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Facilitating systemic eco-innovation to pave the way for a circular economy

A qualitative-empirical study on barriers and drivers in the European polyurethane industry

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Abstract

Scholars, politicians, and practitioners have recently advocated that eco-innovation (EI) is critical to achieve the circular economy (CE) vision. While much of the available body of knowledge on EI has predominantly focused on "eco-efficient" incremental technological innovation, a successful CE transition requires systemic "eco-effective" CE innovation. Yet, little is known about what barriers and drivers are stimulating systemic CE innovation in different sectors and regions. This research aims to deliver an identification of major CE barriers and drivers that impede or facilitate systemic "eco-effective" CE innovation in the European polyurethane plastics industry. A hybrid research approach is applied using an original combination of the inductive GABEK method ("GAnzheitliche BEwältigung von Komplexität"—holistic processing of complexity) with deductive consideration of existing theories. Novel findings indicate that barriers to CE innovation largely materialize on individual firm and intra-industrial levels, while drivers to CE innovation primarily manifest beyond immediate industrial boundaries (inter-/cross-industrial). The key contribution lies on revealing the necessity to reframe the focus from mere individual "optimization", which has been primarily discussed in the contemporary EI literature, to a collective (horizontal) "coordination" challenge across industries to enable a functional CE innovation. In addition, five strategic deliberations are proposed to facilitate and further advance the management of systemic CE innovation activities.

KEYWORDS
circular economy, eco-innovation, barriers and drivers, eco-effectiveness, industrial ecology, plastics

1 | INTRODUCTION

Scholars have recently applied an eco-innovation (EI)[1] perspective on the circular economy (CE) concept (e.g., Cainelli et al., 2020; de Jesus et al., 2019, 2021; Prieto-Sandoval et al., 2018) since EI is expected to be instrumental for facilitating the transition from linear to circular production and consumption systems (Kiefer et al., 2021). However, these interdisciplinary research areas—both situated in the field of industrial ecology (cf. Bruel et al., 2019)—tend to highlight different aspects and a "cross-fertilization between the fields of innovation and CE is … largely absent" (de Jesus et al., 2021, p. 3) in the existing corpus of literature. While the EI literature has predominantly discussed a business-centric view focusing on focal firms' (technological) "eco-efficient" innovation (Hazarika & Zhang, 2019a; He et al., 2018; Xavier et al., 2017) corroborating in studies investigating EI determinants (barriers and drivers) (e.g., Bossle et al., 2016; Díaz-García et al., 2015; Zubeltzu-Jaka et al., 2018), the literature on CE has emphasized the necessity for a system-oriented approach facilitated by "eco-effective" CE innovation (e.g., de Jesus et al., 2021; Kiefer et al., 2021; Prieto-Sandoval et al., 2018). Yet, most of the existing academic knowledge on the CE remains rather focused on eco-efficiency than on eco-effectiveness (Kalmykova et al., 2018) partly transmuting in the remarkable body of literature discussing CE barriers (e.g., Grafström & Aasma, 2021; Hartley et al., 2021; van Keulen & Kirchherr, 2021) or CE barriers and drivers (e.g., Agyemang et al., 2019; Kumar et al., 2019; Tura et al., 2019).

Against this background, scholars have recently criticized that in-depth research regarding the investigation of EI dynamics within the CE is still rare (e.g., de Jesus et al., 2018, 2019, 2021; Kalmykova et al., 2018; Kiefer et al., 2021; Prieto-Sandoval et al., 2018; Vence & Pereira, 2019). Therefore, the recent understanding in academia of whether—and to what extent—the findings of EI can be applied to CE must be enhanced because of the growing emphasis in the literature to address "innovation systematically in the CE context" (de Jesus et al., 2021, p. 17). Contemporary CE literature has emphasized that there exists a limited understanding about the barriers and drivers for a CE transition in specific industries and geographical contexts (Hartley et al., 2021; Kirchherr et al., 2018; Tura et al., 2019). As a result, interdisciplinary in-depth research for CE–EI is in high demand to examine detailed barriers and drivers that impede or facilitate systemic "eco-effective" CE innovation in specific sectors and regions (de Jesus et al., 2021; Kiefer et al., 2021; Stumpf et al., 2021). This theoretical relevance for a detailed investigation has recently been underlined by CE–EI scholars stating that "[t]he CE transition will probably have different dynamics and timescales in different geographies, with EIs emerging and diffusing differently in different locations … [and] the evolution to a CE is dependent upon sector specificities" (Kiefer et al., 2021, p. 1544).

We bridge this gap in the available knowledge by investigating specific CE barriers and drivers that stimulate CE-innovation activities identified in the European polyurethane (PUR) plastics industry. The PUR industry has recently received a growing research interest in CE perspectives (e.g., Kurańska et al., 2020; Schultz et al., 2021), as this industry possesses an enormous but not (yet) realized potential for a CE transition (Brice, 2019).[2] We intend to gain knowledge by understanding "eco-effective" innovation for a CE in the specific industry context of PUR as both research streams are rapidly developing, yet their conceptual interconnection has not been extensively disinterred. Therefore, we have derived the following research question:

What major CE barriers and drivers are faced by firms in the European polyurethane industry that hinder or facilitate systemic "eco-effective" CE innovation?

We address this question by applying qualitative research (Ariño et al., 2016) using an original methodological combination of the inductive method GABEK (German acronym: "GAnzheitliche BEwältigung von Komplexität"—holistic processing of complexity) (Zelger, 2000, 2019) with deductive consideration of existing theories (Gioia et al., 2013). Adding and expanding on the available body of knowledge, our findings show that barriers to CE innovation largely materialize on individual firm and intra-industrial levels, while drivers predominantly appear beyond industrial boundaries (inter-/cross-industrial). Therefore, our study proposes to reframe the CE challenge from mere "optimization" towards "governance innovation" (and thus collective coordination) to enable functional CE innovation across industries and sectors. This requires CE-innovation activities beyond vertical (hierarchical) "eco-efficient" coordination and emphasizes horizontal "eco-effective" coordination with competitors and firms operating in adjacent industries. To facilitate the latter, we have derived five strategic deliberations to promote the management of functional CE-innovation activities.

The article continues with situating our study in the relevant literature streams in Section 2. We delineate our applied research method in Section 3. We then present our findings in detail in Section 4, followed by the discussion of our findings, derived implications, and limitations in Section 5. Finally, the conclusions are presented in section 6.

2 | LITERATURE REVIEW

2.1 | Eco-innovation determinants

While earlier work has highlighted EI as a holistic concept requiring technological, organizational, institutional, and social innovation (Rennings, 1998), large parts of the contemporary literature have extensively explored EI from a narrower perspective of individual businesses and/or policy interventions (Hazarika & Zhang, 2019a). Few studies have defined EI as any innovation that "is fueled by environmental issues" (Fussler & James, 1996, p. xi) reducing the ecological impact of consumption and production activities thus facilitating sustainable development (Carrillo-Hermosilla et al., 2010). Yet, much of the existing literature relies on a narrower view defining EI as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" (OECD/Eurostat, 2005, p. 46).[3]

Against this backdrop, the growing body of EI research focusing on EI determinants (e.g., Bossle et al., 2016; del Rio et al., 2016; Díaz-García et al., 2015; Hazarika & Zhang, 2019b; Horbach, 2008, 2016; Horbach et al., 2012; Zubeltzu-Jaka et al., 2018) has investigated whether these determinants rather materialize as a barrier or as a driver to/for EI activities in focal firms (Marin et al., 2015). Consequently, scholars have categorized determinants into firms' internal and firm-related external factors (e.g., Bossle et al., 2016; del Rio Gonzalez, 2005; He et al., 2018; Horbach, 2008; Kiefer et al., 2019).

Internal stimuli (drivers) or inhibitors (barriers) refer to focal firms' preconditions and features consisting of technological and managerial capabilities (e.g., Cai & Zhou, 2014; Horbach, 2008; Kesidou & Demirel, 2012), potential cost (savings) (e.g., Pereira & Vence, 2012), market share (e.g., Horbach, 2016), environmental management systems (e.g., Kesidou & Demirel, 2012), and firm characteristics (e.g., Horbach, 2008). Complementarily, external determinants relate to market, institutional, and social factors that may affect a focal firms' innovation trajectory (del Rio Gonzalez, 2005).[4] Governmental regulation (coercive pressure) has been acknowledged to be one of the core determinants for EI (Bossle et al., 2016; He et al., 2018) containing existing and expected (future) governmental regulation (e.g., Horbach et al., 2012; Rennings, 2000) as well as fiscal incentives and subsidies (e.g., Horbach, 2008). As a case in point, Aldieri et al. (2021) have examined knowledge spillovers and the role of technological efficiency in "environmental innovation" and has acknowledged that the "[g]overnment is supposed to establish the special funds to encourage the firms to expand innovation activities" Aldieri et al. (2021, p. 4). In fact, for process EIs, scholars have found competitive (mimetic) pressure as the strongest determinant (Hojnik & Ruzzier, 2016a), while for all other EIs regulative (coercive) pressure and market-related (normative) pressure have been uncovered as positively affecting firms' eco-innovation activities (e.g., Andries & Stephan, 2019; Liao, 2018). Further, market-related factors remain the most discussed determinants to EI in the contemporary literature (Hojnik & Ruzzier, 2016b).

The latter encompasses the firms' need to satisfy its stakeholders such as customers, suppliers, and third parties. Recently, stakeholder collaboration has increasingly received attention in EI research (He et al., 2018), which has largely been investigated from a techno-centric R&D perspective (Araújo & Franco, 2021). In addition, Petruzzelli et al. (2011) have exposed that the development of "environmental innovations" (i.e., environmental technologies), in comparison to "conventional" ones, demand firms to establish extended collaboration structures with inter-organizational actors and among intra-organizational groups. However, in large parts of the EI literature, stakeholder collaboration has been mainly centered on the vertical level along the supply chain with suppliers or customers (e.g., He et al., 2018; Triguero et al., 2013). Further, collaboration with third parties such as industry associations (Gonzalez-Moreno et al., 2013), universities, research institutes, and non-governmental organizations (NGOs) has been recognized as a success factor for EI (e.g., Cainelli et al., 2012; De Giorgi et al., 2015; De Marchi & Grandinetti, 2013).

However, scholars have recently noted that EI literature often remains limited to "technological innovation" (He et al., 2018). In fact, it has been discovered that the majority of EI tends to focus on "incremental forms of eco-innovation … enhancing optimizations" (Hazarika & Zhang, 2019a, p. 67), which fuels mostly quantitative studies emphasizing technology-related determinants (Zubeltzu-Jaka et al., 2018). This technology bias in large parts of the academic debate translates into stakeholder coordination that has largely focused on (hierarchical) vertical supply chain and/or third-party coordination, and thus neglects horizontal innovation structures with, for example, competitors, competing supply chains, and/or organizations operating beyond immediate industry boundaries.[5]

2.2 | Circular economy barriers and drivers

To achieve a functional CE, a systemic "eco-effective" EI approach is required to realize "high level" circularity (Kiefer et al., 2021). While there exists significant research on barriers (e.g., Grafström & Aasma, 2021; Kirchherr et al., 2018) or barriers and drivers (e.g., de Jesus & Mendonça, 2018; Tura et al., 2019) that are faced by firms towards advancing to a fully fledged CE transition, scholars have recently argued for a broader perspective on barriers (and drivers) beyond the individual organization (Hartley et al., 2021). Barriers, according to de Jesus and Mendonça (2018), are factors that slow down or derail a CE while drivers streamline or promote the CE transition. Both elements can be clustered into four key dimensions: social/cultural, institutional/regulatory, economic/market, and technological—that are all distinguishable into internal and external factors (e.g., Gong et al., 2020):

- Social/cultural relates to mindsets, mental models, peoples' sensitivity, and awareness.
- Institutional/regulatory covers regulatory initiatives, governmental action, and institutional incentive structures.
- Economic/market relates to market structures, prices of raw materials, and infrastructure.
- Technological includes technology and technical solutions.

While automotive (e.g., Agyemang et al., 2019), construction (e.g., Mahpour, 2018), and textiles (e.g., Hartley et al., 2021) have been the primary sectoral foci for CE research on barriers and drivers, plastics industries have only lately gained momentum in CE research due to their enormous potential for a CE transition. However, more in-depth research is still required (e.g., Bening et al., 2021; Siltaloppi & Jähi, 2021). Studies in the plastics industries on CE have primarily investigated opportunities and challenges connected to recycling and/or bio-based plastics and have revealed remarkable insights on CE plastics barriers and drivers. These discoveries have been largely verified in studies dealing with more general CE barriers and drivers (see details in Tables 1 and 2).

Since large parts of the CE literature have rather produced a "big picture" on barriers and drivers for a CE transition (e.g., Grafström & Aasma, 2021; Tura et al., 2019) "often portrayed as if they were independent of each other" (Bening et al., 2021, p. 1),[6] a research gap remains in exploring detailed barriers and drivers in specific sectors and geographical contexts (Hartley et al., 2021; Kirchherr et al., 2018; Tura et al., 2019).

2.3 | Connecting EI and CE research to pave the way for CE innovation

Our review has revealed that both literature streams gained remarkable insights when viewing through an EI prism on the CE. However, there exists a paucity of empirical research on the relationship between CE and EI, since scholars have recently found that systemic innovation is crucial to create a functional CE instead of further promoting "eco-efficient" incremental EI (e.g., de Jesus et al., 2018, 2019, 2021; Kalmykova et al., 2018; Kiefer et al., 2021; Prieto-Sandoval et al., 2018; Vence & Pereira, 2019). In consequence, CE–EI scholars have explicitly highlighted that "while the connections between EI and CE are stressed and the need for systemic innovation is emphasized as an enabler for the transition towards the CE, detailed in-depth analyses of EI practices and dynamics are still largely absent in the corpus of the CE literature" (de Jesus et al., 2021, p. 15). Historically, innovation has been presented as a broad concept, rather than discussing specific aspects of a conceptualization of innovation, key processes, major stakeholders, and objectives for a CE (de Jesus et al., 2021; Kiefer et al., 2021; Prieto-Sandoval et al., 2018). Even though Rennings (1998) discussed the danger of a "technology bias" to EI research in the late 1990s, large parts of recent CE–EI literature have continued to solely discuss "eco-efficient" innovation for (environmental) technologies (e.g., Cainelli et al., 2020; Durán-Romero et al., 2020) seemingly influencing the political discourse focusing on techno-centric "eco-efficiency" (Colombo et al., 2019). This narrow view translates into firms' CE-innovation practices tending "to be restricted to one type, i.e., to incremental, technological innovation (e.g., to improve efficiencies in production processes)" (Stumpf et al., 2021, p. 11).

Hence, CE–EI scholars have lately proposed to apply a "neo-Schumpeterian" (de Jesus et al., 2019, p. 1494) approach on this emerging research field. Schumpeter originally highlighted the concept of "creative destruction," in which firms' innovation capabilities disrupt products, production methods, organizational forms, and market structures by replacing them with superior ones, thus facilitating (sustainable) development. Taking a Schumpeterian perspective on innovation activities can be beneficial to analyze the dynamics of innovation processes by highlighting the idea of creative market responses to changes in external conditions (cf. Schumpeter, 1934, 1942). This approach provides a promising theoretical avenue to elaborate on the recent call by CE–EI scholars that "[f]urther research pathways should … deepen the knowledge on innovation dynamics within a CE" (de Jesus et al., 2021, p. 16).

