Konsortialpartnern aus, welche ganz unterschiedliche Kompetenzen und Perspektiven einbringen. Bei der Plattform *OP 4.1* haben beispielsweise Akteure des Gesundheitssystems wie das Universitätsklinikum Heidelberg und die Urologische Klinik, das Deutsche Krebsforschungszentrum und Unternehmen wie die SAP SE, die KARL STORZ GmbH & Co. KG oder mbits imaging GmbH mitgewirkt. Während des Projekts wurden vier erste Anwendungen auf der Plattform *OP 4.1* implementiert. Die Anwendung *Augmented Reality* visualisiert beispielsweise Tumorgewebe im Operationsfeld in Echtzeit. Daneben arbeiten die beteiligten Akteure daraufhin die bestehenden Markteintrittsbarrieren insbesondere

für hochinnovative Techstartups zu vermindern. Dies geschieht durch die Offenheit der Plattform, die Lösung von Fragen des Datenschutzes und die Implementierung von Monetarisierungsmöglichkeiten. So können Startups künftig eigene Applikationen im OP 4.1 App Center integrieren und damit das Leistungsangebot der Plattform um zusätzliche Smarte Services ergänzen.

Fall 6: Apple HomeKit und HomeApp Apple hat mit dem eigenen Smart Home Angebot bestehend aus dem *HomeKit* und der *HomeApp* ein Ökosystem rund um die intelligente Vernetzung des eigenen Zuhauses geschaffen. Im Vordergrund steht dabei die einfache Integration und Steuerung des so genannten HomeKit Zubehörs, das mehrheitlich auch von anderen Herstellern smarter Produkte wie beispielsweise Logitech, Ikea oder Philips Hue stammen kann. Der wesentliche Vorteil, den das HomeKit über die HomeApp bietet ist dabei die einfache Integration dieser ganz verschiedenen smarten Objekte zu einem Gesamtsystem und die abgestimmte Steuerung dieses Gesamtsystems über die HomeApp, statt für jedes Objekt eine eigene Appsteuerung zu benötigen. Die integrierte Steuerung des Gesamtsystems erlaubt dabei auch eine zunehmende Automatisierung und Bündelung einzelner Objekte beispielsweise beim Verlassen des Hauses oder beim Betreten einzelner Räume. Daneben eröffnet die HomeApp weiterführende Möglichkeiten wie Dritten die Steuerung des eigenen Smart Homes zu ermöglichen oder die intelligente Überwachung des eigenen Zuhauses bei einer Abwesenheit. Eine Besonderheit dieses Ökosystems, in welchem Apple eine zentrale Position einnimmt ist dabei der Einsatz der Apple Produkte, wie iPhone, iPod, oder iPad, welche hier die Steuerzentrale darstellen und sogar als zentraler Hub eingesetzt werden können.

Fall 7: HERE HERE ist bereits seit 1985 eine Plattform, die Lokalisierungstechnologie und Kartenmaterial in 2D und 3D in einem offenen Ökosystem mit zahlreichen Schnittstellen und verfügbaren ergänzenden Daten bietet. Die kundenbezogenen Daten können dabei von verschiedenen Clouddienstleistern gehostet werden. Die Smart Services, welche HERE ermöglicht beinhalten beispielsweise Routenplanung und Echtzeitverfolgung bei Lieferungen, Befehlssammlungen für autonome Fahrzeuge und andere Robotikeinsatzfelder, sowie 3D-Kartenmodelle beispielsweise zur Netzausbauplanung. Auch im Jahr 2020 wurde HERE um weitere Anwendungen erweitert, wie beispielsweise HERE Navigation On Demand, das Automobilherstellern erlaubt die Navigationsanwendungen in Fahrzeugen auch nach Auslieferung zu modifizieren und zu pflegen oder HERE Last Mile, eine Echtzeitnavigation, die neben der Verkehrslage auch Straßennutzungsgebühren und Kraftstoffpreise

berücksichtigt. Darüber hinaus wurde zusätzliche neutrale Serverkapazität bereitgestellt, die insbesondere anderen Anwendungen im HERE Marktplatz einen sicheren Zugang zu Sensorikdaten moderner Automobile gewährt. Partnerschaften nehmen dabei im Ökosystem zwei besondere Rollen ein, um diese hoch komplexen Services zu ermöglichen. Zum einen sind einflussreiche etablierte Unternehmen insbesondere aus dem Bereich Automotive eng mit HERE verbunden, so halten beispielsweise Audi, BMW, Bosch, Continental, Daimler, Intel, Mitsubishi, NTT und Pioneer Anteile an HERE. Neben diesen Beteiligungen pflegt HERE strategische Partnerschaften beispielsweise mit AWS, escri, Microsoft, Oracle und SAP. Zusätzlich wurden alleine im Jahr 2020 neue strategische Partnerschaften beispielsweise mit Verizon und Bose geschlossen. Die HERE Plattform bietet dabei den am Ökosystem beteiligten Akteuren neben Visualisierungs- und Analysediensten, die Möglichkeit eigene Anwendungen, Services und Karten zu entwickeln und diese am HERE Marktplatz anzubieten. Die Entwicklung innovativer und smarter Services wird dabei durch zahlreiche APIs rund um Karten- und Lokalisierungsdienste unterstützt, worin die Offenheit dieses Plattformökosystems begründet ist.

Fall 8: adidas GMR adidas GMR initiiert ein neues Ökosystem an der Schnittstelle zwischen smarter Bekleidung, Sportanalytik und Gaming. Unter dem Markennamen adidas GMR wird dabei eine Einlegesohle für Fußballschuhe vertrieben, die mit einem smarten Sensor von Jacquard™ by Google ausgestattet die Bewegungsabläufe eines Spielers in der realen Welt erfasst. Zur Erfassung, Verarbeitung und Auswertung der Sensordaten benötigen Nutzer zuerst die adidas GMR Mobile App. Ist eine Integration der Trainingsfortschritte in das Konsolenspiel FIFA von EA erwünscht, sind darüber hinaus die EA FIFIA Mobile App sowie das entsprechende Spiel notwendig. Die Integration der realen Spieldaten ins fiktive Game bietet neben exklusiven Items und Boni, tägliche Herausforderungen sowie die Möglichkeit sich mit anderen Spielern über Bestenlisten zu messen. Neben diesen fiktiven Nutzenkomponenten entstehen durch die intelligente Analytik der realen Spielabläufe auch Trainingsauswertungen und das Potenzial, das eigene Spiel zu verbessern. Die Zusammenarbeit zu adidas GMR lief im September 2021 aus. EA erklärt dies unter anderem mit den Einschränkungen der physischen Aktivitäten durch die weltweite Corona-Pandemie, betont aber gleichzeitig das Potenzial solcher innovativer technologischen Ansätze vormalig getrennte Welten mit neuen Nutzenpotenzialen zu verknüpfen.

4 Ergebnisse und Diskussion

4.1 Implementierung von Smart Services in Ökosystemen

Für die Implementierung von Smart Services bieten sich verschiedene Ausgestaltungsformen, die vom Ökosystem, dem Unternehmen und der verfolgten Strategie bezüglich der Zusammenarbeit abhängig sind. Im Folgenden werden die acht Typen und deren Smart Service-Implementierung in Ökosystemen charakterisiert. Diese *Typologisierung* erfolgt auf Basis der in Abschnitt 3.2 vorgestellten Fallbeispiele. Grundsätzlich kann die Implementierung der Smart Services anhand *zweier Dimensionen* unterschieden werden. Erstens kann der Smart Service in ein *bestehendes Ökosystem integriert* werden oder ein *neues Ökosystem initiieren*. Bei einem bestehenden Ökosystem verändert sich das bisherige Ökosystem in der grundsätzlichen Ausgestaltung nicht. Es kommt hierbei zu kleinen Veränderungen des Leistungsangebots oder der Beziehung zwischen den Akteuren. Wird im Zusammenhang mit der Einführung des Smart Services ein neues Ökosystem geschaffen, entsteht ein System, welches zuvor nicht vorhanden war. Somit wachsen neue Beziehungen zwischen bisher nicht vernetzten Akteuren.