2.4 | Ordonomic perspective

The application of the ordonomic research program appears most appropriate to discuss our research question, because it can help to system(at)ically analyze interdependences between market interactions and external conditions (e.g., Pies, 2016; Pies et al., 2009, 2010). Further, this concept has proven to be functional in corporate sustainability, corporate social responsibility, and CE research (e.g., Beckmann et al., 2014; Pies et al., 2009, 2014, 2020; Schultz et al., 2021).

The original approach developed a three-level framework distinguishing between (1) a basic game: business conduct, (2) a meta game: governance, and (3) a meta-meta game: discourse (Pies et al., 2010). (1) Ordonomics applies game theoretical tools to reconstruct incentive structures that can lead to conflicts—that is, one-sided and many-sided social dilemmas (the former defines an asymmetric situation in which one actor can exploit another, the latter is described by a symmetric situation where all actors can exploit each other). (2) Ordonomics suggests governance (Pies et al., 2019) to change incentive structures in market exchange situations toward new principles and practices (cf. Williamson, 2000, 2002), which can be defined by a (re-)arrangement of "humanly devised constraints that shape human interaction" (North, 1990, p.3). (3) Ordonomics advocates appropriate rule-finding discourses to reorient semantics for driving social learning processes (Pies et al., 2010) facilitating functional rule setting. Semantics relate to categories of thought embedded in ideas influencing how people interpret rules that shape human interactions (Denzau & North, 1994).

We can reformulate the challenges that have primarily been studied in existing EI and CE research using this ordonomic perspective. Whereas much of EI has focused on technological innovation following an "optimization logic" by focal firms, EI activities for a functional CE require to reframe the challenge from a problem of the firm's individual innovation capabilities to a problem of its external constraints aiming at debating on,

TABLE 1 Overview of CE barriers and plastics specific CE barriers

Dimension	Barrier	Studies	Corresponding plastics barrier	Studies (plastics)
Social/Cultural	Lack of consumer (stakeholder) awareness, interest, and demand	Geng & Doberstein, 2008; Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Kumar et al., 2019; Masi et al., 2018; Mont et al., 2017; Singh & Giacosa, 2019; Tura et al., 2019; Vermunt et al., 2019	Low consumer awareness, trust, buy-in, and demand for plastic recyclates and/or bioplastics	Bening et al., 2021; Confente et al., 2020; Dijkstra et al., 2020; Filho et al., 2021; Gong et al., 2020; Milios et al., 2018; Paletta et al., 2019
	Reservations against CE/hesitant company culture	de Jesus & Mendonça, 2018; Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Kumar et al., 2019; Mont et al., 2017; Rizos et al., 2016	Missing motivation to improve environmental quality	Dijkstra et al., 2020
	Limited willingness for collaboration	de Jesus & Mendonça, 2018; Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Kumar et al., 2019; Mont et al., 2017; Vermunt et al., 2019	Limited willingness for collaboration within the supply chain (e.g., R&D)	Dijkstra et al., 2020
	Lack of knowledge about CE principles and practices	Guldmann & Huulgaard, 2020; Kumar et al., 2019; Mahpour, 2018; Rizos et al., 2016; Vermunt et al., 2019	–	–
Institutional/Regulatory	Linear policies and tax schemes	Geng et al., 2010; Guldmann & Huulgaard, 2020; Gumley, 2014; Masi et al., 2018; Su et al., 2013; Witjes & Lozano, 2016	Ineffective policies; lack of efficient supporting mechanism (e.g., taxation)	Bening et al., 2021; Filho et al., 2019; Siltaloppi & Jähi, 2021
	Complexity of laws and regulations	García-Quevedo et al., 2020; Gumley, 2014; Kinnunen & Kaksonen, 2019; Tura et al., 2019	Waste law not aligned with other laws; e.g., recyclates excluded from reuse for food-grade material	Bening et al., 2021
	Lacking CE know-how of politicians	Ilić & Nikolić, 2016; Tura et al., 2019; Xue et al., 2010	Insufficient knowledge and expertise on plastics and CE by politicians/authorities	Bening et al., 2021
	Lack of governmental/institutional support	Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Kumar et al., 2019; Rizos et al., 2016; Tura et al., 2019; Vermunt et al., 2019	Lack of financial support; inefficient standards; insufficient alignment across	Bening et al., 2021; Dijkstra et al., 2020; Gong et al., 2020; Paletta et al., 2019; Siltaloppi & Jähi, 2021
Economic/Market	Lack of financial capabilities/funding	Agyemang et al., 2019; Geng et al., 2010; Guldmann & Huulgaard, 2020; Ilić & Nikolić, 2016; Mahpour, 2018; Rizos et al., 2016	Lack of funding	Bening et al., 2021; Dijkstra et al., 2020
	High upfront investment cost for new technologies	de Jesus & Mendonça, 2018; Gumley, 2014; Kinnunen & Kaksonen, 2019; Kirchherr et al., 2018; Kumar et al., 2019; Masi et al., 2018; Mathews & Tan, 2011; Mont et al., 2017; Rizos et al., 2016	Large initial investment costs for new recycling assets/production capacity	Dijkstra et al., 2020; Milios et al., 2018; Siltaloppi & Jähi, 2021
	Switching cost (e.g., reverse logistics)	Grafström & Aasma, 2021; Kalmykova, Sadagopan, & Rosado, 2018; Lieder & Rashid, 2016	Switching cost for recyclates	Gong et al., 2020; Milios et al., 2018

(Continues)

TABLE 1 (Continued)

Dimension	Barrier	Studies	Corresponding plastics barrier	Studies (plastics)
	High economic uncertainty	de Jesus & Mendonça, 2018; Guldmann & Huulgaard, 2020	Uncertainties regarding recyclates	Dijkstra et al., 2020; Milios et al., 2018
	Low primary (raw) material prices	Guldmann & Huulgaard, 2020; Kinnunen & Kaksonen, 2019; Kirchherr et al., 2018; Masi et al., 2018; Mont et al., 2017	Low production cost of virgin material	Bening et al., 2021; Milios et al., 2018
	Price–performance ratio of secondary raw materials	Guldmann & Huulgaard, 2020; Kinnunen & Kaksonen, 2019	High production cost of recycled materials/lack of supply; higher prices of bio-based and/or recycled plastics	Bening et al., 2021; Dijkstra et al., 2020; Milios et al., 2018; Siltaloppi & Jähi, 2021
	Lack of economic incentives (missing markets and/or market failures)	de Jesus & Mendonça, 2018; Guldmann & Huulgaard, 2020; Tura et al., 2019	Lack of demand/immature markets	Bening et al., 2021; Dijkstra et al., 2020; Siltaloppi & Jähi, 2021
	Lock-in effects in linear infrastructure	Kirchherr et al., 2018; Masi et al., 2018; Mont et al., 2017; Vermunt et al., 2019	Economic lock-ins	Bening et al., 2021; Gong et al., 2020
Technological	Available and appropriate technological solutions	Eriksen et al., 2019; Geng et al., 2014; Yu et al., 2014	Technology and production processes optimized for fossil feedstocks and thus underdeveloped for sorting, mechanical processing, and chemical recycling	Kawashima et al., 2019; Larrain et al., 2020; Milios et al., 2018; Paletta et al, 2019; Siltaloppi & Jähi, 2021
	Limited circular design of products (and services)	Guldmann & Huulgaard, 2020; Kirchherr et al., 2018; Masi et al., 2018; Mont et al., 2017; Shahbazi et al., 2016	Limited circular design for plastics	Gong et al., 2020; Milios et al., 2018; Paletta et al., 2019
	Quality issues of recycled/remanufactured materials	Eriksen et al., 2019; Kinnunen & Kaksonen, 2019; Kirchherr et al., 2018	Material diversity; contaminations; low quality of recyclates/bio-based plastics; Small range of applications for mechanically recycled material	Bening et al., 2021; Dijkstra et al., 2020; Gong et al., 2020; Milios et al., 2018; Paletta et al., 2019; Siltaloppi & Jähi, 2021
	Reliability of supply for recycled/remanufactured materials	Kinnunen & Kaksonen, 2019	Uncertainties regarding supply of recyclates	Dijkstra et al., 2020; Milios et al., 2018
	Missing large-scale projects and industrial scale facilities	Kinnunen & Kaksonen, 2019; Kirchherr et al., 2018; Ilić & Nikolić, 2016; Rizos et al., 2016; Singh & Ordoñez, 2016; Tura et al., 2019	Lack of recycling capacity and infrastructure	Dijkstra et al., 2020; Gong et al., 2020; Milios et al., 2018; Siltaloppi & Jähi, 2021
	Lack of information/data	Kirchherr et al., 2018; Mahpour, 2018	Insufficient information/data	Milios et al., 2018
	Lack of technical know-how/capabilities	Agyemang et al., 2019; de Jesus & Mendonça, 2018; Geng et al., 2010; Rizos et al., 2016; Shahbazi et al., 2016; Tura et al., 2019; Vermunt et al., 2019	Complexity of and limited capabilities in LCAs	Siltaloppi & Jähi, 2021

TABLE 2 Overview of CE drivers and plastics specific CE drivers

Dimension	Drivers	Studies	Corresponding plastics drivers	Studies (plastics)
Social/Cultural	Sensitivity to environmental issues	de Jesus & Mendonça, 2018; Kumar et al., 2019	Consumer awareness and encouragement	Gong et al., 2020; Milios et al., 2018
	Shifting consumer preferences	de Jesus & Mendonça, 2018; Rizos et al., 2016	Shifting consumer preferences	Confente et al., 2020; Dijkstra et al., 2020; Filho et al., 2021
	Business perception, brand, and image benefits	de Jesus and Mendonça, 2018; Geng et al., 2012; van Keulen & Kirchherr, 2021	Business perception, brand, and image benefits	Gong et al., 2020
	Business culture (e.g., senior management support)	Rizos et al., 2016	Senior management support	Gong et al., 2020
Institutional/Regulatory	Standardization	Dong et al., 2016; Velis & Vranken, 2015;	Standardization	Bening et al., 2021
	Directing regulations	Dong et al., 2016; Geng & Doberstein, 2008; Zhu et al., 2011	Regulations on landfill and EoL; governmental support	Dijkstra et al., 2020; Gong et al., 2020
	Taxation, funds, subsidies	Kumar et al., 2019; Witjes & Lozano, 2016	Financial incentives particularly for collection and sorting	Siltaloppi & Jähi, 2021
	"Optimal" mix of rules, taxes, infrastructure	de Jesus & Mendonça, 2018	–	–
Economic/Market	Cost savings by reducing waste, save energy	Esposito et al., 2015; Ghisellini et al., 2016; Kumar et al., 2019; Liu & Bai, 2014; Murray et al., 2017; Rizos et al., 2016	Cost savings due to capturing value from plastics waste streams	Dijkstra et al., 2020
	Opportunities for sustainable value creation and business growth due to new market opportunities	Linder & Williander, 2017; Rizos et al., 2016; Sanyé-Mengual et al., 2014	New market dynamics due to competition based on sustainability benefits	Siltaloppi & Jähi, 2021
	Potentials for innovation (e.g., decoupling material input from revenues and profits)	Geng et al., 2010; 2014	From bulk materials to material solutions and higher profit margins	Dijkstra et al., 2020; Siltaloppi & Jähi, 2021
	Synergy opportunities and benefits by (vertical) industry collaboration	Dong et al., 2016; Hartley et al., 2021	Initiate (vertical) collaboration within the supply chain	Bening et al., 2021; Dijkstra et al., 2020; Gong et al., 2020; Siltaloppi & Jähi, 2021
Technological	Technical capacities and technologies	de Jesus & Mendonça, 2018; Geng et al., 2014; Ghisellini et al., 2016	Technology and capacity development for recyclates	Milios et al., 2018
	Technologies encourage business development	Kumar et al., 2019; Mathews & Tan, 2011	Technology advancements in materials promote business development	Dijkstra et al., 2020; Milios et al., 2018
	Waste management and recycling opportunities are dependent on technical solutions	Eriksen et al., 2019; Yu et al., 2015	Development of recycling infrastructure (e.g., integration of chemical recycling)	Dijkstra et al., 2020; Milios et al., 2018; Siltaloppi & Jähi, 2021

creating, and coordinating a collaborative innovation process. For realizing this aim, CE innovation must be approached beyond mere "optimization" by redirecting incentive structures to enable superior "optimization" activities. As a result, the ordonomic perspective can assist in addressing a major concern recently expressed by CE–EI scholars, namely, that the paucity of conceptual understanding required to constructively connect EI and CE is explicitly restricting the opportunities for knowledge advancement in this important research field (de Jesus et al., 2021).

3 | METHODS

3.1 | Industry context

PUR is part of the "big six" most significant plastic materials in terms of application and economic value. A vast majority of PUR waste is still incinerated (33%) or landfilled (45%) in Europe (PUReSmart, 2020). Since PUR is produced as a mixture of diisocyanates, polyols, and additives, leading to a large range of materials that are used in versatile applications and supply chains (Akindoyo et al., 2016)—for example, automotive, mattresses and furniture, building and construction, packaging, or electronics (PlasticsEurope, 2020; Simón et al., 2018)—its outstanding properties and lost economic value at the end-of-life (EoL) impairs its environmental (and economic) sustainability. In practice, major chemical companies (e.g., Covestro) and end-application producers (e.g., IKEA) have started moving toward circularity. The available literature has distinguished strategies for CE product and material loops into "closing" and "slowing" (Hansen & Revellio, 2020) proposing a 3-R (Murray et al., 2017) to a 9-R (Potting et al., 2017) approach of value retention loops. Yet, slowing strategies (repair, reuse, remanufacture) are of limited value to accurately solve the waste issue for PUR due to the contamination at the EoL. In contrast, the "closing" strategy of chemical recycling has been found to provide the most promising avenue toward circularity in this industry (Simón et al., 2018), offering win–win potentials to reduce the environmental footprint by simultaneously improving material properties (Ugarte et al., 2018).

3.2 | Sampling

The research method of our study follows a qualitative approach (Ariño et al., 2016). We applied a two-step contacting process securing 22 experts for interviews (Table 3) who are particularly knowledgeable about the topic of interest.[7] First, we approached firms and industry experts dealing with CE by contacting relevant PUR industry associations. Second, we contacted and selected viable interview partners by a randomized snowball sampling (Handcock & Gile, 2011). As a result, we were able to attract representative PUR organizations covering the entire supply chain. A large share of interviewees possesses profound experience between 10 and 40 years. Our medium *N*-sample design ($10 < N < 100$) further addresses Kirchherr and van Santen's (2019) criticism regarding a lack of medium and large *N*-samples in available CE research.

3.3 | Data collection

We conducted semi-structured interviews lasting between 45 and 85 min (1209 min audio-recording time in total) in English or German, which were carried out face-to-face or via online conference. All interviews were recorded and transcribed. After transcription, the interview memos were sent back to interviewees for validation and clarification. Anonymity of interviewees was guaranteed to gain trust and allow for additional insights (Berry, 2002; Gioia et al., 2013). All interviews were conducted between November 2019 and June 2020.