In der zweiten Dimension kann zwischen einer *Konzentration auf die Leistungserbringung* – also dem Smart Service selbst – und einer *Fokussierung auf die Ökosystemstruktur* unterschieden werden. Bei leistungsbezogenen Innovationen steht der Smart Service eines Unternehmens im Zentrum der Implementierung und kann anhand der Nähe zu den bisherigen Geschäftsaktivitäten differenziert werden. So kann der Smart Service beispielsweise die bisherigen Leistungen des Unternehmens inkrementell verbessern oder einen bestehenden Markt disruptiv verändern. Bei strukturellen Innovationen liegt der Fokus auf den unterschiedlichen Akteuren des Ökosystems. Hierbei kann der Smart Service im Zuge der Koordination die Steuerung, Orchestrierung und Interaktion im Ökosystem verbessern oder durch die Kooperation zwischen unterschiedlichen Akteuren entstehen. Der Mehrwert entsteht somit nicht nur durch einen einzelnen Service, sondern durch die Steuerung und Vernetzung verschiedener klassischer Dienstleistungen und Smarten Services. Tabelle II.5-1 strukturiert die unterschiedlichen Typen anhand der beiden zuvor beschriebenen Dimensionen.

Table II.5-1: Typologisierung

Bestehendes Ökosystem	Neues Ökosystem

Leistungsbezogene Innovation (Smart Service Fokus)	I Digital Enabler: Anreicherung von Produkten um Smart Services in offenen Ökosystemen	II Digital Incumbent: Weiterentwicklung und Ergänzung von Smart Services in einem offenen Ökosystem	IV Digital Disruptor: Entwicklung disruptiver Smart Services und Etablierung eines neuen Ökosystems
	III Service Extender: Erweiterung des bestehenden Leistungsspektrums um neue Smart Services für bestehende Kunden		
Strukturelle Innovation (Ökosystem Fokus)	V Digital Optimizer: Koordination der Verbesserung der Leistungserstellung eines Ökosystems durch einen Smart Service	VI Digital Ecosystem Extender: Koordination von Smart Services durch Entwicklung eines Ökosystems	
	VII Vertical Integrator: Kooperation bei der Integration zentraler Smart Services in bestehendes Ökosystem	VIII Horizontal Bridge Builder: Kooperation unterschiedlicher Akteure mit mehreren Leistungsspektren zu einem neuen Ökosystem	

(Eigene Darstellung)

I Digital Enabler Als Digital Enabler nehmen etablierte Unternehmen meist die *Rolle eines Komplementors* in einem neuen oder bestehenden Ökosystem ein. Diese Unternehmen ergänzen bestehende Produkte um smarte Services und erweitern den physischen Kern. Somit geht es diesen Unternehmen häufig um die inkrementelle Weiterentwicklung bestehender Angebote und die *Ergänzung eines Produktes um digitale Komponenten*. In diesem Zusammenhang steht für die Unternehmen die Leistungs differenzierung durch neue Services im Fokus, die häufig automatisiert erfolgt. Das Unternehmen bietet vordefinierte Möglichkeiten der Individualisierung, die durch den Kunden während der Nutzung ausgewählt werden können. Eine individuelle Anpassung des Service durch den Anbieter während der Nutzung findet selten statt, notwendige Sensoren werden in die angebotenen Produkte integriert. Der Smart Service basiert somit auf zentralen Funktionalitäten. Beispiele für diesen Typ sind unter anderem Leuchtmittel von Philips Hue und smarte Haushaltsgeräte von Herstellern wie Bosch und Siemens. Der Smart Service kann in diesem Kontext entweder bestehende Aspekte ersetzen, oder neue Servicekomponenten ergänzen. Ein Beispiel für die Digitalisierung

bestehender Aspekte ist die Möglichkeit die Farbe der Philips Hue Lampe mittels App anstelle einer Fernbedienung zu ändern. Ein neuer smarter Service ist das Ein- oder Ausschalten der Lampe von unterwegs.

II Digital Incumbent Entwickeln fokale Unternehmen in einem bestehenden Ökosystem neue Smart Services oder digitalisieren bestehende Services, agieren sie als Digital Incumbents. Durch die zentrale Position besitzen diese Unternehmen häufig die Macht und Ressourcen das Ökosystem anzupassen oder eine neue Plattform aufzubauen. In diesem Zusammenhang können auch *Geschäftsmodelle verändert und weiterentwickelt* werden. Aus Ökosystemperspektive bieten entsprechende Plattformen die Möglichkeit sowohl eigene Leistungen anzubieten als auch Smart Services von Komplementoren zu ermöglichen. Häufig zeichnen sich die Smart Services bei diesem Typ durch *Individualisierung, neue Leistungsaspekte und eine veränderte Kundenbeziehung* aus. So werden kundenspezifische Daten genutzt um den Smart Service anzupassen. Dies ist beispielsweise im Kontext der vorausschauenden Wartung zu erkennen. Weiterhin ermöglicht diese Individualisierung neue Leistungen anzubieten und die Kundenbeziehung durch die neue Plattform zu intensivieren. Basis dieser Aktivitäten sind hierbei sowohl die Softwareebene als auch die Dienstleistungsebene. Die fokale Position erlaubt es den Digital Incumbents sich auf diese beide Ebenen zu fokussieren und mittels der Plattform als Kundenschnittstelle eine automatisierte Leistungserbringung sicherzustellen. In diesem Zusammenhang besitzen die Smart Services hohe strategische Bedeutung für die Unternehmen, da häufig das *Kerngeschäft weiterentwickelt* wird. Beispiel für eine solche Implementierung von Smart Services durch einen digitalen Incumbent ist MindSphere von Siemens.

III Service Extender Neben der Fokussierung auf das Kerngeschäft und der Digitalisierung der Produkte, können etablierte Unternehmen innerhalb eines bestehenden Ökosystems Smart Services auch mit *vollständig neuen Leistungsdimensionen* anbieten. Hierbei dienen die Smart Services einer *Ergänzung der bisherigen meist physischen Angebote*. Diese Smart Services stehen nicht in einem direkten Zusammenhang mit den bestehenden Produkten oder sind noch nicht in diese integriert. Stattdessen werden sie als eigenständige Lösung angeboten. Ein Beispiel für diese neue Leistungsdimension ist Smart Forst von Stihl. Ziel ist hierbei die Unterstützung des Kunden mit zusätzlichen Smart Services. Da diese Angebote als eigenständige Apps funktionieren, werden mit geringen Eintrittsbarrieren kundenspezifische Aufgaben gelöst. Weiterhin erlauben diese Smart Services die Intensivierung der

Kundenbeziehung und ermöglichen es dem Anbieter eine zentralere Position im Ökosystem einzunehmen. Hierbei ist hervorzuheben, dass das Unternehmen diese Veränderung aktiv anstößt. Das bisherige physische Kerngeschäft wird um digitale Aspekte erweitert und benötigt keine zusätzliche menschliche Interaktion. Langfristig kann sich die Rolle des Service Extenders *von einem reinen Entwickler von Apps zu einem zentralen Akteur des Ökosystems* wandeln. Entscheidend für diese Entwicklung ist die Integration der Smart Services und die Etablierung einer zentralen Plattform, die smarte Services, Anwendungen und die Datenbasis nutzenstiftend verknüpft.

IV Digital Disruptor Digitale Disruptoren begründen als fokale Unternehmen ein neues Ökosystem und bieten hierbei neuartige und bisher nicht vorhandene Smart Services an. Diese Smart Services sind durch einen disruptiven Charakter gekennzeichnet und beinhalten sowohl *neue Leistungsaspekte* als auch eine *veränderte Kundenbeziehung*. Das innovierende Unternehmen legt den Fokus auf die digitalen Aspekte des Leistungsangebots und entwickelt in diesem Zusammenhang *eine Plattform oder App, die als Basis und Schnittstelle des Ökosystems dient*. Somit besitzt das fokale Unternehmen die Hoheit und Verantwortung im Ökosystem. Während es sich häufig auf die digitalen Komponenten fokussiert, werden physische Leistungen und Produkte an Dritte ausgelagert. Das fokale Unternehmen erbringt die automatisierbaren und service-bezogenen zentralen Leistungen, wohingegen die Partner die menschliche Interaktion und die kundenorientierten Leistungen ausführen. Diese Komplementoren sind häufig dezentral organisiert und bieten ihre Leistungsbeiträge günstig an. Obwohl die digitalen Disruptoren sowohl bei der Implementierung als auch beim Betrieb des Smart Service mit Partnern zusammenarbeiten, ändern sich diese häufig über die verschiedenen Evolutionsstufen des Ökosystems. Als Initiator dieser neuen Partnerschaften kann meist das fokale Unternehmen identifiziert werden. Als Beispiel für einen solchen digitalen Disruptor kann Uber Technologies Inc. angesehen werden. Uber kontrolliert die Plattform und vermittelt bzw. steuert damit die Leistungserbringung zwischen Fahrer und Passagier. Meist finden sich die entsprechenden smarten Services im Konsumentenbereich und breiten sich von hochpreisigen Nischenmärkten zu Massenmärkten aus.