3.4 | Data analysis

This study relies on an abductive research approach that combines (1) inductive category development with (2) deductive consideration of existing theories (Gioia et al., 2013). We adopted an insider/outsider design, in which one researcher collected, structured, and analyzed the data while the second researcher kept distance and worked as "devil's advocate" (Crosina & Pratt, 2019; Strike & Rerup, 2016). This iterative procedure allowed us to significantly improve the research quality by asking critical questions, reconsidering data, and providing further clarification.

(1) Following the recommendations by Gioia et al. (2013), we initiated our data analysis procedure through inductive category development. Methodologically, we applied the qualitative-empirical method GABEK (Zelger, 2000, 2019) with the associated computer-assisted program WinRelan, which enabled us to systematically analyze the large quantities of the collected unstructured interview data (Raich et al., 2014). The explorative GABEK-WinRelan method employs a systematic inductive procedure, and thus it is particularly appropriate for analyzing verbal data derived from interviews (Schmid, 2020). It enables the in-depth examination of information, attitudes, and knowledge of individual interview statements. Furthermore, it empowers the researcher(s) to zoom in and out in the level of detail, thus allowing to easily go back and forth to

TABLE 3 Details of the 22 experts selected for interviews

#	Professional position	Organization	Experience (years)	Country	Time (hh:mm)
1	Senior Manager—CE	Chemical Company	35	Belgium/Netherlands	01:14[1]
2	Senior Manager—Sustainability	Chemical Company	25	Belgium	01:14[1]
3	Vice President—R&D Additives	Chemical Company	2	Germany	00:54
4	Manager—Technical Service	Chemical Company	7	Germany	01:15
5	(Former) Senior Manager—R&D	Chemical Company	38	Germany	01:25
6	Senior Manager—PUR Elastomers	Distributor	10	Germany	01:00
7	Director—CEO	PUR-Manufacturer	25	Germany	00:58
8	Director—Marketing	PUR-Manufacturer	25	Germany	01:00
9	Director —CEO	Waste Collector & Recycler	30	Germany	00:55
10	Director—CEO	Waste Collector & Recycler	20	Germany	00:59
11	Manager—Chemical Recycling	Waste Collector & Recycler	3	Germany	01:05
12	Senior Manager—Sustainability	End-Application Producer & Retailer	20	Sweden	00:58[2]
13	Manager—PUR Technology	End-Application Producer & Retailer	16	Sweden	00:58[2]
14	Secretary General	PUR-Industry Association	20	Belgium	01:14[1]
15	Secretary General	PUR-Industry Association	16	Belgium	01:16
16	Secretary General	PUR-Industry Association	4	Germany	01:02
17	Senior Manager—PUR Technology	PUR-Research Institute	22	Germany	01:23
18	Partner & Managing Director	Top-Management Consultancy	25	Germany	00:48
19	Partner & Managing Director	Top-Management Consultancy	25	Germany	00:47
20	Director—CEO*	PUR-Consultancy	30	Germany	01:13
21	Director—CEO*	PUR-Consultancy	25	Germany	01:12
22	Senior Manager—Chemicals	Top-Management Consultancy	14	Great Britain	00:45

1;2 Within one interview session
*Former Senior Manager at Raw Material Producer.

the appropriate degree of individual statement analysis for any case (Rhein & Sträter, 2021). We applied GABEK-WinRelan as it has been found advantageous compared to other qualitative methods (e.g., Atlas.ti, NVivo, and so on) since (1) it combines qualitative analysis steps—coding and evaluating—with quantitative analysis steps—counting and clustering—on the same textual dataset (Raich et al., 2014) and (2) the rule-based analysis of GABEK-WinRelan improves the accuracy of content analysis while allowing for scrutinizing detailed and abstract questions (Hielscher & Will, 2014; Müller et al., 2011). Therefore, it can support the elaboration on individual problems as well as advancing to more abstract levels of analysis. This rule-based procedure of systematizing, coding, and interpreting the data is (finally) able to enhance the validity of data and findings (Müller et al., 2011). Further, GABEK-WinRelan has proven efficient in related research fields such as corporate environmentalism investigating US companies from the Fortune 500 index and German companies from the DAX-30 index across different industries (Müller et al., 2011), or corporate sustainability research of German companies from the DAX-30 index (Hielscher & Will, 2014). In the plastics packaging industry context, the method has recently been effectively applied by scholars in circular economy and sustainable consumption research (e.g., Herrmann et al., 2022; Rhein & Sträter, 2021).[8]

Our coding process involved multiple iterative coding cycles. The first stage covered detailed reading of interview transcripts examining the collected data, which was followed by an initial coding of the dataset. Applying GABEK-WinRelan ensured to guarantee the coding quality since it can systematically analyze the argumentative structure of transcribed interviews by examining the sentence structure, intent, and underlying concept (Zelger, 2000). In this step, interview transcripts were manually divided into so-called text units that one single thought of an interviewee exactly represents one text unit. One text unit can be described as a comprehensible and meaningful set of coherent ideas that typically encompasses one to two sentences (Zelger, 1991). This procedure resulted in 680 distinct text units. Each text unit was saved on a single digital index card in the WinRelan system of index cards (Herrmann et al., 2022). In the next step, three to nine keywords per text unit were identified and coded since psychological research suggests that a person can simultaneously bear up to nine thoughts in mind (cf. Miller, 1956). The keywords, which include the semantic essence, were checked for synonyms and replaced accordingly. Finally, we obtained 372 distinct keywords. Second, we clustered and synthesized codes under abstract and theoretical categories (Saldaña, 2016) with the purpose to create linguistic "gestalten." The terminology "gestalt" is used in analogy to psychological research on perceptive appearances. In the context of GABEK, we use the definition of Raich et al. (2014, p. 748), who has defined a linguistic gestalt as "an abstract entity consisting of a specific, meaningful group of text units fulfilling syntactic, semantic, and pragmatic rules." Creating linguistic gestalten has been conducted recursively (Müller et al., 2011) followed by synthesizing and clustering to hyper-gestalten (Figure 1).

(2) We conducted an iterative empirical–theoretical analysis, in which we identified gestalten, bundled them into hyper-gestalten inductively, and then aggregated these hyper-gestalten into hyper-hyper-gestalten.[9] We sensitized the latter to the four key dimensions proposed by extant CE literature (e.g., Grafström & Aasma, 2021) resulting in the gestalten tree(s) "skeleton" (Figure 1). Consequently, we applied a complementary EI perspective on the "skeleton" of CE barriers and drivers by extending the contemporary EI determinants' categorization (e.g., Kiefer et al., 2019) toward the differentiation between internal, external (intra-industrial), and external (inter-/cross-industrial) (Figure 1). Finally, we employed the theoretical concept of the ordonomic three-level framework on the gestalten tree(s). Based on the final deductive steps, we aimed to create an enhanced understanding by revealing a novel perspective on barriers and drivers that hinder or facilitate systemic "eco-effective" CE innovation.

4 | FINDINGS

As illustrated in Figure 1, our findings reveal that barriers to CE innovation largely manifest on individual firm (internal) and/or intra-industrial (external) levels, while drivers to CE innovation primarily emerge beyond industrial boundaries on the inter-/cross-industrial level (external).

4.1 | Social/Cultural

4.1.1 | Barriers

On the firms' internal level, findings indicate that fear and avoidance of uncertainty and risks of producers (and their employees) in relation to circular practices, materials, and processes obstruct learning processes. In addition, hesitant and even reactionary business culture has frequently been mentioned during the interviews as a barrier to CE innovation within firms.

On the intra-industrial level, there seems to exist an issue of silo-thinking between the companies in PUR industries (and beyond), which leads to significant disadvantages to achieve the idea of systemic CE innovation as stated by the CEO of a PUR Manufacturer *"[I]t would be beneficial, if we could share a common language on this topic [CE] to find a consensus … I have got the feeling, everyone is 'backing own bread' and we cannot afford to act like this in [our] industry"* (see Table A1 in Appendix 1 for details). A reoccurring critique point from interviewees was that CE innovation suffers from costumer (B2B) and consumer (B2C) acceptance of CE products. Furthermore, unconcerned, and inappropriate consumer (buying) behavior is counterproductive. Particularly relevant for products that are embedded in other materials, the lack of consumers' knowledge and awareness is hindering cultural change in the PUR industry.

On the inter-industrial level, third parties, for example, NGOs are perceived by many interviewees as an integral part for a multi-stakeholder discourse to facilitate a functional CE. However, interviewees with different backgrounds were, at times, apprehensive of negative influences toward the public discourse due to third parties' (i.e., NGOs) own interests and agendas. More concretely, some interviewees mentioned that particularly NGOs may lack required and specific CE know-how. This runs the risk of channeling the public debate into an emotive rather than a fact-based one. Few interviewees mentioned that some NGOs further lack the ability to carefully consider issues and ignore a required differentiation competence.

4.1.2 | Drivers

On the inter-industrial level, drivers for CE innovation include an open and mindful communication beyond immediate industry boundaries. Relatedly, transparency for the public, academic, and business discourses are essential and a precondition for consumer education toward CE principles and practices. A system approach and thus companies' and industries' interdisciplinary exchange in open loops between various (plastics) industries requires moving beyond silo-thinking and setting-up diverse inter-disciplinary expert teams to create new and interrelated knowledge. This was mentioned by the CEO of a PUR Consultancy *"[O]pen-loops [are] much smarter because I can leverage opportunities, which have not previously existed"* (see Table A1 in Appendix 1 for details). This development can further be accelerated by continuous exchanges through feedback loops between

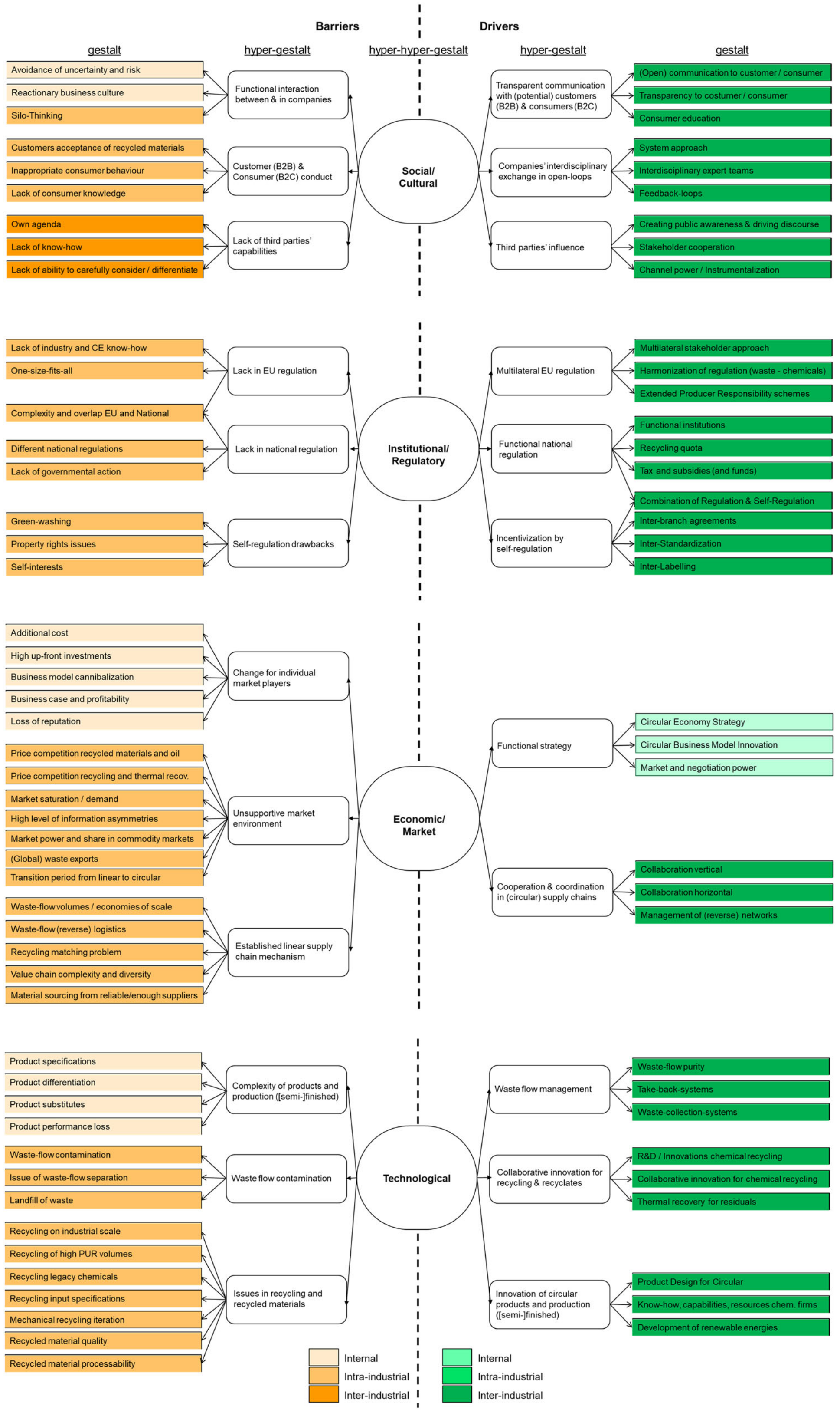

FIGURE 1 Gestalten tree(s)

different yet synergetic industries. Commenting on the third parties' (e.g., NGOs, industry associations) roles to facilitate systemic CE innovation, interviewees confirmed their critical role, principally to create public awareness, to drive a fact-based public discourse, and to educate the civil society. Surprisingly, some interviewees noted that channeling or even "instrumentalizing" of their immense power can accelerate the CE progress beyond immediate industry boundaries to enable CE innovation by, for example, orchestrating stakeholder collaborations.

4.2 | Institutional/Regulatory

4.2.1 | Barriers

On the intra-industrial level, the interview findings confirmed that there exists a high degree of complexity regarding different regulations and overlaps on European and national levels to PURs. Yet, different regulations in EU countries remain the norm, such as waste, raw material treatment, and shipping. This stands in contrast to the notion that waste must be understood as a secondary raw material circling in (open) loops. Furthermore, in the eastern European regions, government activity (national and local) in the area of auditing must be significantly strengthened. Moreover, interviewees observed that regulatory institutions in the EU lack knowledge on PURs and know-how to adequately support the CE transition. Due to the high versatility of PUR supply chains and end-industries, one-fits-all solutions are difficult to implement as stated by a Senior Manager of a Chemical Company *"Our materials are part of different streams, which have/or not already have dedicated obligations… It is not that we can direct all of these things… You cannot have a one-fit-all solution"* (see Table A2 in Appendix 2 for details). Besides public ordering, interviewees also referred to private ordering barriers for CE innovation. Namely, a Manager of a Recycler underlined *"We need to partly distance from the topic of self-regulation, because it has always a touch of pure greenwashing"* (see Table A2 in Appendix 2 for details), thus deteriorating sincere CE-innovation activities by firms. Other interviewees are apprehensive that industrial property rights or issues of "unmanageable" self-interests could contradict self-regulatory effort.

4.2.2 | Drivers

On the inter-industrial level, the EU is perceived as an immense driver to enable functional incentivization by directives and/or regulations. For developing adequate rules, a multilateral stakeholder approach toward functional regulation is highly appreciated since *"with the circular economy, obviously we see new stakeholders become relevant"* (Senior Manager, Chemical Company) (see Table A2 in Appendix 2 for details). In particular, the harmonization of chemical and waste legislation across industries at EU level stood out as one desirable aim. An effective extended producer responsibility (ERP) scheme was emphasized as one key driver for the transition period since it significantly increases the producers' responsibilities. Further, the call for functional national institutions in all EU countries has been observed. Whereas the instrument of a recycling quota was controversially discussed, interviewees mostly agreed on the idea(s) of using CE-innovation funds, taxation, and/or subsidization. Remarkably, various interviewees recognized a combination of self-regulation (private ordering) and legislative regulation (public ordering) as the most promising path toward functional rules for facilitating CE innovation: *"self-commitment and governmental regulation, they are a good combination, both of them together"* (Manager, Chemical Company) (see Table A2 in Appendix 2 for details). Interviewees frequently mentioned branch agreements, standardization of (secondary) raw materials, and credible labeling as viable means of incentivization through self-regulation. The respondents emphasized the need for their extension on inter-/cross-industrial structures to redirect competitive processes within industries, and particularly to address potential (future) synergistic adjacent industries.

4.3 | Economic/Market

4.3.1 | Barriers

On the firms' internal level, interviewees raised the concern of additional costs in supply chain areas such as production, logistics, and distribution. Additional high upfront investment costs and different states of assets are challenging to move toward innovative CE practices. A former Senior Manager of a Chemical Company stated that firms face the issue to potentially cannibalize their current linear business (model) when innovating circular businesses. Consequently, engaging in CE innovation needs to become a profitable business case for firms. Yet, companies' fear to lose their reputation by moving individually toward circularity.

On the intra-industrial level, interviewees noted that recycling options depend on the crude oil price since there exists a price competition between the use of recycled and virgin materials. Moreover, the currently established globalized markets are saturated regarding customer demand of pre-consumer and post-consumer recyclates. Namely, a high level of information asymmetries between actors in PUR markets are hindering CE innovation. Interviewees emphasized two possible drawbacks of using recyclates. First, the PUR industry could suffer a competitive disadvantage being substituted by other plastic materials and second, companies operating within PUR markets fear to lose existing market shares. Some interviewees perceived current global waste exports as a key barrier since they reduce input materials for domestic recycling. A Manager (Recycler) stressed *"if you push innovative concepts, this will cost more during the transition period, compared to well-established linear systems. This is a fact"* (see Table A3 in Appendix 3 for details). Established linear supply chain mechanisms are causing very low quantities of good-quality waste-flow volumes and thus issues regarding profitable economies of scale. For voluminous materials such as PUR foams, an efficient reverse logistics approach is absent. Furthermore, mechanical recycling suffers a matching problem between recyclers and manufacturers. PUR supply chains possess a huge complexity and diversity, and thus, it is difficult to source secondary (raw) materials from reliable and enough suppliers to guarantee high quality and security of supply.

4.3.2 | Drivers

On the firms' internal level, interviewees emphasized organizational innovation of circular business models in combination with a vital CE strategy as crucial since it is expected as advantageous regarding the market and negotiation power of firms.

On the inter-industrial level, collaboration schemes are stated by interviewees as the most promising driving force. Collaboration of firms on a horizontal basis with competitors and firms operating beyond immediate industrial boundaries can enable CE innovation as stated by a Manager (Recycler) *"if you want to improve [CE-innovation], [a variety of firms] need to come together, [like] shoe manufacturer, mattress manufacturer, … waste management companies"* (see Table A3 in Appendix 3 for details). In contrast, collaboration on a vertical basis along the supply chain has been rather acknowledged as an "optimization" strategy. A viable management of (reverse) network collaboration with other industries is essential to connect the different pieces for realizing a functional circular supply network.

4.4 | Technological

4.4.1 | Barriers

On the firms' internal level, interviewees noted that although product differentiation leads to competitive advantages for individual firms, the immense variety is perceived as a drawback for circularity due to immense variabilities. PUR material substitutes impede firms to engage in CE-innovation activities. Furthermore, issues in quality of recycled input can lead to performance issues for firms' production of (semi-)finished products.

On the intra-industrial level, PUR waste flows are primarily contaminated by biological content or by legacy chemicals, which impair their remanufacturing opportunities.[10] This also affects the difficult process of waste separation of PUR. Further, the vast majority of PUR waste still ends in landfills, leading to the destruction of immense value pools and the deterioration of eco-systems. In addition, recycling plants on industrial scale have not yet reached a "technically ready level." The PUR foam waste takes vast volumes, which causes processing and logistic issues. Yet, high-quality recycling requires high-quality input and thus current recycling is limited by iteration and primarily results in downcycling. Further, low qualities (e.g., color, hazardous substances) cause processability risks (see Table A4 in Appendix 4 for details).

4.4.2 | Drivers

On the inter-industrial level, drivers are an efficient waste flow management and an industry-overarching waste-management infrastructure ensuring pure waste flows including efficient collection systems and/or take-back systems across different industries. Most interviewees acknowledged collaborative technological innovation beyond immediate industry boundaries as vital precondition. This consists of collaborative innovation for (chemical) recycling but also thermal recovery options for residuals. Since PUR is embedded in other materials, product design for circularity needs to be addressed inter-/cross- industrial to enable the versatile supply chains for realizing circular material flows (see Table A4 in Appendix 4 for details).

5 | DISCUSSION

5.1 | Barriers and drivers that hinder or facilitate CE innovation

In response to the current knowledge gap on CE-innovation dynamics, we introduce a dynamic Schumpeterian perspective to the ordonomic three-level framework to conceptually discuss our findings on CE barriers and drivers stimulating CE innovation in the PUR industry. We propose to *endogenize technological innovation* since eventually technology depends on incentive properties. As already noted by Schumpeter ([1911] 2006),

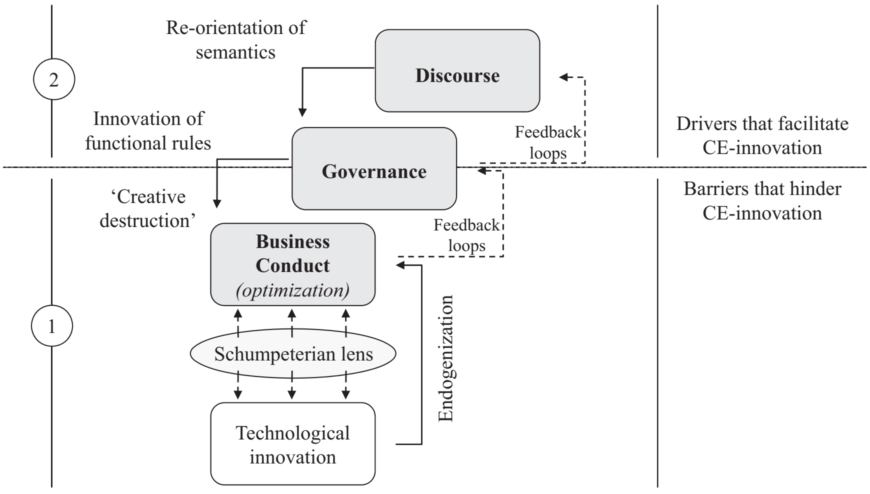

FIGURE 2 Technological endogenization in the three-level framework (inspired by Pies et al., 2010)

historically it has not been the case that technological inventions have led to the emergence of capitalism, but capitalism has led to the emergence of technological inventions and innovations. In fact, redirecting incentive properties by "coordination" can enable enhanced collaboration (and competition) structures that assist reframing the CE-innovation challenge from mere individual firms' "optimization" toward "governance innovation." As a result of this endogenization, we can utilize the ordonomic tree-level framework distinguishing between two major stages to systematically discuss our findings on (1) barriers and (2) drivers as illustrated in Figure 2—further elaborated on in Sections 5.1.1 and 5.1.2, respectively.

5.1.1 | Barriers

Major findings indicate that barriers hindering CE innovation are largely related to firms' internal and intra-industrial (external) levels, which was confirmed by recent studies (e.g., Hartley et al., 2021). However, our study moves beyond existing results from the literature and correlates these barriers to the business conduct (basic game) since firms still face linear incentive systems that lead them to choose their "best strategies" individually. This forces individual firms, however, to continue incremental innovation for "eco-efficiency" selecting discrete *moves within a given (linear) game*.

In the technological dimension, our findings validate recent CE studies on plastics by, for example, Kawashima et al. (2019), Paletta et al. (2019), or Siltaloppi and Jähi (2021) who discovered that technological limitations cause barriers in plastics industries, that is, waste flow contamination, complexity of products, and shortcomings in production processes. Although CE scholars found different significances of technological barriers ranging from relatively high (de Jesus & Mendonça, 2018) to relatively low (Kirchherr et al., 2018), our approach proposes to redirect attention toward the creation of appropriate incentive structures by endogenizing technological advancement and thus shifting the debate to enhanced coordination activities.

In the economic/market dimension, our findings indicate lock-in effects in current linear infrastructures, excessive upfront investment cost, high cost for production/selling of circular products, and an unsupportive market environment as barriers, which is in line with findings by, for example, Vermunt et al. (2019) and plastics-focused CE study results by, for example, Dijkstra et al. (2020). Nevertheless, our study advances on available knowledge through novel insights in revealing a "recycler matching problem" beyond what has been documented in the available literature on plastics barriers. In addition, the immense supply chain complexity and diversity, found in the specific PUR industry setting, is particularly highlighted as an enormous barrier.

In the institutional/regulatory dimension, large parts of the existing CE literature (e.g., Moreau et al., 2017; Stumpf et al., 2021; van Keulen & Kirchherr, 2021) and EI literature (e.g., Aldieri et al., 2021; Petruzzelli et al., 2011) highlighted public ordering that calls for political interference via laws and regulations *only* to shape the conditions for businesses. This insight substantiates in the plastics sector since, for example, Bening et al. (2021) and Paletta et al. (2019) predominantly emphasized the role of political decision-makers to shape institutional conditions for a transition to a CE perceiving firms as "passive rule-takers." However, our findings indicate that self-regulatory (private ordering) drawbacks also need to be considered in plastics industries as complementary institutional barrier to CE innovation, thus additionally appreciating firms as "active rule-makers."

In the social/cultural dimension, our findings suggest that consumer awareness and culture are certainly barriers to CE innovation as similarly highlighted by Kirchherr et al. (2018). However, our study moves beyond this generic insight and uncovers that those barriers are still related to the basic game since awareness and cultural determinants would not be (predominantly) decisive for CE innovation when functional rules already exist. Further, our study highlights that firms must consider and anticipate missing third parties' capabilities that can hinder CE innovation. Although very few studies mentioned the relevance of third parties (e.g., NGOs) for plastics industries (Gong et al., 2020) or for CE in general (Kalmykova et al., 2018), anticipation of positive and even negative characteristics as well as their active management has mostly been neglected.

5.1.2 | Drivers

Our study reveals that drivers facilitating CE innovation primarily emerged beyond immediate industry boundaries. Against this backdrop, "governance innovation" appears to be instrumental to reframe the innovation challenge from a problem of the firm's individual innovation capabilities to a problem of its external constraints. This view emphasizes "coordination" for collaborative innovation processes beyond individual firms and industry boundaries. Hence, our study moves beyond findings on the CE from Hartley et al. (2021) and on "environmental innovation" perspectives from, for example, Petruzzelli et al. (2011) by unearthing the importance of inter-/cross-industrial incentive structures to enable collaborative innovation within the PUR industry. Most notably, our findings highlight the exchange with adjacent industries (i.e., using same [secondary] raw materials, e.g., PET, PP, etc.).

In the economic/market dimension, our findings confirm CE plastics studies by, for example, Bening et al. (2021) and Dijkstra et al. (2020) and "environmental innovation" studies (e.g., Petruzzelli et al., 2011) that emphasized the relevance of inter-organizational relationships, but particularly stressed vertical coordination along the supply chain and third-party involvement. However, our findings move beyond what has been reported in these studies and reveal that such vertical (hierarchical) coordination rather follows an "optimization logic." Even more, our study shows that functional CE innovation demands horizontal "coordination" and thus requires a change in perspective from a customer-centric structure in current (institutionalized) industry settings toward increasingly paying attention to a procurement-centric structure (i.e., origin of secondary raw materials) to redirect competitive processes within an industry (e.g., direct competitors) but also with firms operating in adjacent industries (potential future competitors operating not in the same branch but in same [e.g., raw material] markets).

This insight also affects the institutional/regulatory dimension acknowledging current governance initiatives by, for example, trade associations (branch agreements, standards, etc.), which have been mentioned in few available CE studies (e.g., Dijkstra et al., 2020; Tura et al., 2019). Our study ascertains that a sole customer-centric view is only limitedly able to establish viable incentive structures for inter-/cross-industrial collaboration. We found that inter-/cross-industrial branch agreements, inter-/cross-industrial standardization, and inter-/cross-industrial labeling are key to create vital incentive structures (by private ordering) beyond immediate industry boundaries. While recent CE (e.g., Tura et al., 2019) and innovation studies (e.g., Aldieri et al., 2021; Petruzzelli et al., 2011) have largely implicated public ordering by governmental interference as a functional driver, we discovered that only a vital combination of (i) public ordering and (ii) private ordering considering (cross-)industry dependencies holds an immense potential to (re-)arrange incentive structures, which can then enable CE-oriented "creative destruction" of markets.

Relatedly, our findings stress the importance of creating and driving functional discourses. Yet, the CE literature largely lacks a nuanced perspective on positive and even negative characteristics of involved stakeholders that influence the functionality of (public, political, and business) discourses, which are necessary to reorient semantics for creating (novel) shared categories of thinking and change mental models aiming at a (re-)forming of functional institutional arrangements. Instead of addressing the mere "optimization paradigm" of focal firms within given constraints, our findings expose that social interaction proactively needs to be (horizontally) "coordinated" (and not solely optimized) beyond immediate industry boundaries. As a result, our study accentuates an important but underemphasized aspect in the literature that besides the emergence of innovative concepts, the CE particularly requires innovative actors (and stakeholders) (Table 4), thus responding to various CE–EI scholars who called for further research to the role of diverse stakeholders in CE-innovation processes (e.g., de Jesus et al., 2021; Kiefer et al., 2021; Prieto-Sandoval et al., 2018).

5.2 | Implications for literature, politics, and practice

The focus on "eco-efficiency" in the contemporary EI literature (see, e.g., Hazarika & Zhang, 2019a; He et al., 2018) has been conveyed in the CE–EI research (e.g., Cainelli et al., 2020; Demirel & Danisman, 2019; Scarpellini et al., 2020). As a case in point, some of the latter studies have predominantly discussed mere "optimization" concluding that "[t]he dynamics of CE-related innovation imply a slow techno-economic transformative process … more a 'reform' than a 'revolution'" (Cainelli et al., 2020, p. 10). However, our study advances existing knowledge by arguing to redirect attention to "governance innovation" for enabling "eco-effective" ("revolutionary") CE innovation. We revealed functional discourses as prerequisite including diverse (new) stakeholders. While studies by Durán-Romero et al. (2020) or by Jakhar et al. (2019) discuss major stakeholders in a generic manner, our study enriches their insights by identifying novel relevant stakeholders for CE–EI and particularly hints to stakeholders that operate beyond immediate industry boundaries.