V Digital Optimizer Anders als bei den zuvor beschriebenen Typen, bei welchen der Smart Service durch einen Akteur implementiert wird, sind beim Digital Optimizer mehrere Akteure beteiligt. Diese arbeiten sowohl bei der Entwicklung als auch bei der Erbringung des Smart Service zusammen. Dieser dient zur *Koordination mehrerer Akteure eines bestehenden*

Ökosystems. Durch die Implementierung einer gemeinsamen Plattform, die als Softwareebene fungiert, werden *zuvor menschliche Leistungen automatisiert*. Somit kommt es zu einer Erneuerung des bestehenden Ökosystems. Vorteile werden in Form von Effizienzsteigerungen und dem Angebot neuer Smart Services erreicht. Häufig erfolgt die Entwicklung und Implementierung der Smart Services in Form von Konsortien und teilweise in staatlich geförderten Forschungsprojekten. Hierbei können Fragen des Schutzes von Eigentum und Daten gemeinsam geklärt werden. In diesem Zusammenhang entwickelt der Digital Optimizer Plattformen, die zuvor physische Prozesse digital miteinander verknüpfen. Zahlreiche Beispiele finden sich in den Bereichen Pflege und Gesundheit. So werden unter anderem Dokumentation und Abläufe im Projekt OP 4.1 mittels Smart Service digitalisiert.

VI Digital Ecosystem Extender Neben der Digitalisierung bestehender Ökosysteme, initiieren Digital Ecosystem Extender als fokales Unternehmen neue Ökosysteme. Wie bei den zuvor beschriebenen Digital Optimizer legen auch sie den Fokus auf die Koordination und somit die Steuerung verschiedener klassischer und smarter Services. Hierbei gestalten sie Kundenbeziehungen neu aus und nehmen Positionen an Schnittstellen ein. Diese neuen Systeme fokussieren sich somit auf die Integration und können sowohl offen als auch geschlossen ausgestaltet sein. Das Hauptaugenmerk der Digital Ecosystem Extender liegt auf der *Integration unterschiedlicher eigener oder fremder Smart Services in ein eigenes Ökosystem*. Diese Integration ermöglicht eine Zentralisierung verschiedener Smart Services, die automatisiert auf der Softwareebene miteinander verknüpft sind. Häufig wird ein solches System in eigene Leistungsangebote integriert. Für einen Digital Ecosystem Extender ist es wichtig die Entwicklung von der Initiierung des Ökosystems hin zur Führung schnell zu erreichen, da dieser von einer breiten Akzeptanz abhängig ist. Hierbei kann ein bereits vorhandenes digitales Leistungsangebot hilfreich sein. Ein Beispiel für einen Digital Ecosystem Extender stellt Apple mit seinem System Apple HomeKit dar. Hierbei werden verschiedene Angebote unterschiedlicher Hersteller aus dem Bereich Smart Home integriert. Eine Steuerung der verschiedenen Services ist über die Smart Home App möglich. Weiterhin integriert Apple die App in das eigene Leistungssystem und ermöglicht damit die Steuerung mit verschiedenen eigenen Geräten. Das geschaffene Ökosystem ist für Komplementoren offen, kann aber auch für Wettbewerber geöffnet werden.

VII Vertical Integrator Vertical Integrator zeichnen sich durch eine Zusammenarbeit mit verschiedenen Akteuren der gleichen Branche aus. Auf Grundlage strategischer Überlegungen,

wie beispielsweise Kostensenkungspotentialen, *implementieren unterschiedliche Akteure einer Branche oder eines Ökosystems gemeinsam einen Smart Service*. Neben der eigenen Entwicklung des Smart Services kann dieser auch am Markt eingekauft werden. Unternehmen dieses Typs fokussieren sich häufig auf neue Leistungsdimensionen, die durch die Zusammenarbeit effizient erreicht werden können. Hierbei werden die Software- und die Dienstleistungsebene in das Zentrum der Aktivitäten gerückt. Ziel ist es die Position eines Leaders einzunehmen. Dies kann insbesondere beim Zukauf des Smart Services durch die Erneuerung eines bestehenden und etablierten Service erfolgen. Ein Beispiel für einen solchen übernommenen Smart Service stellt die Kartenplattform HERE dar, bei der Automobilbauer gemeinsam einen Großteil des Unternehmens erworben haben. Smarte Lokalisierungsdienste gelten als wichtiger Bestandteil für die Entwicklung des autonomen Fahrens. Ein solches Vorgehen bietet sich insbesondere bei Services an, die für die Entwicklung und Nutzung anderer Angebote essenziell sind aber gleichzeitig wenig Differenzierungspotenzial bieten. Somit sichert die kooperative Integration des Smart Service das eigene Leistungsangebot.

VIII Horizontal Bridge Builder Neben der Zusammenarbeit innerhalb einer Branche können auch *Unternehmen verschiedener Branchen* gemeinsam einen Smart Service in einem neuen gemeinsamen Ökosystem anbieten. Hierbei erfolgt die *Integration und Verknüpfung mehrerer Leistungsangebote, die zuvor unabhängig voneinander waren*. Eine solche Kooperation ermöglicht es den beteiligten Akteuren neue Leistungen anzubieten, diese zu individualisieren und Kundenbeziehungen neu zu gestalten. In diesem Kontext greifen die Unternehmen auf alle drei Ebenen des Smart Service zurück und können die physische Ebene sowie die Software- und die Dienstleistungsebene innovieren. Durch die Integration der drei Ebenen können die Unternehmen einen automatisierten und kundennahen Service erbringen. Kennzeichnend ist in diesem Fall, dass die Horizontal Bridge Builder einen gemeinsamen Schnittpunkt besitzen und die Leistungen entsprechend ihrer Kompetenzen und bisherigen Leistungsangebote integrieren. So ergab sich bei adidas GMR eine Vernetzung zwischen realem Fußballspiel und dem Konsolenspiel. Durch die Verknüpfung digitaler und physischer Komponenten können bestehende Leistungen verknüpft werden und durch Zusatzleistungen angereichert werden.

Überblick der Smart Service-Implementierungen in Ökosystemen Bei der Betrachtung der zuvor beschriebenen Typen von Smart Services in Ökosystemen fällt auf, dass die Typen innerhalb der Innovationsdimension *leistungsbezogene Innovation* und *strukturelle Innovation* in klaren Beziehungen zueinanderstehen. Die ersten vier Typen, welche der leistungsbezogenen

Innovation zugeordnet werden, unterscheiden sich im Grad der Innovation. Dieser reicht von inkrementellen Innovationen bei Digital Enablern bis zu disruptiven Innovationen bei Digital Disruptors. Digital Enabler (Typ I) verbessern bisherige Produkte und Services in beschränktem Umfang indem digitale Technologien integriert werden. Wie zuvor beschrieben bleibt die Kernfunktion erhalten. Somit wird sich auf eine graduelle Verbesserung fokussiert. Digital Incumbents (Typ II) bauen auf den bisherigen Leistungen auf, beschränken sich jedoch nicht auf die Weiterentwicklung bestehender Produkte. Stattdessen kommt es zur Integration verschiedener Leistungen und der Implementierung neuer Smart Services, die in einem engen Zusammenhang zu den bestehenden Angeboten stehen. Service Extender (Typ III) beschränken die Innovationen nicht auf das Kerngeschäft. Stattdessen werden bewusst neue Services angeboten, die zwar in der gleichen Branche und für die gleichen Kunden entwickelt sind, aber sich grundsätzlich von den bisherigen Angeboten unterscheiden. Somit sind hier häufig größere Veränderungen zu finden. Digitale Disruptoren (Typ IV) erschüttern mit ihren Smart Services gesamte Branchen. Hierbei werden nicht nur Leistungen in vollständig neuer Art und Weise erbracht, sondern auch die bisherigen Branchenstrukturen aufgebrochen und neu geordnet.

Während bei den Typen I bis IV *ein Unternehmen Ausgangspunkt* für den Smart Service ist, sind bei den Typen V bis VIII *mehrere Akteure* beteiligt. Diese Akteure interagieren auf zwei unterschiedlichen Wegen, koordiniert oder kooperativ. Bei der Koordination übernimmt meist ein Akteur oder eine Gruppe von Akteuren die Rolle des Dirigenten und steuert über eine zentrale Plattform die Erbringung von Smart Services im Ökosystem. Bei der Kooperation werden Smart Services von verschiedenen Akteuren zusammen erbracht. Der Mehrwert des Smart Services wird in diesen Fällen durch die Zusammenarbeit geschaffen, da auf diese Weise entweder Kosten geteilt werden können oder durch die Verbindung vormals getrennter Bereiche neue Leistungen geschaffen werden können.

Betrachtet man die Rollen, ist zu erkennen, dass Anbieter von Smart Services grundsätzlich *unterschiedliche Positionen* im Ökosystem einnehmen können. Erstens kann das fokale Unternehmen der Anbieter des Smart Service sein. Hierbei kann der Smart Service das zentrale Leistungsversprechen des Ökosystems beinhalten. Daneben können Lieferanten, Kunden oder Komplementoren mittels Smart Services die zentrale Leistung erweitern oder ergänzen.

4.2 Diskussion

Der Vergleich der vorliegenden Typen eröffnet interessante Einblicke, die Ansatzpunkte für eine kritische Auseinandersetzung liefern. Als erster Aspekt wird die *Rolle der Akteure und deren Strategie* betrachtet. Zuerst fällt auf, dass sich die Typen I Digital Enabler und II Digital Incumbent in zwei unterschiedlichen Ökosystemrollen befinden. Der Enabler nimmt die Rolle eines Komplementors im Ökosystem ein (Kapoor/Agarwal 2017; Dedehayir et al. 2018; Ozalp et al. 2018) und verfolgt in dieser Rolle eine Differenzierungsstrategie durch die Ergänzung bisheriger Produkte durch smarte Funktionalitäten (Porter 1985; Porter/Heppelmann 2014). Dem steht in Typ II der Digital Incumbent gegenüber, welcher nun die Rolle des Ökosystemleaders innehat und aus dieser Rolle heraus eine Strategie der Differenzierung verfolgt (Moore 1993). Nun wird ersichtlich, weshalb Typ I diese Strategie sowohl im bestehenden, als auch in neuen Ökosystemen verfolgen kann. Dies ist möglich, da es sich bei Typ I nicht selbst um den zentralen Akteur im Ökosystem handelt. So entsteht die Chance, die eigenen Produkte mit smarten Funktionalitäten in mehreren Ökosystemen anzubieten. Dies ist jedoch ebenso mit dem Risiko verbunden, abhängig von der Strategie des Leaders zu sein.

Weiterhin fällt beim Vergleich der Typen III und VI auf, dass beide ihr bestehendes Leistungsspektrum um Smart Services ergänzen, weshalb sie eine *Strategie der Differenzierung bzw. Kundenbindung* verfolgen. Erwähnenswert ist, dass sich der Weg zur Implementierung des Smart Services unterscheidet. Typ III der Service Extender erbringt den Smart Service selbst, wohingegen Typ VI der Digital Ecosystem Extender ein Ökosystem zur Erbringung des Smart Services aufbaut und koordiniert. Dies greift die etablierte Frage nach Eigenfertigung oder Bezug am Markt im Kontext der Smart Service Implementierung im Ökosystem auf.

Die Typen V, VII und VIII erzielen jeweils auf einzigartige Weise Kostenvorteile durch strukturelle Neugestaltungen des Ökosystems. Typ V ist dabei durch die Zusammenarbeit von Akteuren innerhalb eines Ökosystems geprägt, welche neben der Differenzierung insbesondere *Kostenvorteile im Betrieb des Smart Service* anstreben. Deutlich wird das beim Beispiel OP 4.1. Hier ermöglicht die Zusammenarbeit die Koordination von Einzelleistungen über die zentrale Plattform. Dies eröffnet Effizienz- und schließlich auch Kostenvorteile im laufenden Betrieb. Im Gegensatz hierzu ermöglicht die Kooperation zentraler Akteure, wie sie bei HERE rund ums autonome Fahren stattfindet, Kostenvorteile in der Entwicklung, die durch die Bündelung der Bemühungen entstehen. Typ VIII, der Horizontal Bridge Builder schließlich erringt ebenso Kostenvorteile, welche jedoch aufgrund der Kombination von heterogenem Wissen und den daraus resultierenden Sparpotenzialen im Vergleich zur Eigenentwicklung

entstehen. Die Betrachtung der Rollen und Strategien zeigt also, dass die verschiedenen Typen auch hinsichtlich dieser Aspekte interessante Einblicke liefern können.

Der *Grad der Veränderung* ist grundsätzlich die am weitesten verbreitete Möglichkeit Dienstleistungsinnovationen voneinander abzugrenzen und zu kategorisieren (Snyder et al. 2016). Dieser Grad reicht bei den betrachteten Smart Services von kleineren Verbesserungen über mittlere Veränderungen des Service bis hin zu größeren und allumfassenden Neugestaltungen. In den beschriebenen Fällen wird die gesamte Bandbreite an möglichen Veränderungen ausgeschöpft. Inkrementelle Serviceinnovationen stellen dabei kleinere Veränderungen dar, wohingegen radikale Innovationen jegliche Elemente der Leistung berühren (Snyder et al. 2016). Dies steht in klarem Zusammenhang zur zuvor beschriebenen strategischen Ausrichtung des Unternehmens, der Position im Ökosystem und dessen Kompetenzen. Insbesondere bei radikalen Innovationen und der damit verbundenen Veränderung aller zentralen Serviceelemente, benötigen die andere Akteure des Ökosystems für eine andauernde erfolgreiche Zusammenarbeit neue Fähigkeiten (Snyder et al. 2016). Es ist in diesem Zusammenhang ersichtlich, dass die Innovation nicht losgelöst vom Ökosystem stattfindet.

Die Wettbewerbsfähigkeit eines Ökosystems wird durch dessen Fähigkeit zukünftig Innovationen hervorzubringen bzw. dessen Innovationspotenzial durch die Nutzung von Ökosystemressourcen bestimmt (Yoo et al. 2010; Parker et al. 2017; Hein et al. 2020). Gelingt es einem Ökosystem das Innovationspotenzial auszuschöpfen und Innovationen zu entwickeln, wird die Erneuerung des Ökosystems unterstützt. Indizien für das *Innovationspotenzial eines Ökosystems* sind die Offenheit, sowie die Kompatibilität mit anderen Systemen. Diese prägen das Innovationspotenzial eines Ökosystems zum einen dadurch, dass das Vorhandensein von beispielsweise standardisierten Schnittstellen sowie die Möglichkeit zur Integration von komplementären Produkt- und Serviceinnovationen ergänzende Innovationen überhaupt erst ermöglicht. Darüber hinaus kann eine Kompatibilität mit anderen Ökosystemen die Attraktivität von Innovationsaktivitäten aufgrund der zusätzlichen Monetarisierungschancen zusätzlich erhöhen. Bei Typ I fällt dabei auf, dass dessen zukünftiges Innovationspotenzial maßgeblich von anderen Akteuren, nämlich den jeweiligen Ökosystemleadern abhängt. Gelingt es das eigene Produkt in mehreren Ökosystemen zu platzieren, wie es bei Philips Hue der Fall ist, eröffnet dies perspektivisch mehr Chancen für weitere Innovationsaktivitäten. Bei den Typen, welche einen Smart Service-Fokus aufweisen zeichnet sich sonst nur noch Typ II, der

Digitale Incumbent, durch eine hohe Offenheit aus. Diese Offenheit stellt beim Beispiel Siemens MindSphere und dem verbundenen Netzwerk MindSphere World eine zentrale Funktionsweise des Ökosystems dar, bei welcher der Wissensaustausch und der Erhalt der zukünftigen Innovationskraft im Vordergrund stehen. Bei den Typen III und VI lassen sich hingegen kaum Hinweise auf eine solche bewusste Ausgestaltung der Offenheit finden. Hier scheinen aktuell noch interne Innovationsaktivitäten im Vordergrund zu stehen, was gerade in Zeiten von immer kürzeren digitalen Innovationszyklen Fragen aufwirft.

Weniger überraschend zeichnen sich die Typen V-VIII, welche der *strukturellen Innovation* zugeordnet sind, durch eine *größere Offenheit* aus. Dies zeigt sich hier regelmäßig durch die Zusammenarbeit von Wettbewerbern bei Typ V und VII (beispielsweise bei HERE und OP 4.1) oder die Zusammenarbeit über Wertschöpfungsstufen hinweg (Apple HomeKit) bzw. mit branchenfremden Akteuren (adidas GMR). Diese Zusammenarbeit erfordert die bedachte Ausgestaltung von Schnittstellen und Standards sowie der Eigentumsverhältnisse beispielsweise von erzeugten Daten. Ein Beispiel hierfür liefert HERE, da hier die beteiligten Automobilunternehmen Sensordaten der Fahrzeuge unter Berücksichtigung von datenschutzrechtlichen Regelungen über neutrale Server teilen um neue Services zu entwickeln.