Although the CE literature on barriers and drivers has revealed remarkable findings, future studies could increasingly benefit from cross-disciplinary research by applying theoretical concepts from literature streams that have a more detailed pronounced emphasis on fundamental theory. This becomes evident when evaluating recent studies on CE barriers (e.g., Dijkstra et al., 2020; Hartley et al., 2021) that contributed to

TABLE 4 (New) stakeholder constellations can drive CE innovation

Stakeholders	Current view: EI	View: CE innovation	CE-innovation driver
Suppliers	Intra-industrial	Intra-industrial and inter-/cross-industrial	Investigation beyond current procurement perspectives on cross-industry level (i.e., same raw materials)
Customers	Intra-industrial	Intra-industrial and Inter-/cross-industrial	Examination beyond current end-market structures to novel end-markets in a CE
NGOs	Inter-/cross-industrial	Inter-/cross-industrial	Consideration of NGOs positive contribution but also negative influence
Universities, research institutes	Inter-/cross-industrial	Inter-/cross-industrial	Exploration of collaboration options with researchers and scholars
Industry associations	Intra-industrial	Intra-industrial and inter-/cross-industrial	Refocus activities from current end-market perspective to future procurement perspective across industries
Subject matter experts	Internal, intra-industrial	Internal and intra-industrial and inter-/cross-industrial	Examination of internal, intra-industrial, and inter-/cross-industrial R&D
Competitors	Intra-industrial	Intra-industrial	Consideration of CE-oriented branch agreements (only) as first step
Potential (future) competitors	—	Inter-/cross-industrial	Investigation of inter-/cross-industrial industry agreements (future procurement perspective), standardizations, labeling

TABLE 5 Five derived strategic deliberations to facilitate CE innovation

#	Strategy
(i)	*Re-direct* attention from business-centric (eco-)innovation activities focusing on technological innovation and thus optimization toward governance innovation enabling coordination of collaborative approaches with multiple actors (even when at first glance there appeared to be no win–wins in the past)
(ii)	*Interpret* negative externalities not as "market failures" but as 'missing markets" or "missing exchanges" and thus as a business opportunity to "creatively destruct" existing market structures facilitating development of new markets for a CE
(iii)	*Create* a CE-enabling (innovation) environment by, that is, building strategic alliances with actors beyond immediate industry boundaries
(iv)	*Exhaust* opportunities for the collective introduction of viable inter-/cross-industrial (self-)commitments (private ordering)
(v)	*Participate in* and *(re-)direct* functional (public) discourses with multiple stakeholders to actively shape the prerequisites for vital public and private ordering. Anticipate positive and even negative characteristics of (all) involved actors

literature by, for example, deriving strategies to overcome identified CE barriers (solely) emphasizing "collaboration within the supply chain," which (un-)intentionally implies vertical (hierarchical) "optimization" and largely neglects horizontal "coordination." Adding and expanding on these studies, we revealed that a refocus on horizontal "coordination" beyond immediate industry boundaries is a prerequisite for successful CE innovation. In fact, even though the studies by, for example, Hartley et al. (2021) or Kirchherr et al. (2018) provide noteworthy insights into CE barriers, their understandings in form of a "chain reaction" and "salience of CE barriers" were merely based on interview data. Yet, such studies would further benefit by systematically applying a theoretical lens on their remarkable findings.[11]

Furthermore, the interconnected CE–EI literature stream as well as the political discourse could further benefit by moving away from the largely applied diametrical "dialectic between the state *vs* private actors" (Colombo et al., 2019, p. 653) since this terminology frequently ends in zero-sum thinking framing both as "rivals" instead of complementary partners. Our study suggests refocusing from stressing political interventions in EI (Hojnik & Ruzzier, 2016b) and CE (e.g., Paletta et al., 2019) to emphasize a detailed investigation of both as complements—private and public ordering.

Overall, we hope to contribute to the development of complementary approaches by deriving five vital strategic deliberations to facilitate systemic CE innovation for practitioners (Table 5). We expect that our approach can also be applied to other industries and geographies beyond PUR, and thus, this may pave the way for future studies and insights on how to advance toward functional CE innovation. We explicitly call for future research to constructively criticize our idea aiming to strengthen this contemporary field that in our view can create critical and significant momentum for enhanced sustainable development, eventually leading to a system-wide transformation as part of a resilient, inclusive, and sustainable economy.

5.3 | Limitations

Although our study provides novel insights, it is also subject to limitations. First, the presented findings are narrowly industry and geography specific. Therefore, we invite further empirical research to test our findings in other industries and wider geographical scopes. Second, our study revealed relevant economic and "non-economic" actors who play a crucial role to drive functional discourses. However, we call for future research to expand and deepen our findings and to critically investigate the role of NGOs, industry associations, universities, consultancies, etc., expanding beyond immediate industry boundaries. Third, our research is the basis for the examination of detailed institutional arrangements and governance. Thus, we suggest to further investigate governance mechanisms for inter-industrial collaboration. Finally, and while the knowledge on systemic EI for CE is still emerging, this field requires additional conceptual studies to successfully decouple economic growth and environmental benefits by considering possible CE-innovation rebound effects (e.g., Zink & Geyer, 2017) investigating the opportunities for their active management instead of solely promoting renunciation.

6 | CONCLUSION

The aim of this research was to deliver an identification of major CE barriers and drivers that hinder or facilitate CE innovation in the European PUR industry. This study found that CE innovation will challenge conventional innovation knowledge indicating the necessity to redirect attention from individual firm and intra-industrial levels to the functional coordination beyond immediate industrial boundaries (inter-/cross-industrial). One of the major contributions is the argumentation that mere "optimization" is limitedly able to enhance CE innovation, whereas "governance innovation" for vertical and particularly horizontal coordination can promote CE-innovation activities more efficiently. Thus, this study highlighted vital implications to enrich future research for functional CE–EI. In addition, five strategic deliberations were derived to facilitate systemic CE-innovation activities with the aim to support managers in redirecting innovation activities from "eco-efficiency" toward "eco-effectiveness" for easing and underpinning the transition to a functional CE, eventually resulting in more sustainable and resilient economic systems.

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DATA AVAILABILITY STATEMENT

Data available on request due to privacy/ethical restrictions—The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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NOTES

[1] In EI research, the terms "*environmental innovation*," "*green innovation*," "*sustainable innovation*," and "*eco-innovation*," have been used interchangeably (e.g., Bitencourt et al., 2020; de Jesus et al., 2021; Díaz-García et al., 2015; Karakaya et al., 2014). Whereas we generally appreciate a differentiation between these concepts, we subsume "*environmental innovation*," "*green innovation*," and "*sustainable innovation*" under the umbrella concept of "*eco-innovation*" *(EI)* due to the interrelatedness of these concepts in the literature and the research aim of this study.

[2] To the best of the authors' knowledge, there exists no previous study that provides specific insights on CE barriers and drivers stimulating innovation for this particular industry.

[3] This article does not address the discussion in academia whether the intention for ''eco'' in EI is decisive or not (see, e.g., del Río et al., 2016).

[4] Although the theoretical backgrounds of EI studies on determinants differ significantly (e.g., general innovation theory, resource-based view, institutional theory, stakeholder theory, and so on), the identified (categories of) determinants are very similar in the literature (Hojnik & Ruzzier, 2016b).

[5] This insight also corroborates in the closely related literature stream on sustainable (including green, environmental) supply chain management as indicated by Chen et al. (2017) noting that in the literature "horizontal collaboration with competitors and others … were rarely studied" (Chen et al., 2017, p. 77). As highlighted by Schultz and Everding (2022) and Schultz (2021), functional circular supply chain management requires to move beyond vertical structures.

[6] Exceptions to this statement are Hartley et al. (2021) and Kirchherr et al. (2018) who have reproduced a "chain reaction" of CE barriers primarily based on interview statements.

[7] Researchers applying GABEK recommended "executing about 20 oral interviews … more oral interviews do not provide a surplus value in gaining additional knowledge" (Raich, 2008, p. 27).

[8] GABEK-WinRelan has proven functional in various research settings and literature streams, for example, business model research in the retail industry (food, textile, and furniture) (Haas, 2019); organization and management research in the financial service industry (Raich et al., 2014); service management research in the medical equipment industry (Paluch, 2014); tourism management research in hospitality industry (Sharma et al., 2012); human resources management in European crisis managers (Haus et al., 2016).

[9] Terminologies: (i) gestalten (similar to Corley & Gioia's (2004) notion of first-order concepts); (ii) hyper-gestalten (similar to Corley & Gioia's (2004) notion of second-order themes; (iii) hyper-hyper-gestalten (similar to Corley & Gioia's (2004) notion of aggregated dimensions).

[10] As noted by most interviewees, slowing strategies (repair, reuse, remanufacture) are of limited value to properly solve the PUR waste issue. This is in line with academic literature and practice-oriented studies on PURs mentioned in Section 3.1 of this study.

[11] As already stated by Karl Popper in 1934: "observation is always *observation in the light of theories*" (Popper ([1934] 2002, p. 37, emphasis in original) further underlined by Milton Friedman in 1959: "A theory is the way we perceive 'facts', and we cannot perceive 'facts' without a theory" (Friedman [1959] 2008, p. 166).

REFERENCES

Agyemang, M., Kusi-Sarpong, S., Khan, S. A., Mani, V., Rehman, S. T., & Kusi-Sarpong, H. (2019). Drivers and barriers to circular economy implementation: An explorative study in Pakistan's automobile industry. *Management Decision*, *57*(4), 971–994.

Akindoyo, J. O., Beg, M. D. H., Ghazali, S., Islam, M. R., Jeyaratnam, N., & Yuvaraj, A. R. (2016). Polyurethane types, synthesis and applications – A review. *Royal Society of Chemistry Advances*, *6*, 114453–114482.

Aldieri, L., Brahmi, M., Chen, J., & Vinci, C. P. (2021). Knowledge spillovers and technical efficiency for cleaner production: An economic analysis from agriculture innovation. *Journal of Cleaner Production*, *320*, 128830. https://doi.org/10.1016/j.jclepro.2021.128830

Andries, P., & Stephan, U. (2019). Environmental innovation and firm performance: How firm size and motives matter. *Sustainability*, *11*(13), 3585. https://doi.org/10.3390/su11133585

Araújo, R., & Franco, M. (2021). The use of collaboration networks in search of eco-innovation: A systematic literature review. *Journal of Cleaner Production*, *314*, 127975.

Ariño, A., LeBaron, C., & Milliken, F. J. (2016). Publishing qualitative research in academy of management discoveries. *Academy of Management Discoveries*, *2*(2), 109–113.

Beckmann, M., Hielscher, S., & Pies, I. (2014). Commitment strategies for sustainability: How business firms can transform trade-offs into win-win outcomes. *Business Strategy and the Environment*, *23*(1), 18–37.

Bening, C. R., Pruess, J. T., & Blum, N. U. (2021). Towards a circular plastics economy: Interacting barriers and contested solutions for flexible packaging recycling. *Journal of Cleaner Production*, *302*, 126966.

Berry, J. M. (2002). Validity and reliability issues in elite interviewing. *PS Political Science and Politics*, *35*(4), 679–682.

Bitencourt, C. C., de Oliveira Santini, F., Zanandrea, G., Froehlich, C., & Ladeira, W. J. (2020). Empirical generalizations in eco-innovation: A meta-analytic approach. *Journal of Cleaner Production*, *245*, 118721.

Bossle, M. B., de Barcellos, M. D., Vieira, L. M., & Sauvée, L. (2016). The drivers for adoption of eco-innovation. *Journal of Cleaner Production*, *113*, 861–872.

Brice, A. (2019). PU players target circular economies. *Urethanes Technology International*, *36*, 26–29.

Bruel, A., Kronenberg, J., Troussier, N., & Guillaume, B. (2019). Linking industrial ecology and ecological economics: A theoretical and empirical foundation for the circular economy. *Journal of Industrial Ecology*, *23*(1), 12–21.

Cai, W. G., & Zhou, X. L. (2014). On the drivers of eco-innovation: Empirical evidence from China. *Journal of Cleaner Production*, *79*, 239–248.

Cainelli, G., D'Amato, A., & Mazzanti, M. (2020). Resource efficient eco-innovations for a circular economy: Evidence from EU firms. *Research Policy*, *49*, 103827.

Cainelli, G., Mazzanti, M., & Montresor, S. (2012). Environmental innovations, local networks and internationalization. *Industry and Innovation*, *19*(8), 697–734.

Carrillo-Hermosilla, J., Del Río, P., & Könnölä, T. (2010). Diversity of eco-innovations: Reflections from selected case studies. *Journal of Cleaner Production*, *18*, 1073–1083. https://doi.org/10.1016/j.jclepro.2010.02.014

Chen, L., Zhao, X., Tang, O., Price, L., Zhang, S., & Zhu, W. (2017). Supply chain collaboration for sustainability: A literature review and future research agenda. *International Journal of Production Economics*, *194*, 73–87.

Colombo, L. A., Pansera, M., & Owen, R. (2019). The discourse of eco-innovation in the European Union: An analysis of the eco-innovation action plan and horizon 2020. *Journal of Cleaner Production*, *214*, 653–665. https://doi.org/10.1016/j.jclepro.2018.12.150

Confente, I., Scarpi, D., & Russo, I. (2020). Marketing a new generation of bio-plastics products for a circular economy: The role of green self-identity, self-congruity, and perceived value. *Journal of Business Research*, *112*, 431–439.

Corley, K. G., & Gioia, D. A. (2004). Identity ambiguity and change in the wake of a corporate spin-off. *Administrative Science Quarterly*, *49*, 173–208.

Crosina, E., & Pratt, M. G. (2019). Toward a model of organizational mourning: The case of former Lehman Brothers bankers. *Academy of Management Journal*, *62*(1), 66–98.

De Giorgi, C., Dal Palu, D., & Allione, C. (2015). Development and results of a cross border network project, aimed at the engineering of eco-compatible products. *Journal of Cleaner Production*, *106*, 619–631.

De Jesus, A., & Mendonça, S. (2018). Lost in transition? Drivers and barriers in the eco innovation road to the circular economy. *Ecological Economics*, *145*, 75–89. http://www.sciencedirect.com/science/article/pii/S0921800916316597

De Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2018). Eco-innovation in the transition to a circular economy: An analytical literature review. *Journal of Cleaner Production*, *172*, 2999–3018.

De Jesus, A., Antunes, P., Santos, R., & Mendonça, S. (2019). Eco-innovation pathways to a circular economy: Envisioning priorities through a Delphi approach. *Journal of Cleaner Production*, *228*, 1494–1513.

De Jesus, A., Lammi, M., Domenech, T., Vanhuyse, F., & Mendonça, S. (2021). Eco-innovation diversity in a circular economy: Towards circular innovation studies. *Sustainability*, *13*, 10974.

De Marchi, V., & Grandinetti, R. (2013). Knowledge strategies for environmental innovations: The case of Italian manufacturing firms. *Journal of Knowledge Management*, *17*(4), 569–582.