Neben der Partnerwahl lässt auch die Art der Zusammenarbeit Schlussfolgerungen zu. Steht bei der leistungsbezogenen Innovation und dem damit einhergehenden Fokus auf die Implementierung des Smart Services diese gemeinsame Zielsetzung im Vordergrund (Kooperation), so scheint sich diese Schwerpunktsetzung bei den Typen V-VIII, die einen Ökosystemfokus aufweisen, zur Koordination zu verlagern (Salvato et al. 2017). Bei Typ V übernimmt der Smart Service selbst im Ökosystem eine koordinierende Funktion zur Verbesserung der Leistungserstellung durch Effizienzsteigerungen und Kostenvorteile im Betrieb. Der Digitale Ökosystem Extender (Typ VI) koordiniert ein emergentes Ökosystem um ergänzende Smart Services zu implementieren. Eine Auffälligkeit im Vergleich zu Typ III ist dabei die Herangehensweise. Der Service Extender (Typ III) entwickelt und implementiert die smarten Ergänzungen selbst, während Typ VI den Fokus auf die Integration Leistungen Dritter legt. Die Zusammenarbeit mit Unternehmen der gleichen Wertschöpfungsstufe beispielsweise Automobilunternehmen (Typ VII) weist neben kooperativen Elementen auch koordinierende Elemente auf. Beispiele hierfür sind Abstimmungen bzgl. Schnittstellen oder das Teilen von Datenmaterial. Diese Koordination eröffnet das Potenzial von Kostenvorteilen in der Entwicklung von Smart Services. Ähnlich erscheint die Zusammenarbeit bei Horizontal Bridge

Buildern (Typ VIII) zwischen Unternehmen verschiedener Branchen zu sein. Hier eröffnet die Verbindung unterschiedlicher Wissensbasen und die damit einhergehende Aufteilung von Entwicklungsaufgaben durch die koordinierte Zusammenarbeit Zeit- und Kostenvorteile.

5 Fazit

Im Rahmen dieses Beitrags wurden zuerst die theoretischen Grundlagen zu Smart Services, Ökosystemen und schließlich der Implementierung von Smart Services in Ökosystemen dargestellt. Im Anschluss daran erfolgte eine kurze Beschreibung des Vorgehens im Rahmen der vergleichenden Fallstudie. Zur Umsetzung der Fallstudie wurden zunächst systematisch Smart Service-Implementierungen in Ökosystemen identifiziert und schließlich acht möglichst vielseitige Fälle für die weitere Analyse gewählt. Die acht Fälle Philips Hue, Siemens MindSphere, Smart Forst Stihl, Uber Technologies Inc., OP 4.1, Apple HomeKit, HERE und adidas GMR wurden zunächst deskriptiv dargestellt. Anschließend fand eine Einordnung der acht Fälle bzgl. der beiden Dimensionen Innovationsfokus (leistungsbezogene Innovation mit Smart Service Fokus bzw. strukturelle Innovation mit Ökosystemfokus) und Bestehen des Ökosystems (bestehendes Ökosystem bzw. neues Ökosystem) statt. Durch die Einordnung wurden die Fälle systematisiert und zur Bildung der folgenden acht Idealtypen genutzt: Digital Enabler (I), Digital Incumbent (II), Service Extender (III), Digital Disruptor (IV), Digital Optimizer (V), Digital Ecosystem Extender (VI), Vertical Integrator (VII) und Horizontal Bridge Builder (VIII). Die Matrix, welche durch die Zuordnung der Typen zu den Dimensionen entstand, bildete schließlich die Basis für die Diskussion. Im Rahmen der Diskussion fand eine Auseinandersetzung mit den unterschiedlichen Strategien der identifizierten Typen statt. Darüber hinaus wurden Unterschiede in der aktuellen Innovationstätigkeit sowie in zukünftigen Innovationspotenzialen ergründet. Schließlich wurde die unterschiedliche Schwerpunktsetzung der Zusammenarbeit der unterschiedlichen Akteure bei der Implementierung eines Smart Service im Ökosystem bzgl. koordinierter und kooperativer Elemente thematisiert.

Die Diskussion der vorgestellten Implementierungsansätze von Smart Services in Ökosystemen ergänzt die vorhandene Wissensbasis in mehrfacher Hinsicht. Zuerst findet eine *Typologisierung der Implementierung von Smart Services* bzgl. der innovierenden Akteure statt. Diese Differenzierung bezieht sich dabei auf die Rolle im Ökosystem. Es wird argumentiert, dass unterschiedliche Ökosystemrollen alternative Implementierungspotentiale mitbringen. Darüber hinaus werden verschiedene Ansätze der Implementierung von Smart

Services im Ökosystem hinsichtlich des Innovationsgrades systematisiert. Diese Systematisierung kann einen Ausgangspunkt für weitere Überlegungen rund um die Smart Service Innovation im Ökosystem darstellen. Beispielsweise stellt sich die Frage, in welchen Situationen sich Unternehmen für inkrementelle Veränderungen (Digital Enabler, Typ I; Digital Incumbents, Typ II), bzw. radikalere (Service Extender, Typ III) oder gar disruptive Smart Service Innovationen (Digital Disruptor, Typ IV) entscheiden. Die Auseinandersetzung mit den strukturellen Innovationen, welche einen Ökosystemfokus aufweisen, macht deutlich, dass hier sowohl Kooperation als auch Koordination dominieren kann. Dies erweitert die vorherrschende Auseinandersetzung um etablierte Konzepte der Zusammenarbeit, die bisher in der Ökosystemperspektive wenig beachtet wurden. Schließlich zeigt die vorliegende Arbeit, dass die *Implementierung von Smart Services in Ökosystemen äußerst facettenreich möglich ist*. So kann ein Smart Service ein bestehendes Ökosystem nur am Rande um zusätzliche intelligente Funktionalitäten erweitern oder aber das essenzielle Herzstück eines Ökosystems darstellen.

Im Rahmen dieses Beitrags werden unterschiedliche *strategische Optionen* für die Implementierung von Smart Services in Ökosystemen aufgezeigt. So gilt es aus praktischer Sicht zuerst grundsätzlich die Entscheidung zu treffen, ob der Fokus der Innovation auf dem Smart Service selbst (Typen I-IV) oder dem umgebenden Ökosystem (Typen V-VIII) liegen soll. Daneben bezieht sich die zweite Entscheidungsalternative darauf, ob der Smart Service im bestehenden Ökosystem (Typen I, II, III, V, VII) oder durch den Aufbau eines neuen Ökosystems (Typen I, IV, VI, VIII) implementiert werden soll. Durch die Beschreibung des realen Falles sowie der abstrakten Idealtypen zeigt die erarbeitete Systematik die verschiedenen Optionen zur Implementierung von Smart Services in Ökosystemen übersichtlich auf. Damit kann diese Übersicht auch zur Unterstützung entsprechender Entscheidungen herangezogen werden.

Eine wesentliche *Limitation* des vorliegenden Beitrags liegt in der Auswahl der acht Fälle verbunden mit dem Ziel der Formulierung von theoretisch und praktisch relevanten Zusammenhängen. Diese Zusammenhänge sollen dabei eine gewisse Generalisierbarkeit und Übertragbarkeit auf andere Fälle aufweisen (Eisenhardt 2021). Die Generalisierbarkeit ist jedoch dahingehend begrenzt, dass davon auszugehen ist, dass es weitere Fälle gibt, die sich unseren Erklärungsansätzen entziehen. Es kann nicht ausgeschlossen werden, dass die acht Fälle, die auch die Basis für die dargestellten Idealtypen bilden, nur einen begrenzten Ausschnitt der Realität abbilden. Durch die systematische Identifikation von über 40

potenziellen Fällen und die sorgfältige Auswahl der analysierten Fälle wurde die Limitation zwar adressiert, konnte jedoch nicht vollständig gelöst werden. Deshalb könnten weitere Fallstudien der Implementierung von Smart Services in Ökosystemen wertvolle Ergänzungen der vorgestellten Idealtypen und zusätzliche Erkenntnisse beispielsweise bzgl. der Geschäftsmodelle der verschiedenen Idealtypen liefern.

Eine weitere wichtige Einschränkung der vorliegenden Ergebnisse bezieht sich auf die *fehlende Betrachtung einer Erfolgsgröße*. Die beschriebenen Idealtypen erlauben noch keine Schlüsse darüber, ob eine Herangehensweise mehr oder weniger bzw. leichter erfolgreich verfolgt werden kann. Dies hat zwei Gründe. Zum einen fand keine explizite Analyse bzgl. des Erfolgs der vorgestellten Fälle für die beteiligten Ökosystemakteure statt. Zum anderen müsste eine Analyse des Erfolgs bereits bei der Konzeption des Fallstudiendesigns berücksichtigt werden, um beispielsweise eine Verfälschung der Ergebnisse durch die alleinige Auswahl erfolgreicher Implementierungsansätze von Smart Services zu vermeiden. Diese Problematik deutet sich hier zumindest an, da in der Auswahl der betrachteten Fälle lediglich eine Implementierung aktuell nicht fortbesteht. Ein weiterer vielversprechender Ansatz für die zukünftige Auseinandersetzung mit der Implementierung von Smart Services in Ökosystemen ist daher insbesondere, ob die Herangehensweisen der identifizierten Idealtypen unterschiedliche Erfolgsaussichten haben. Hierzu erscheinen neben weiteren Fallstudien insbesondere quantitative Ansätze interessant.

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III Synopsis – Epilogue

III.1 Key findings and contribution

This part of the synopsis provides a final summary and discussion of the results. These are discussed in terms of their contribution to closing the research gaps outlined in the prologue. As theoretical contributions involve findings that "change, challenge, or fundamentally advance our understanding the findings cause us to think about a phenomenon in a way that past research would not normally suggest" (Bansal & Corley, 2011, p. 235), the presented key results are placed in relation to earlier research in order to highlight the respective contributions. Furthermore, the theoretical framework presented in the introduction (content of innovation, perception of innovation, context of innovation) is used as structure.

Figure III.1-1 summarizes the key findings of all five included works in relation to content of innovation. As explained in the introduction, this gap can be divided into three sub-areas (digital sustainability, CE-oriented innovation, digital innovation). Research into digital sustainability focuses on the interaction between digital technologies and sustainability (Chatzistamoulou, 2023; George et al., 2021; Guandalini, 2022). Digital sustainability is defined as the "development and deployment of digital resources and artifacts toward improving the environment, society, and economic welfare" (Kotlarsky et al., 2023, p. 938). On the one hand, digital technologies are typically associated with diverse sustainability potential. On the other hand, digitalization can also have negative effects owing to the associated consumption of resources and the change in governance mechanisms. Paper 1 shows that two groups of energy incumbents engage in projects regarding virtual power plants. The underlying digital technology brings with it digitalization advantages such as efficiency and thus cost effects as well as sustainability potential. The findings of Paper 1 highlight that the technological frames influence the resulting business models. Actors with a single-focused frame concentrate on digital aspects and therefore miss the opportunity to fully realize the sustainability potential in their business models. In contrast, actors with the dual technological frame have implemented both the sustainability potential and digitalization potential in their business models. In line with the definition of digital sustainability, the results show that a technology with sustainability potential does not automatically become an example of digital sustainability, but that the perception of the technology and its targeted implementation are necessary for this potential to emerge. Furthermore, the twofold frame is crucial for a comprehensive assessment of the technology. The dimension of the technology strategy reflects the reasons why the energy

companies are implementing the technology (Orlikowski & Gash, 1994; Saarikko et al., 2020). If this is a strategy with a focus on digitalization, the implementation of the strategy is also only assessed in relation to these goals. The sustainability dimension is thus neglected in strategy evaluation. When assessing the achieved sustainability potential, firms should take account of not only the company's perspective, but also the entire value creation, including ecological and social components.

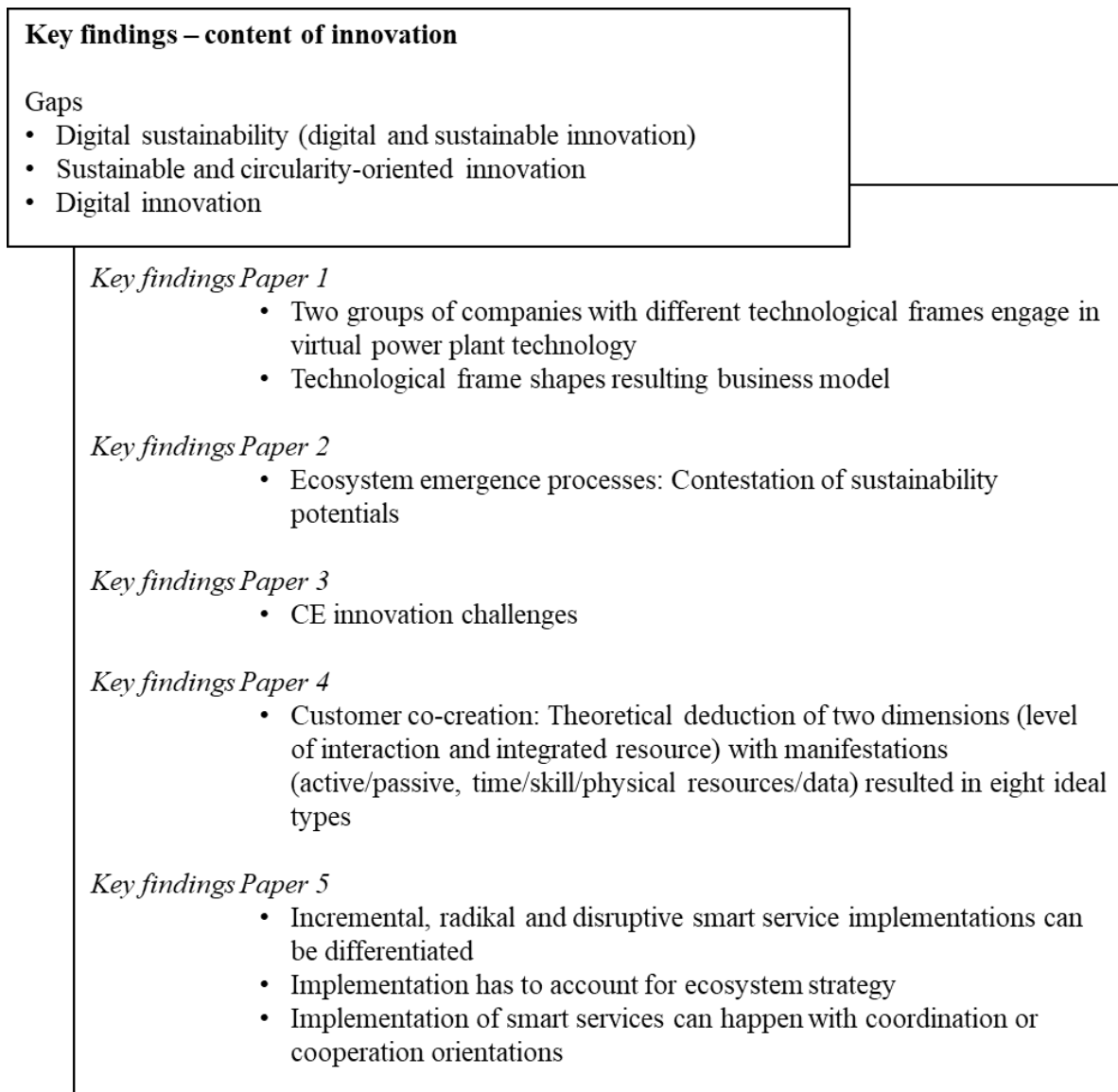


Figure III.1-1: Key findings - content of innovation
(Author's own illustration)

The second sub-area refers to sustainable and CE-oriented innovation. As explained in the introduction, CE-oriented innovation continues to be an emerging practice and there is limited knowledge about the challenges and experiences of firms leading this transition (Piila et al., 2022). Papers 2 and 3 contribute new insights regarding our understanding of the CE transition. The findings of Paper 2 show - by means of the example of chemical recycling - how ecosystem actors engage in the processes of ecosystem emergence, such as framing and contestation. The data analysis confirmed that there are various ideas for the future of chemical recycling. These range from abandoning further research and application in the field of plastic recycling, to small-scale use to complement incineration, coordinated further development, and high-tech implementation. According to Bauwens et al. (2020), the high-tech solution is the most probable one because it would require the least amount of fundamental changes to the overall system. This solution suggests that continuing as before is possible. The findings of Paper 2 indicate that there are actors who are aware of the limited sustainability potential compared to other approaches and therefore deny that chemical recycling is recycling (low circular economy fit framing). These actors are in conflict with a few other ecosystem actors, but are otherwise relatively isolated (i.e., they rarely participate in projects). With reference to previous findings on solving the grand challenges (Ferraro et al., 2015; George et al., 2016), the emergence of ecosystems (Daymond et al., 2023; L. D. W. Thomas et al., 2022), and frame contestation (Hiatt & Carlos, 2019; Kaplan, 2008), the effect of the observed circular economy fit frame incongruence is unclear. On the one hand, the problems typically associated with incongruent frames can slow down or prevent implementation of chemical recycling (Lundberg et al., 2022; Orlikowski & Gash, 1994; Young et al., 2016). On the other hand, it is precisely this contestation that could contribute to making potentially more sustainable solutions more desirable for society as a whole owing to the conscious engagement with the different technology frames, and hence further enhance the sustainability potential of CE activities (Bertassini et al., 2021; Sharma et al., 2021).