Del Rio Gonzalez, P. (2005). Analyzing the factors influencing clean technology adoption: A study of the Spanish pulp and paper industry. *Business Strategy and the Environment*, *14*, 20–37.

Del Río, P., Peñasco, C., & Romero-Jordán, D. (2016). What drives eco-innovators? A critical review of the empirical literature based on econometric methods. *Journal of Cleaner Production*, *112*, 2158–2170. https://doi.org/10.1016/j.jclepro.2015.09.009

Demirel, P., & Danisman, G. O. (2019). Eco-innovation and firm growth in the circular economy: Evidence from European small- and medium-sized enterprises. *Business Strategy and the Environment*, *28*, 1608–1618.

Denzau, A. T., & North, D. C. (1994). Shared mental models: Ideologies and institutions. *Kyklos*, *47*, 3–31. https://doi.org/10.1111/j.1467-6435.1994.tb02246.x

Dijkstra, H., van Beukering, P., & Brouwer, R. (2020). Business models and sustainable plastic management: A systematic review of the literature. *Journal of Cleaner Production*, *258*, 1–14.

Dong, L., Fujita, T., Dai, M., Geng, Y., Ren, J., Fujii, M., Wang, Y., & Ohnishi, S. (2016). Towards preventative eco-industrial development: An industrial and urban symbiosis case in one typical industrial city in China. *Journal of Cleaner Production*, *114*, 387–400.

Durán-Romero, G., López, A. M., Beliaeva, T., Ferasso, M., Garonne, C., & Jones, P. (2020). Bridging the gap between circular economy and climate change mitigation policies through eco-innovations and Quintuple Helix Model. *Technological Forecasting and Social Change*, *160*, 1–13.

Díaz-García, C., González-Moreno, A., & Sáez-Martínez, F. (2015). Eco-innovation: Insights from a literature review. *Innovation Management Policy and Practice*, *17*, 6–23.

Eriksen, M. K., Damgaard, A., Boldrin, A., & Astrup, T. F. (2019). Quality assessment and circularity potential of recovery systems for household plastic waste. *Journal of Industrial Ecology*, *23*(1), 156–168.

Esposito, M., Tse, T., & Soufani, K. (2015). Is the circular economy a new fast-expanding market? *Thunderbird International Business Review*, *49*(5), 630–631.

Filho, W. L, Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M., & Voronova, V. (2019). An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. *Journal of Cleaner Production*, *214*, 550–558.

Filho, W. L., Salvia, A. L., Bonoli, A., Saari, U. A., Voronova, V., Kloga, M., Kumbhar, S. S., Olszewski, K., De Quevedo, D. M., & Barbir, J. (2021). An assessment of attitudes towards plastics and bioplastics in Europe. *Science of the Total Environment*, *755*, 142732.

Friedman, M. ([1959] 2008). The methodology of positive economics. In Hausman, D. M. (Ed.), *The philosophy of economics: An anthology* (pp. 145–178, 3rd ed.). Cambridge University Press.

Fussler, C., & James, P. (1996). *Driving eco innovation: A breakthrough discipline for innovation and sustainability*. Pitman Publishing.

García-Quevedo, J., Jové-Llopis, E., & Martínez-Ros, E. (2020). Barriers to the circular economy in European small and medium-sized firms. *Business Strategy and the Environment*, *29*(6), 2450–2464. https://doi.org/10.1002/bse.2513

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving 'leapfrog development'. *International Journal of Sustainable Development & World Ecology*, *15*(3), 231–239.

Geng, Y., Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. *Journal of Cleaner Production*, *23*, 216–224.

Geng, Y., Liu, Z., Xue, B., Dong, H., Fujita, T., & Chiu, A. (2014). Emergy-based assessment on industrial symbiosis: A case of Shenyang Economic and Technological Development Zone. *Environmental Science and Pollution Research*, *21*, 13572–13587.

Geng, Y., Xinbei, W., Qinghua, Z., & Hengxin, Z. (2010). Regional initiatives on promoting cleaner production in China: A case of Liaoning. *Journal of Cleaner Production*, *18*, 1502–1508.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32.

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the Gioia methodology. *Organizational Research Methods*, *16*(1), 15–31.

Gong, Y., Putnam, E., You, W., & Zhao, C. (2020). Investigation into circular economy of plastics: The case of the UK fast moving consumer goods industry. *Journal of Cleaner Production*, *244*, 118941.

González-Moreno, A., Sáez-Martínez, F. J., & Díaz-García, C. (2013). Drivers of eco innovation in the chemical industry. *Environmental Engineering and Management Journal*, *12*(10), 2001–2008.

Grafström, J., & Aasma, S. (2021). Breaking circular economy barriers. *Journal of Cleaner Production*, *292*, 126002.

Guldmann, E., & Huulgaard, R. D. (2020). Barriers to circular business model innovation: A multiple-case study. *Journal of Cleaner Production*, *243*, 118160.

Gumley, W. (2014). An analysis of regulatory strategies for recycling and re-use of metals in Australia. *Resources*, *3*, 395–415.

Haas, Y. (2019). Developing a generic retail business model – A qualitative comparative study. *International Journal of Retail & Distribution Management*, *47*(10), 1029–1056.

Handcock, M. S., & Gile, K. J. (2011). Comment: On the concept of snowball sampling. *Sociological Methodology*, *41*(1), 367–371.

Hansen, E. G., & Revellio, F. (2020). Circular value creation architectures: Make, ally, buy, or laissez-faire. *Journal of Industrial Ecology*, *24*(6), 1250–1273. https://doi.org/10.1111/jiec.13016

Hartley, K., Roosendaal, J., & Kirchherr, J. (2021). Barriers to the circular economy: The case of the Dutch technical and interior textiles industries. *Journal of Industrial Ecology*, *26*, 477–490.

Haus, M., Adler, C., Hagl, M., Maragkos, M., & Duschek, S. (2016). Stress and stress management in European crisis managers. *International Journal of Emergency Services*, *5*(1), 66–81.

Hazarika, N., & Zhang, X. (2019a). Evolving theories of eco-innovation: A systematic review. *Sustainable Production and Consumption*, *19*, 64–78.

Hazarika, N., & Zhang, X. (2019b). Factors that drive and sustain eco-innovation in the construction industry: The case of Hong Kong. *Journal of Cleaner Production*, *238*, 117816.

He, F., Miao, X., Wong, C. W. Y., & Lee, S. (2018). Contemporary corporate eco-innovation research: A systematic review. *Journal of Cleaner Production*, *174*, 502–526.

Herrmann, C., Rhein, S., & Sträter, K. F. (2022). Consumers' sustainability-related perception of and willingness-to-pay for food packaging alternatives. *Resources, Conservation and Recycling*, *181*, 106219.

Hielscher, S., & Will, M. (2014). Mental models of sustainability: Unearthing and analyzing the mental images of corporate sustainability with qualitative empirical research. *Systems Research and Behavioral Science*, *31*, 708–719.

Hojnik, J., & Ruzzier, M. (2016a). The driving forces of process eco-innovation and its impact on performance: Insights from Slovenia. *Journal of Cleaner Production*, *133*, 812–825.

Hojnik, J., & Ruzzier, M. (2016b). What drives eco-innovation? A review of an emerging literature. *Environmental Innovation and Societal Transitions*, *19*, 31–41.

Horbach, J. (2008). Determinants of environmental innovation—New evidence from German panel data sources. *Research Policy*, *37*, 163–73.

Horbach, J. (2016). Empirical determinants of eco-innovation in European countries using the community innovation survey. *Environmental Innovation and Societal Transitions*, *19*, 1–14.

Horbach, J., Rammer, C., & Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull. *Ecological Economics*, *78*, 112–22.

Ilić, M., & Nikolić, M. (2016). Drivers for development of circular economy - A case study of Serbia. *Habitat International*, *56*, 191–200.

Jakhar, S. K., Mangla, S. K., Luthra, S., & Kusi-Sarpong, S. (2019). When stakeholder pressure drives the circular economy. *Management Decision*, *57*(4), 904–920.

Kalmykova, Y., Sadagopan, M., & Rosado, L. (2018). Circular economy – From review of theories and practices to development of implementation tools. *Resources, Conservation and Recycling*, *135*, 190–201.

Karakaya, E., Hidalgo, A., & Nuur, C. (2014). Diffusion of eco-innovations: A review. *Renewable and Sustainable Energy Reviews*, *33*, 392–399.

Kawashima, N., Yagi, T., & Kojima, K. (2019). How do bioplastics and fossil-based plastics play in a circular economy? *Macromolecular Materials and Engineering*, *304*(9), 1–14.

Kesidou, E., & Demirel, P. (2012). On the drivers of eco-innovations: Empirical evidence from the UK. *Research Policy*, *41*(5), 862–870.

Kiefer, C. P., Del Río, P., & Carrillo-Hermosilla, J. (2019). Drivers and barriers of eco-innovation types for sustainable transitions: A quantitative perspective. *Business Strategy and the Environment*, *28*, 155–172.

Kiefer, C. P., Del Río, P., & Carrillo-Hermosilla, J. (2021). On the contribution of eco innovation features to a circular economy. A micro-level quantitative approach. *Business Strategy and the Environment*, *30*, 1531–1547.

Kinnunen, P. H. M., & Kaksonen, A. H. (2019). Towards circular economy in mining: Opportunities and bottlenecks for tailings valorization. *Journal of Cleaner Production*, *228*, 153–160.

Kirchherr, J., & van Santen, R. (2019). Research on the circular economy: A critique of the field. *Resources, Conservation and Recycling*, *151*, 104480.

Kirchherr, J., Piscicelli, L., Bour, R., Kostende-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the circular economy: Evidence from the European Union (EU). *Ecological Economics*, *150*, 264–272.

Kumar, V., Sezersan, I., Garza-Reyes, J. A., Gonzalez, E. D. R. S., & AL-Shboul, M. A. (2019). Circular economy in the manufacturing sector: Benefits, opportunities and barriers. *Management Decision*, *57*(4), 1067–1086.

Kurańska, M., Leszczyńska, M., Malewska, E., Prociak, A., & Ryszkowska, J. (2020). Implementation of circular economy principles in the synthesis of polyurethane foams. *Polymers*, *12*(9), 2068.

Larrain, M., Van Passel, S., Thomassen, G., Kresovic, U., Alderweireldt, N., Moerman, E., & Billen, P. (2020). Economic performance of pyrolysis of mixed plastic waste: Open loop versus closed-loop recycling. *Journal of Cleaner Production*, *270*, 122442.

Liao, Z. (2018). Institutional pressure, knowledge acquisition and a firm's environmental innovation. *Business Strategy and the Environment*, *27*(7), 849–857.

Lieder, M., & Rashid, A. (2016). Towards circular economy implementation: A comprehensive review in context of manufacturing industry. *Journal of Cleaner Production*, *115*, 36–51.

Linder, M., & Williander, M. (2017). Circular business model innovation: Inherent uncertainties. *Business Strategy and the Environment*, *26*(2), 182–196.

Liu, Y., & Bai, Y. (2014). An exploration of firms' awareness and behavior of developing circular economy: An empirical research in China. *Resources Conservation and Recycling*, *87*, 145–152.

Mahpour, A. (2018). Prioritizing barriers to adopt circular economy in construction and demolition waste management. *Resources, Conservations and Recycling*, *134*, 216–227.

Marin, G., Marzucchi, A., & Zoboli, R. (2015). SMEs and barriers to eco-innovation in the EU: Exploring different firm profiles. *Journal of Evolutionary Economics*, *25*(3), 671–705.

Masi, D., Kumar, V., Garza-Reyes, J. A., & Godsell, J. (2018). Towards a more circular economy: Exploring the awareness, practices, and barriers from a focal firm perspective. *Production Planning & Control*, *29*(6), 539–550.

Mathews, J. A., & Tan, H. (2011). Progress toward a circular economy in China. *Journal of Industrial Ecology*, *15*(3), 435–457.

Milios, L., Christensen, L. H., McKinnon, D., Christensen, C., Rasch, M. K., & Eriksen, M. H. (2018). Plastic recycling in the Nordics: A value chain market analysis. *Waste Management*, *76*, 180–189.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81–97.

Mont, O., Plepys, A., Whalen, K., & Nußholz, J. L. K. (2017). *Business model innovation for a circular economy: Drivers and barriers for the Swedish industry – The voice of REES companies*. Lund University. https://portal.research.lu.se/portal/en/publications/business-model-innovationfor-a-circular-economy(833402ef-b4d4-4541-a10e-34d1e89d2146).html

Moreau, V., Sahakian, M., van Griethuysen, P., & Vuille, F. (2017). Coming full circle: Why social and institutional dimensions matter for the circular economy. *Journal of Industrial Ecology*, *21*(3), 497–506.

Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: An interdisciplinary exploration of the concept and application in a global context. *Journal of Business Ethics*, *140*(3), 369–380.

Müller, J., Abfalter, D., Hautz, J., & Raich, M. (2011). Differences in corporate environmentalism: A comparative analysis of country and industry differences in leading US and German companies. *European Journal of International Management*, *5*, 122–148.

North, D. C. (1990). Institutions, institutional change, and economic performance. Cambridge University Press.

OECD/Eurostat. (2005). *Oslo manual guidelines for collecting and interpreting innovation, the measurement of scientific and technological activities*. OECD Publishing.

Paletta, A., Filho, W. L., Balogun, A. L., Foschi, E., & Bonoli, A. (2019). Barriers and challenges to plastics valorization in the context of a circular economy: Case studies from Italy. *Journal of Cleaner Production*, *241*, 118149.

Paluch, S. (2014). Customer expectations of remote maintenance services in the medical equipment industry. *Journal of Service Management*, *25*(5), 639–653.

Pereira, Á., & Vence, X. (2012). Key business factors for eco-innovation: An overview of recent firm-level empirical studies. *Cuadernos De Gestión*, *12*, 73–103.

Petruzzelli, A., Dangelico, R. M., Rotolo, D., & Albino, V. (2011). Organizational factors and technological features in the development of green innovations: Evidence from patent analysis. *Innovation: Management Policy & Practice*, *13*, 291–310.

Pies, I. (2016). The ordonomic approach to order ethics. In Luetge, C. & Mukerji, N. (Eds.), *Order ethics: An ethical framework for the social market economy* (pp. 19–35). Springer.

Pies, I., Beckmann, M., & Hielscher, S. (2010). Value creation, management competencies, and global corporate citizenship: An ordonomic approach to business ethics in the age of globalization. *Journal of Business Ethics*, *94*, 265–278.

Pies, I., Beckmann, M., & Hielscher, S. (2014). The political role of the business firm: An ordonomic concept of corporate citizenship developed in comparison with the aristotelian idea of individual citizenship. *Business & Society*, *53*(2), 226–259.

Pies, I., Hielscher, S., & Beckmann, M. (2009). Moral commitments and the societal role of business: An ordonomic approach to corporate citizenship. *Business Ethics Quarterly*, *19*(3), 375–401.

Pies, I., Hielscher, S., & Everding, S. (2020). Do hybrids impede sustainability? How semantic reorientations and governance reforms can produce and preserve sustainability in sharing business models. *Journal of Business Research*, *115*, 174–185.