The second key finding that relates to sustainable and CE-related innovation is highlighted in Paper 3. While the focus of Paper 3 is on the interplay between internal reorganization and the adaptation of external collaboration, the underlying CE innovation challenges are also presented. Although the topic of CE innovation has already been addressed in a number of studies (Arekrans et al., 2023; T. Köhler et al., 2022; Suchek et al., 2021), and general challenges of CE are a frequently addressed topic (Bui et al., 2023; Fraccascia et al., 2019; Piila et al., 2022), the discussion of CE innovation challenges has so far been less in-depth (Aminoff

& Pihlajamaa, 2020; Kuhlmann et al., 2023; Sehnem et al., 2022). We identify three CE innovation challenges (content of innovation, timing of innovation, creating processes) in Paper 3. In comparison to an earlier study on innovation challenges (Aminoff & Pihlajamaa, 2020), we have not identified ecosystem level change, organizational inertia, and lack of market demand as challenges. We assume that this is because we looked at the implementation of the CE innovation instead of the early phase of the innovation process. Therefore, we concluded from our observations that internal reorganizing and the adaptation of collaboration were able to solve these specific innovation challenges successfully in the analyzed companies. Internal reorganizing breaks up the inertia and creates space for CE transformation. In addition, the adaptation of CE collaboration addresses the ecosystem-level change and the lack of demand. Targeted collaboration will successfully initiate changes at the external company level. Furthermore, the collaboration ensures that research and development addresses customer problems and that there is demand for the jointly developed solutions. The last two papers, 4 and 5, contribute to our understanding of the implementation of digital innovations in ecosystems. To avoid repetition, the results are therefore presented with reference to the third research gap (context of innovation).

Two of the included papers use the theoretical perspective of the technological frame and make a contribution from this perspective (Paper 1 and Paper 2). A summary can be found in Figure III.1-2. The contribution of Paper 1 that lies particularly in the integration of the perspective as a microfoundation of business model research has already been explained in the previous section. The findings of Paper 1 regarding the existence of incongruence in the different dimensions of the technological frame, as well as their impact on the resulting business models, inspired the research questions of Paper 2. While the circular economy fit incongruence seems to be consistent with previous results on negative effects (Lundberg et al., 2022; Orlikowski & Gash, 1994; Young et al., 2016), the results on the technology maturity frame are a groundbreaking contribution of this work to further research on the effects of frame incongruence. First, it becomes clear that this form of incongruence does not seem to prevent collaboration. This observation of technology maturity incongruence and relationship patterns therefore opens up the potential to even cause positive creativity and innovation-enhancing effects. The existence of such effects has been speculated upon (Spieth et al., 2021), but further evidence is still pending. The presented results at least support the theoretical idea with conclusive empirical observations.

Key findings – perception of innovation**Gaps**

- Role of frames in sustainable business model innovation
- Potential effects of frame (in-)congruence and relationships in ecosystem emergence

Key findings Paper 1

- A single-focused technological frame leads to a concentration on economic value missing sustainable value creation opportunities
- The twofold digital and sustainable technological frame opens up additional socioenvironmental value components (system support, renewable energy enabling)

Key findings Paper 2

- Congruent technology maturity frames do not prevent conflict, nor do incongruent technology maturity frames cause conflict
- Congruence in circular economy fit frames strongly influences collaboration
- Incongruent circular economy fit frames lead to conflict

Figure III.1-2: Key findings - perception of innovation

(Author's own illustration)

The last perspective of the theoretical framework refers to context of innovation (ecosystems). Figure III.1-3 summarizes all findings in relation to ecosystems. As prosumers emerged as an interesting new and upcoming actor role in Paper 1, this finding inspired Paper 4 on customer roles in digital business ecosystems. While customers are often considered part of value-creating actors in ecosystems because they combine the focal value proposition and complementary offerings to maximize their value, other forms of customer contributions are less often discussed in the literature on value co-creation in ecosystems (Agrawal & Rahman, 2015; Nambisan & Baron, 2009; Ng et al., 2019). The systematic analysis of customer contributions to value co-creation revealed eight possible forms in relation to level of interaction and integrated resource. While passive forms are controlled by the company (focal actor) and often require comparatively little commitment from customers, the passive integration of data in particular is being increasingly discussed critically in relation to data governance and data ownership, especially in the context of artificial intelligence applications (Díaz-Rodríguez et al., 2023; Sebastian, 2023). Furthermore, the active forms of customer co-creation show how the interaction can be controlled specifically by the customer, which may

enhance the influence of this group of actors on value creation in the entire ecosystem and can therefore also lead to a redistribution of value contributions. Against the background of the sustainability discussion, this development is still open; on the one hand, this decentralization and democratization can strengthen previously powerless actors, but on the other hand, particularly precarious constellations can also arise (Barile et al., 2020; Nylund et al., 2021). Here, the results only indicate the potential effects of the various forms of customer co-creation. After Paper 4 focuses on customers, the other papers take the perspective of the companies involved.

Paper 3 enriches the knowledge on ecosystem emergence with a focus on framing and contestation with data on interconnected ecosystem actors. Paper 2 links the external (ecosystem) dimension with internal organizational structures and processes. Paper 5 complements the perspective of implementation alternatives regarding smart services in the ecosystem of individual actors. All these papers support ecosystem actors in finding solutions to new ecosystem-related challenges (how to form relationships and engage in framing in ecosystems, how to organize internally to engage in external collaboration, and how to implement smart services in relation to ecosystem stage and own ecosystem role). Together, the papers contribute to a better understanding of the development and emergence of ecosystems, which is increasingly receiving attention as an important field of research (Daymond et al., 2023; Kuan & West, 2023; Shen et al., 2024).

The findings of Paper 2 contribute to our understanding of dominant frames and contestation within ecosystems (Kaplan, 2008; Olesen, 2014). While the high CE fit frame appears dominant among ecosystem actors, those with low CE fit frames often engage in conflict, demonstrating contestation. The study reveals that environmental NGOs regularly engage in one-sided conflict with firms, which could hinder ecosystem emergence, as unresolved incongruence may persist over time. The study also expands on Thomas and Ritala's (2022) idea of discursive legitimization, revealing that framing is not confined to orchestrators. Governmental, nongovernmental, and media actors actively shape ecosystem sensemaking, indicating their internal role due to their engagement in performative legitimization processes like funding and standard-setting. Additionally, many firm actors remain silent in framing processes, possibly on account of the early development stage of the ecosystem or because they wish to uphold a position of strategic neutrality in order to maintain relationships within the existing ecosystem.

This could be a tactic to avoid conflicts while positioning for future opportunities in the new ecosystem - a topic that future research could explore further.

Key findings – context of innovation

Gaps

- New actors, new roles in ecosystems
- Potential effects of frame (in-)congruence in ecosystem emergence
- Organizational configuration of internal elements and external ecosystem
- Customer roles and customer contribution in ecosystem value co-creation
- Innovation implementation in ecosystems

Key findings Paper 1

- Prosumers as new form of actors

Key findings Paper 2

- Ecosystem emergence processes: Contestation of sustainability potentials

Key findings Paper 3

- New insights into interplay of intra- and interorganizational dimensions in CE transformation

Key findings Paper 4

- Customer co-creation: Theoretical deduction of two dimensions (level of interaction and integrated resource) with manifestations (active/passive, time/skill/physical resources/data) resulted in eight ideal types

Key findings Paper 5

- Incremental, radikal and disruptive smart service implementations can be differentiated
- Implementation has to account for ecosystem strategy
- Implementation of smart services can happen with coordination or cooperation orientations

Figure III.1-3: Key findings - context of innovation

(Author's own illustration)

Paper 3 reveals key insights into the organizational transformation required for CE transitions in the plastics industry and the associated engagement in the emerging CE ecosystem. Internally, firms must reorganize permanent and temporary structures, and overhaul value creation processes, aligning with previous research that highlights the need for organizational redesign (Assmann et al., 2023; Bocken & Geradts, 2020). Externally, firms adapt by modifying partner selection criteria, strengthening relationships, adding new partners, and consolidating collaboration networks (Aarikka-Stenroos et al., 2022; Gebhardt et al., 2022). The study's key finding relates to the interplay between internal and external reorganization. The findings contribute to understanding how internal restructuring empowers CE collaborations, extending CE efforts beyond individual firms and into broader ecosystems (Parida et al., 2019). Internal restructuring not only supports partner selection but also signals a firm's commitment to CE, fostering new collaborations. Finally, the study enhances our understanding of CE dynamic capabilities (Khan et al., 2020; J. Köhler et al., 2022), showing how established firms reconfigure internal structures and value creation processes, in tandem with external collaboration adjustments.

A comparison of the implementation types in Paper 5 reveals critical insights, particularly in the roles and strategies of actors within ecosystems (Dedehayir et al., 2018, 2022; Lingens et al., 2022). Type I (Digital Enabler) acts as a complementor, using a differentiation strategy by adding smart functionalities to products, while Type II (Digital Incumbent) is an ecosystem leader with a similar strategy but a focal role. This allows Type I to operate across multiple ecosystems, though it risks dependency on the leader's strategy. Type III (Service Extender) and Type VI (Digital Ecosystem Extender) both expand their services with smart services but differ in approach: Type III delivers the service themselves, while Type VI builds and coordinates an ecosystem to offer it, raising the "make or buy" question in the context of ecosystems. Types V, VII, and VIII achieve cost advantages through structural changes in the ecosystem. This shows that classic strategy approaches retain their relevance in the ecosystem (cost and price leadership, differentiation), but additional dimensions such as ecosystem role must be taken into account when formulating strategies.

As the summarizing discussion shows, the five included studies provide diverse results that contribute to the three perspectives (content of innovation, perception of innovation, context of innovation). These key findings point the way for future research, as new questions continue to emerge. These future research opportunities are summarized in the following section.

III.2 Future research

Although the findings of this work have contributed to deepening our understanding of sustainable and digital innovations in the ecosystem context, the five included works have also opened up numerous new avenues for future research. The following Figure III.2-1 provides an overview of the identified opportunities for future research.

Content of innovation	Perception of innovation:
• Dynamic interplay between digital and sustainable innovation (<i>Paper 1</i>) • CE implementation failures (<i>Paper 3</i>) • Data governance in co-creation (<i>Paper 5</i>)	• Frames of multiple actors (<i>Paper 1</i>) • (In)congruence dynamics over time (<i>Paper 2</i>) • Interplay between different frame domains (<i>Paper 2</i>)
Context of innovation:	
• Consequences of frame (in)congruence for ecosystem emergence (<i>Paper 2</i>) • Interplay between internal organizing and external ecosystem dimension (<i>Paper 3</i>) • CE ecosystem collaboration: forms of collaboration, diverse partners (<i>Paper 3</i>) • Customer co-creation in ecosystems: motivation and co-destruction (<i>Paper 4</i>) • Success of different ecosystem implementation strategies (<i>Paper 5</i>)	

Figure III.2-1: Future research opportunities

(Author's own illustration)

In relation to content of innovation, the dynamic interplay between digital and sustainable innovation remains underexplored, especially regarding how these parts of the twin transition influence one another (*Paper 1*). Longitudinal methods in particular can track, over longer periods of time, how digital transformation is associated with the sustainability transition and what impact this twin transition has on internal company processes and external collaboration relationships in the ecosystem. There is also a need for a deeper understanding of CE implementation failures and the challenges they pose (*Paper 3*). Since *Paper 3* focuses on successful existing CE implementations, a comparison with failed CE implementations ensures that the presented findings are not the result of a survival bias (Gudmundsson & Lechner, 2013).

It cannot yet be ruled out that companies using the same approaches may also fail. Hence, future research should further contextualize the results and deepen the insights regarding CE innovation barriers (Aminoff & Pihlajamaa, 2020; Bocken & Geradts, 2020; Huang et al., 2021). Moreover, the role of data governance in co-creation processes (Díaz-Rodríguez et al., 2023; Sebastian, 2023), particularly within ecosystems, demands further investigation (Paper 5).

The second important theoretical perspective in this work is perception of innovation. There emerge three interesting open questions for future research. The framing of innovation by multiple actors introduces complexity, hence it would be particularly interesting to observe how these frames align or diverge over time (Paper 1 and 2). Since this is again a question regarding a temporal development, longitudinal approaches such as process studies would be suitable (Gehman et al., 2018; Langley & Ravasi, 2019). Additionally, the interplay between different frame domains requires more thorough exploration to clarify its impact on innovation outcomes (Paper 2). Although the findings of Paper 2 suggest that a congruent CE fit frame can potentially overcome any negative effects of an incongruent technology maturity frame, this postulated relationship requires further empirical testing. As concluded in Paper 1, it seems logical that the strategy - which is based on the sustainability-related purpose of a company (Evans et al., 2017; George & Schillebeeckx, 2022) - is crucial, but further empirical evidence is needed.

The final avenues for future research relate to the context of innovation under investigation: ecosystems. Understanding the consequences of frame (in)congruence for ecosystem emergence is vital, as such consequences directly affect the development and stability of ecosystems (Paper 2). As has been stated several times, the emergence of new ecosystems and the legitimacy required for this is a strand of ecosystem research that has only recently garnered attention (Daymond et al., 2023; Polese et al., 2021; L. D. W. Thomas et al., 2022). The presented results enrich the previously predominant theoretical and conceptual basis of the processes of ecosystem emergence with empirical observations. Furthermore, the theory of technological frames provides a solid basis for further studies on (in)congruences in fledgling ecosystems. There is also a critical need to examine the interplay between internal organizational structures and the external dimensions of ecosystems, particularly in the context of CE and sustainability transitions (Paper 3). Since the results of Study 3 indicate causal complexity, i.e. that a certain combination of characteristics is crucial for the success of the CE implementations under consideration, a further investigation of this issue using methods that

can depict causal complexity appears particularly promising. This includes, in particular, qualitative comparative analysis (Fiss, 2011; Juntunen et al., 2019; Reck & Fliaster, 2022), which can uncover the combinations of factors that underlie a successful organizational CE transformation. The various forms of collaboration within CE ecosystems, along with the diversity of partners involved are additional topics ripe for further study (Paper 3). Furthermore, customer co-creation in ecosystems, including motivations for customers to engage in co-creation (Danatzis et al., 2022) and the potential for co-destruction (Lumivalo et al., 2024), requires deeper investigation (Paper 4). Finally, the success of different strategies for implementing digital and sustainable innovations is an area that warrants more empirical research (Paper 5).

III.3 Conclusion

The presented research papers provide a comprehensive exploration of digital innovation and sustainability innovation in the ecosystem context. Paper 1, "The twofold transition: Framing digital innovations and incumbents' value propositions for sustainability," lays the groundwork for understanding how incumbent firms in Germany's energy sector are approaching digital virtual power plant technologies. It examines the influence of digitalization and sustainability on these companies' technological frames and how these frames affect their sustainable value propositions and broader societal impacts. Using a qualitative multicase approach, the study identifies two distinct groups of companies: one focusing solely on economic value, potentially missing sustainable opportunities, and another embracing both digital and sustainable dimensions, thus enhancing socio-environmental benefits. These insights drive the focus of Paper 2.

Paper 2, "Framing struggles in emerging ecosystems: Frames of chemical recycling and ecosystem relationships," explores the influence of frame congruence and incongruence on relationships within the emerging chemical recycling ecosystem. This study, set against the backdrop of controversial chemical recycling technology, uses a qualitative approach involving extensive document analysis and network visualization. It finds that while congruence in technology maturity frames can foster collaboration, incongruence often leads to conflict, impacting ecosystem dynamics. This transition from technological frames to ecosystem perspectives sets the stage for Paper 3.

Paper 3, "How companies move to circularity: Adjusting external collaboration and internal reorganizing," connects ecosystem-level changes with internal corporate transformations towards CE initiatives. By focusing on established plastics firms, the study highlights the adaptations in external collaborations and internal reorganizations needed to achieve circularity. It reveals changes in partner selection, relationship strength, and collaboration networks, as well as internal structural and process transformations.

Paper 4, "Customer roles in digital business ecosystems: Different forms of customer contribution in value creation," investigates the various roles customers play in digital ecosystems and their impact on value creation. By analyzing diverse case studies, the paper identifies eight ideal customer roles based on interaction levels and resource types. These roles

range from active contributions like content creation to passive roles like service grading, highlighting the motivations behind customer contributions and potential challenges in digital ecosystems.

Finally, Paper 5, "Implementation of smart services in ecosystems," examines how ecosystem characteristics, smart service design, and company ecosystem roles interact during smart service implementation. It uses a comparative case study approach, analyzing eight cases from companies like Philips Hue and Siemens MindSphere. The study identifies eight ecosystem roles associated with smart service implementation and differentiates between incremental, radical, and disruptive approaches. It also notes that smart service implementation can be driven by either coordination or cooperation, providing a nuanced view of how companies can navigate ecosystem dynamics to effectively deploy smart services.

While the call for sustainable and digital innovations is high worldwide and in Europe, innovation also comes with major challenges. The presented works show how digital and sustainable innovation activity is interwoven with engagement in ecosystems. Ecosystem relationships contribute to overcoming barriers to innovation and resource constraints, but they also bring with them new challenges. It is my hope that the presented results, contributions and approaches for future research will inspire further research on the most practically and socially relevant topics, provoke curiosity, and help to challenge assumptions about these topics.

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