Pies, I., Schreck, P., & Homann, K. (2019). Single-objective versus multi-objective theories of the firm: Using a constitutional perspective to resolve an old debate. *Review of Managerial Science*, *15*, 779–811. https://doi.org/10.1007/s11846-019-00376-x

PlasticsEurope. (2020). *Plastics - The facts 2020*. https://www.plasticseurope.org/de/resources/publications/4312-plastics-facts-2020

Popper, K. R. ([1934] 2002). *The logic of scientific discovery, translation of Logik der Forschung*. Routledge.

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). *Circular economy: Measuring innovation in the product chain*. PBL – Netherlands Environmental Assessment Agency. https://www.pbl.nl/sites/default/files/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf

Prieto-Sandoval, V., Jaca, C., & Ormazabal, M. (2018). Towards a consensus on the circular economy. *Journal of Cleaner Production*, *179*, 605–615.

PUReSmart. (2020). *PURESMART progress after 18 months*. https://www.puresmart.eu/puresmart-progress-after-18-months/#_ftn2

Raich, M. (2008). Basic values and objectives regarding money: Implications for the management of customer relationships. *International Journal of Bank Marketing*, *26*(1), 25–41.

Raich, M., Müller, J., & Abfalter, D. (2014). Hybrid analysis of textual data: Grounding managerial decisions on intertwined qualitative and quantitative analysis. *Management Decision*, *52*(4), 737–754.

Rennings, K. (1998). *Towards a theory and policy of eco-innovation – Neoclassical and (co-)evolutionary perspectives*. ZEW.

Rennings, K. (2000). Redefining innovation e eco-innovation research and the contribution from ecological economics. *Ecological Economics*, *32*(2), 319–332.

Rhein, S., & Sträter, K. F. (2021). Corporate self-commitments to mitigate the global plastic crisis: Recycling rather than reduction and reuse. *Journal of Cleaner Production*, *296*, 126571.

Rizos, V., Behrens, A., van der Gaast, W., Hofman, E., Ioannou, A., Kafyeke, T., Flamos, A., Rinaldi, R., Papadelis, S., Hirschnitz-Garbers, M., & Topi, C. (2016). Implementation of circular economy business models by small and medium sized enterprises (SMEs): Barriers and enablers. *Sustainability*, *8*(11), 1212.

Saldaña, J. (2016). *The coding manual for qualitative researchers*. Sage.

Sanyé-Mengual, E., Pérez-López, P., González-García, S., Lozano, R. G., Feijoo, G., Moreira, M. T., Gabarrell, X., & Rieradevall, J. (2014). Eco-designing the use phase of products in sustainable manufacturing. *Journal of Industrial Ecology*, *18*(4), 545–557.

Scarpellini, S., Valero-Gil, J., Moneva, J. M., & Andreaus, M. (2020). Environmental management capabilities for a "circular eco-innovation. *Business Strategy and the Environment*, *29*, 1850–1864.

Schmid, M. (2020). Challenges to the European automotive industry in securing critical raw materials for electric mobility: The case of rare earths. *Mineralogical Magazine*, *84*(1), 5–17. https://doi.org/10.1180/mgm.2020.9

Schultz, F. C. (2021). Governance as a "game changer" for the circular economy: A commentary on circular supply chain governance. *Academy of Strategic Management Journal*, *20*, 1–3.

Schultz, F. C., & Everding, S. (2022). The governance of circular plastics supply chain collaboration. In P. Ghadimi, M. D. Gilchrist, & M. Xu (Eds.), *Role of circular economy in resource sustainability. Sustainable production, life cycle engineering and management*. Springer.

Schultz, F. C., Everding, S., & Pies, I. (2021). Circular supply chain governance: A qualitative-empirical study of the European polyurethane industry to facilitate functional circular supply chain management. *Journal of Cleaner Production*, *317*, 128445.

Schumpeter, J. A. (1934). *The theory of economic development: An inquiry into profits, capital, credit, interest, and the business cycle*. Transaction Publishers.

Schumpeter, J. A. (1942). *Capitalism, socialism, and democracy*. Harper.

Schumpeter, J. A. ([1911] 2006). *Theorie der wirtschaftlichen Entwicklung. Nachdruck der ersten Auflage von 1912 [eigentlich 1911], herausgegeben und ergänzt um eine Einleitung von Jochen Röpke und Olaf Stiller*. Duncker & Humblot.

Shahbazi, S., Wiktorsson, M., Kurdve, M., Jönsson, C., & Bjelkemyr, M. (2016). Material efficiency in manufacturing: Swedish evidence on potential, barriers and strategies. *Journal of Cleaner Production*, *127*, 438–450.

Sharma, A., Pechlaner, H., & Volgger, M. (2012). How to promote cooperation in the hospitality industry., *International Journal of Contemporary Hospitality Management*, *24*(6), 925–945.

Siltaloppi, J., & Jähi, M. (2021). Toward a sustainable plastics value chain: Core conundrums and emerging solution mechanisms for a systemic transition. *Journal of Cleaner Production*, *315*, 128113.

Simón, D., Borreguero, A. M., de Lucas, A., & Rodríguez, J. F. (2018). *Waste Management*, *76*, 147–171.

Singh, J., & Ordoñez, I. (2016). Resource recovery from post-consumer waste: Important lessons for the upcoming circular economy. *Journal of Cleaner Production*, *134*, 342–353.

Singh, P., & Giacosa, E. (2019). Cognitive biases of consumers as barriers in transition towards circular economy. *Management Decision*, *57*(4), 921–936.

Strike, V. M., & Rerup, C. (2016). Mediated sensemaking. *Academy of Management Journal*, *59*(3), 880–905.

Stumpf, L., Schöggl, J. P., & Baumgartner, R. J. (2021). Climbing up the circularity ladder? – A mixed-methods analysis of circular economy in business practice. *Journal of Cleaner Production*, *316*, 128158, https://doi.org/10.1016/j.jclepro.2021.128158

Su, B., Hesmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215–227.

Triguero, A., Moreno-Mondéjar, L., & Davia, M. A. (2013). Drivers of different types of eco-innovation in European SMEs. *Ecological Economics*, *92*, 25–33.

Tura, N., Hanski, J., Ahola, T., Ståhle, M., Piiparinen, S., & Valkokari, P. (2019). Unlocking circular business: A framework of barriers and drivers. *Journal of Cleaner Production*, *212*, 90–98.

Ugarte, L., Calvo-Correas, T., Gonzalez-Gurrutxaga, I., Peña-Rodriguez, C., Etxeberria, O., Corcuera, M. A., & Eceiza, A. (2018). Towards circular economy: Different strategies for polyurethane waste recycling and the obtaining of new products. *Proceedings*, *2*(23), 1490.

Van Keulen, M., & Kirchherr, J. (2021). The implementation of the circular economy: Barriers and enablers in the coffee value chain. *Journal of Cleaner Production*, *281*, 125033.

Velis, C. A., & Vrancken, K. C. (2015). Which material ownership and responsibility in a circular economy? *Waste Management and Research*, *33*(9), 773–774.

Vence, X., & Pereira, A. (2019). Eco-innovation and circular business models as drivers for a circular economy. *Contaduría Y Administración*, *64*(1), 1–19.

Vermunt, D. A., Negro, S. O., Verweij, P. A., Kuppens, D. V., & Hekkert, M. P. (2019). Exploring barriers to implementing different circular business models. *Journal of Cleaner Production*, *222*, 891–902.

Williamson, O. E. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature*, *38*(3), 595–613.

Williamson, O. E. (2002). The theory of the firm as governance structure: From choice to contract. *Journal of Economic Perspectives*, *16*, 171–195.

Witjes, S., & Lozano, R. (2016). Towards a more circular economy: Proposing a framework linking sustainable public procurement and sustainable business models. *Resources, Conservation and Recycling*, *112*, 37–44.

Xavier, A. F., Naveiro, R. M., Aoussat, A., & Reyes, T. (2017). Systematic literature review of eco-innovation models: Opportunities and recommendations for future research. *Journal of Cleaner Production*, *149*, 1278–1302.

Xue, B., Chen, X. P., Geng, Y., Guo, X. J., Lu, C. P., Zhang, Z. L., & Lu, C. Y. (2010). Survey of officials' awareness on circular economy development in China: Based on municipal and county level. *Resources, Conservation and Recycling*, *54*(12), 1296–1302.

Yu, C., de Jong, M., & Dijkema, G. P. J. (2014). Process analysis of eco-industrial park development – The case of Tianjin. *China. Journal of Cleaner Production*, *64*, 464–477.

Yu, F., Han, F., & Cui, Z. (2015). Evolution of industrial symbiosis in an eco-industrial park in China. *Journal of Cleaner Production*, *87*, 339–347.

Zelger, J. (1991). A holistic method of mastering complexity. In H. E. Klein (Ed.), *Managing change with cases, simulations, games and other interactive methods* (pp. 255–267).World Association for Case Method Research and Application.

Zelger, J. (2000). Twelve steps of GABEKWinRelan: A procedure for qualitative opinion research, knowledge organization and systems development. In R. Buber & J. Zelger (Eds), *GABEK II. Zur qualitativen Forschung - On qualitative research* (pp. 205–220). Studien-Verlag.

Zelger, J. (2019). *Erforschung und Entwicklung von Communities: Handbuch zur qualitativen Textanalyse und Wissensorganisation mit GABEK®*. Springer Fachmedien.

Zhu, Q., Geng, Y., Sarkis, J., & Lai, K. H. (2011). Evaluating green supply chain management among Chinese manufacturers from the ecological modernization perspective. *Transportation Research Part E: Logistics and Transportation Review*, *47*(6), 808–821.

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, *21*(3), 593–602.

Zubeltzu-Jaka, E., Erauskin-Tolosa, A., & Heras-Saizarbitoria, I. (2018). Shedding light on the determinants of eco-innovation: A meta-analytic study. *Business Strategy and the Environment*, *27*(7), 1093–1103.

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APPENDIX 1

TABLE A1 Social/Cultural barriers and drivers - interview statements

	Internal	Intra-industrial external	Inter-industrial external
Social/cultural barriers	**Functional interaction in companies** **Avoidance of uncertainty and risk** If you talk to a producing company, there is always a little bit the thought of 'Danger!'- recyclates are a risk .... *(CEO, Waste Management & Recycler)* **Reactionary business culture** "Currently, I do see only word of mouth but no real action". *(CEO, PUR Consultancy)*	**Functional interaction between companies** **Silo-Thinking** "[I]t would be beneficial, if we could share a common language on this topic [CE] to find a consensus … I have got the feeling, everyone is 'backing own bread' and we cannot afford to act like this in plastic industries." *(CEO, PUR Manufacturer)* "I am so much PUR oriented in my daily business, although our firm is operating in other plastic segments as well … the exchange is very low." *(Senior Manager, Distributor)* **Customer (B2B) and consumer (B2C) conduct** **Customers' acceptance of recycled materials** "If we talk about post-consumer PUR, we have a huge problem with acceptance in the market. … In my opinion, the acceptance is markedly low." *(CEO, Waste Management & Recycler)* **Inappropriate consumer behavior** "I think a lot of the issues with circularity is also peoples' behavior." *(Senior Manager, Chemical Company)* "[T]he reason why there is plastic in the ocean is not the industry has put the packaging waste in the ocean, it is because people didn't put it in the bin and that is very important. It is rather an issue at the society level, it is not only a raw material producers' responsibility. It is a society which is not educating the people to use materials wisely." *(Senior Manager, Chemical Company)* **Lack of consumer knowledge** "Frequently, end-consumers do not know what [PUR-]materials the products [they buy] contain." *(former Senior Manager, Chemical Company)*	**Lack of third parties' capabilities** **Own agenda** "There are many different [organizations] focusing on circular economy … But they actually follow their own agenda as well." *(Senior Manager, Consultancy)* "NGOs are very important, they initiate very much, but they can partly become an obstacle, if they rely too much on their own perseverance and assertiveness [subjective opinion]." *(Secretary General)* all plastics are bad per se. Plastics chemically recycled or properly recovered aren't bad, but fine. *(Managing Director, Consultancy)* "[Y]ou cannot underestimate the role of NGOs. In my opinion, they are very positive. Even if sometimes the development goes into a wrong direction like for plastics in Europe." *(CEO, Waste Management & Recycler)*

(Continues)

TABLE A1 (Continued)

	Internal	Intra-industrial external	Inter-industrial external
Social/cultural drivers			**Transparent communication with (current and potential) customer (B2B) and consumer (B2C) beyond industry boundaries** **(Open) communication to customer / consumer** "[Use of circular materials] is not something right now that we communicate so openly. We are communicating in forums, which as mentioned [are] more about driving change in the industry. Because we are still piloting certain projects, it becomes a bit more difficult for us to communicate very openly from a customer perspective. *(Senior Manager, End-Application Producer & Retailer)* "We appreciate the communication with customers, which is exhausting and time consuming. But we experience that customer increasingly order." *(CEO, PUR Manufacturer)* **Transparency costumer/consumer** "[P]articularly at the present time, it is very important to provide enlightenment to consumers and counter sciolism." *(CEO, PUR Manufacturer)* **Consumer education** "[P]eople think 'it's only one piece and it doesn't matter' … so, whatever we do in Europe, it will probably not affect the littering of the ocean and it's only by educating the consumers across the globe that we will be able to reduce it." *(Senior Manager, Chemical Company)* "[We] should be able to recognize there is value in [plastics] and .... should educate the consumer to use it wisely" *(Senior Manager, Chemical Company)* **Companies' interdisciplinary exchange in open loops** **System approach** "[O]pen-loops [are] much smarter because I can leverage opportunities, which have not previously existed." *(CEO, PUR Consultancy)* **Interdisciplinary expert teams** "For the CE … you have to bring together different experts, which have never been worked together in the past, because at first glance there was no win-win." *(CEO, PUR Consultancy)* **Feedback loops** "[P]roduct innovation .... need innovation in waste management, in the circularity at all … and currently a viable feedback mechanism is missing." *(Manager, Waste Management & Recycler)***Third parties' influence** **Creating public awareness and driving discourse** "[T]here have been taken a lot of measures to cope with the flood of plastics in short period … If the public and NGOs would use the same power to push recycling, this topic would make great progress within the shortest time." *(CEO, Waste Management & Recycler)* "I think NGOs should be there to educate the people to use packaging wisely, but they should not actually go for plastic packaging 'is bad', no! We need plastic packaging for society." *(Senior Manager, Chemical Company)* **Stakeholder cooperation** "NGOs which bring these topics into the debate need to exist. They should focus … on collaboration and should show solutions for the problems." *(Senior Manager, Consultancy)* "NGOs and associations can help to provide collective commitment services and coordination functions." *(Senior Manager, Research Institute)* **Channel power/instrumentalization of third parties** "[T]hose kinds of organization, they have bigger influence on people than the government" *(Manager, Chemical Company)* "I perceive the NGOs as an instrument to change public opinion and create awareness. But this can move also in a wrong direction." *(former Senior Manager, Chemical Company)* "You ought to have 'instrumentalize' [some organizations], but this is an art." *(CEO, Waste Management & Recycler)*

APPENDIX 2

TABLE A2 Institutional/Regulatory barriers and drivers - interview statements

	Internal	Intra-industrial external	Inter-industrial external
Institutional/regulatory barriers		**Lack in EU regulation** **Lack of industry and CE know-how** "Sometimes, politicians have no clue … [Authorities] have to ensure that some practices are prevented. How you get there, this should be left to the industry, because they research, and they are dealing with these topics day-by-day and they know what is technologically feasible." *(CEO, PUR Manufacturer)* **One-size-fits-all** Our materials are part of different streams, which have/or not already have dedicated obligations … It is not that we can directing all of the things … You cannot have a one-fit-all solution. *(Senior Manager, Chemical Company)* **Complexity and overlap EU and national** "[Y]ou have now a debate which will come up again. Also, in the part of the green deal for the chemical regulation, because you have chemical regulations, you have product regulations, and you have waste regulations. And of course, that should be somehow aligned in the end." *(Senior Manager, Chemical Company)* **Lack in national regulation** **Different national regulations** "[T]he waste definitions are different within Europe already. In France, the waste is allowed to be freely transported and so on, it might be different in Germany and there are still barriers to waste movement. And this of course needs to be resolved, because today, raw materials are freely shipped across Europe, but waste is different." *(Senior Manager, Chemical Company)* "Productions by-products are easy to export but post-consumer materials are labelled as waste and therefore difficult to export." *(Secretary General)* **Lack of governmental action** "[If the industry] gets a clear law, e.g., waste legislation, first of all this is an obligation. If this law will be implemented [by companies] and audited is another issue." *(CEO, Waste Management & Recycler)* **Self-regulation drawbacks** **Green washing** "I think, we need to partly distance from the topic of self-regulation, because it has always a touch of pure greenwashing." *(Manager, Waste Management & Recycler)* **Property rights issues** "In the initial period of CE, chemical companies [at the very beginning of the supply chains] are likely to create entrance barriers [to markets] by using property rights." *(Senior Manager, Distributor)* **Self-interests** "For example, the yellow bin [in Germany]: From today's perspective, is it really something beneficial for the environment or is it only a pseudo-sign for some firms, some people, who are making themselves rich? It's a legitimate question. Such a disaster should not occur in a CE." *(CEO, PUR Consultancy)*	

(Continues)

TABLE A2 (Continued)

	Internal	Intra-industrial external	Inter-industrial external
Institutional/regulatory drivers			**Multilateral EU regulation** **Multilateral stakeholder approach** "[T]he crucial point is that the industries need to be motivated. It means, they need guidelines [laws], because they are incentivized to increase their sales and to satisfy customer demands, but not to move toward a CE by themselves. This is still far away in companies' foci." *(CEO, Waste Management & Recycler)* "[W]ith the circular economy, obviously we see new stakeholders become relevant." *(Senior Manager, Chemical Company)* **Harmonization of regulation (waste, chemicals)** "It would be better to have a better clarification between the boundaries of chemical legislation and waste legislation." (Secretary General) "[I]n the CE, we will have to find a way to harmonize how waste is being treated as a secondary raw material [beyond borders and boundaries]." *(Senior Manager, Chemical Company)* **Extended producer responsibility schemes** "Recycling companies need financial support, and this is ensured by EPR." *(Secretary General)* **Functional national regulation** **Functional institutions** "[W]e need functional national institutions." *(CEO, Waste Management & Recycler)* **Recycling quota** „[It] is driven by legislation [...] to significantly increase our recycling-quota over the next few years. *(Vice President, Chemical Company)* **Tax and subsidies (and funds)** "Currently, there is no price for negative externalities [...] it is the duty of the government to intervene at this issue." *(Managing Director, Consultancy)* "Without a (cross-)subsidization, CE will not work, because no company is currently covering the whole circle. The burden needs to be shared." *(CEO, PUR Consultancy)* **Incentivization by self-regulation** **Combination of regulation and self-regulation** "[S]elf-commitment and governmental regulation, they are a good combination, both of them together." *(Manager, Chemical Company)* **Inter-branch agreements** "[T]here are already some branch agreements or projects ... that are picking-up this topic [but they need to be enhanced]." *(Vice President, Chemical Company)* **Inter-standardization** "In the [various] supply chains, it is necessary to find an agreement or standard of testing recyclates and batches. [...] We need an agreement in the supply chains that balances safety and economic feasibility of recycling." *(Secretary General)* **Inter-labeling** "If industry associations establish [common] labels for CE, it can work from my point of view." *(former Senior Manager, Chemical Company)*

APPENDIX 3

TABLE A3 Economic/Market barriers and drivers - interview statements

	Internal	Intra-industrial external	Inter-industrial external
Economic/market barriers	**Change for individual market players** **Additional cost** "Finally, each change cause cost. Always, change processes are expensive. You have to change your assets, you have to invest, you have to send out the sales-team, etc." *(CEO, PUR-Manufacturer)* **High upfront investments** "If I have already (ailing) depreciated assets, I am more likely to change toward CE compared to someone who invested five years ago and needs to proceed with the current assets. This is a difference in state of diverse companies. It can be a tricky road-blocker." *(Managing Director, Consultancy)* **Business model cannibalization** "The problem is: a firm that wants to change from traditional [linear] to CE would cannibalize its current core-business. The question is: which incentive they may have for doing this?" *(former Senior Manager, Chemical Company)* **Business case and profitability** "It is at the end absolutely necessary that it is also a case of profitability to achieve a full circular economy … Is it then also a proper business case in terms of making profits? This needs still to be assessed." *(Secretary General)* **Loss of reputation** "[If] businesses becoming green. That has magnificently impact for chemical, gas or plastic industries. They always worry about their reputation." *(Senior Manager, Consultancy)*	**Unsupportive market environment** **Price competition recycled materials and oil** "[C]urrently, the situation is difficult due to the very low oil price. Because in the plastics recycling business … we compete with the crude oil price." *(Manager, Waste Management & Recycling)* **Price competition recycling and thermal recovery** "[T]hermal recovery is 'so cheap' … waste finds its way towards the minimum price." *(Manager, Waste Management & Recycling)* "[I]t is not an unsolvable technical issue, but an economic one, because collection and separation is extremely expensive." *(CEO, PUR Consultancy)* **Market saturation/demand** "The market for recyclates is diminishing." *(Secretary General)* "[Producers] prefer production scrap, because they get a better quality and the drawbacks like odor and color are not playing any role." *(CEO, Waste Management & Recycler)* **High level of information asymmetries** "There exists a high level of information asymmetries ...." *(Senior Manager, Distributor)* **Market power and share in commodity markets** "I do not expect that we can generate additional markets, but we will lose existing markets. […] There will be a cannibalization of the PUR business, if the PUR industry does not provide a reasonable solution." *(CEO, PUR Consultancy)* "The question is: what market shares would they lose? Because maybe the used recycled materials will become worse in quality or the price increases." *(former Senior Manager, Chemical Company)* **(Global) waste exports** "[F]inally, it is wrong to promote [global] waste tourism. Especially, in Germany we do not have own resources and receive our resources from abroad, so we should reuse these resources and find solutions." *(CEO, PUR Manufacturer)* **Transition period from linear to circular** "[I]f you push innovative concepts, this will cost more during the transition period, compared to well-established linear systems. This is a fact." *(Manager, Waste Management & Recycler)* **Established linear value chain mechanism** **Waste-flow volumes/economies of scale** "You have different materials, so either you find a solution to the mix but then the value is probably lower, or you manage to separate the different materials that have different properties that you can bring value from. … So, you do not achieve as quickly as you may think the economies of scale … You have smaller stream of good quality and therefore of good value, but they are smaller, and they are much more difficult to handle." *(Senior Manager, Chemical Company)* **Waste-flow (reverse) logistics** "A crucial problem, particularly for mattresses, is the issue of an efficient reverse logistics … this is an important topic." *(CEO, PUR Consultancy)* **Recycling matching problem** "Especially for mechanical recycling, there exists a matching issue between recycler and plastics-manufacturer [....] the re-granulate needs to match with virgin-granulates to produce a viable mixture." (Manager, Waste Management & Recycler) **Value chain complexity and diversity** "One challenge for the PUR industry is also linked to the huge number of applications with different value chains and the different lengths of the value chains." *(Secretary General)* **Material sourcing from reliable/enough suppliers** "We must re-look at how we source materials." *(Senior Manager, End-Application Producer & Retailer)*	

(Continues)

TABLE A3 (Continued)

	Internal	Intra-industrial external	Inter-industrial external
Economic/market drivers	**Functional strategy** **Circular economy strategy** "[Successful companies] have a very clearly defined circular economy strategy." *(Manager, Chemical Company)* **Circular business model innovation** "[W]e must rethink our whole business model. We must relook at how we source materials; we need to look at how we produce products, how we move products everywhere, etc." *(Senior Manager, End-Application Producer & Retailer)* **Market and negotiation power** "[F]rom a large-scale retailer perspective, [CE] is something that we have taken as part of our responsibility to do, to contribute back to the environment. And we can do that, because we are a large company, and we've always seen this as a very important direction." *(Senior Manager, End-Application Producer & Retailer)*		**Cooperation and coordination in (circular) value chain** **Collaboration vertical** "[S]ome chemical players are working along the supply chain with their customers and build different research consortia. Each one of them is approaching chemical recycling from different angles. … So, they approach circularity from different angles." *(Secretary General)* **Collaboration horizontal** "If you want to improve [CE], [various firms] need to come together, [like] shoe manufacturer, mattress manufacturer, and waste management companies." (Senior Manager, Waste Management Company) "Actually, there already exist horizontal collaboration. Different producers of PUR expanding-foam-cans in Germany have unified 25 years ago … to jointly organize a take-back and recycling system for these cans." *(CEO, Waste Management & Recycler)* **Management of (reverse) networks** "[Our] partnerships are working very well, because everybody has their own specialist function. There is a company who is a specialist in waste collection, they're already doing that. And then there's a company that's a specialist in disassembly. So, when you bring these pieces together, you can then optimize the final supply chain." *(Senior Manager, End-Application Producer & Retailer*

APPENDIX 4

TABLE A4 Technological barriers and drivers - interview statements

	Internal	Intra-industrial external	Inter-industrial external
Technological barriers	**Complexity of products and production (semi-finished and finished)** **Product specifications** "[W]e have a plenty of applications but even within an application, … there is not only one type of material. … They may have the same name; they may still be polyurethane but technically and mechanically these are not the same materials." *(Senior Manager, Chemical Company)* **Product differentiation** "We are in an industry where companies are struggling with creating an individual advantage to customers. .... [It needs to become clear] that they can create customer value by closing loops, which then differentiates their products." *(Managing Director, Consultancy)* **Product substitutes** "[A] lot of companies are looking for substitutes. Consider one application and then use another application which can substitute it. All that becomes barriers for a circular economy." *(Senior Manager, Consultancy)* **Product performance loss** "You get post-consumer waste; you like to remanufacture somehow .... the quality of this [input material] is different and cannot be used in a similar product due to performance losses". *(Vice President, Chemical Company)*	**Waste flow contamination** **Waste-flow contamination** "There are two issues, which are not impossible to overcome but where people need to pay attention to: first, biological contamination (e.g. sweating in mattresses - bacteria, microorganism), so it is not possible to reuse such products. … [A]n issue is also the fear of using recyclates, because companies fear issues of e.g. biological contamination which is not the issue with virgin materials." *(Secretary General)* **Issue of waste-flow separation** "[Mostly PUR products are] composite materials .... and it is extremely difficult to separate single parts to finally get PUR in a relative pure form". *(Manager, Waste Management & Recycler)* **Landfill of waste** "[T]he longer we can obviously use some materials, the longer we can use our natural resources like oil … this is also something which is of value for us. This factor of limitedness of the natural goods. But I would say that this is something what people see less. What people see more now is the foam, which is landfilled." *(Manager, Chemical Company)* **Issues in recycling and recycled materials** **Recycling on industrial scale** "[R]egarding chemical recycling … the biggest challenge is that all technologies are not yet stable on industrial scale. .... There are smaller pilot-plants and they work … but the move to an industrial scale is still missing." *(Manager, Waste Management & Recycler)* **Recycling of high PUR volumes** "[PUR] is a lot of waste which is growing and growing, especially if we talk about the PUR foam. Foam takes volume. So, 100 kilos of slabstock foam take a huge volume." *(Manager, Chemical Company)* **Recycling legacy chemicals** "PUR materials, produced 20 years ago, contain substances that are critical from today's perspective, like flame retardants, which cannot be easily recycled yet." *(Vice President, Chemical Company)* **Recycling input specifications** "Similarly, for mechanical and chemical recycling, you have high requirements for the input material, especially if you like to produce high-quality output. … [I]t holds the rule of thumb 'trash in, trash out'." *(Manager, Waste Management & Recycler)* **Mechanical recycling iteration** "[W]hen you use mechanical recycling, you will reach a moment at which the materials are not good enough anymore due to the poorer quality … You can recycle it once, twice, but at some point, it is not possible to recycle it anymore." *(Secretary General)* **Recycled material quality**"„[I]f you get different recipe-mixes from different producers, and you like to produce a recyclate out of it, automatically you do not get a defined substance, but a mix out of 17 recipes. In the aftermath, this mixture is not suitable to produce chemically clean components." *(CEO, Waste Management & Recycler)* **Recycled material processability** "There are huge technical challenges regarding processability to adapt continuous processes towards recycled materials." *(Senior Manager, PUR Research Institute)*	

(Continues)

TABLE A4 (Continued)

	Internal	Intra-industrial external	Inter-industrial external
Technological drivers			**Waste flow management and reverse logistics** **Waste-flow purity** "[T]echnology-wise, elements are there to be able to find a useful second life to materials. We need clean waste. This is very important, because PUR is rarely used as a PUR piece, it is always embedded in other products in various industries." *(Senior Manager, Chemical Company)* **Take-back systems** "[O]f course, obviously, it's the collecting point that enables us to recycle in the end of the day." *(Senior Manager, End-Application Producer & Retailer)* **Waste-collection systems** "[S]ome countries are very advanced in this area and other countries have little or no [waste-collection-] system .... I think there's an incorrect idea amongst some companies that we can be collectors. *(Senior Manager, End-Application Producer & Retailer)*" **Collaborative innovation for recycling and recycled materials** **Research and Development/innovation chemical recycling** "[F]or chemical recycling it's a relatively new technology … R&D processes need to be developed to be able to run smoothly." *(Manager, End-Application Producer & Retailer)* "The chemical industry always has been innovative … it is not to push for innovation, it is more to provide the context, the environment, the legal frame that enables innovation." *(Secretary General)* **Collaborative innovation for chemical recycling** "It is good that the companies from different steps in [different] supply chains have set up research consortia and eventually joint ventures to deal with [innovation for chemical recycling and thus a CE]." *(Secretary General)* **Thermal recovery for residuals** "Alternatively, thermal recovery should be considered as option (due to cost-benefit)" *(Senior Manager, PUR Research Institute)* **Innovation of circular products and production (semi-finished and finished)** **Product design for circular** "PUR is often embedded in another article, so you need to do a kind of separation and dismantling. I have seen already initiatives in various countries in Europe on an end-article-level, of e.g. retailers. They do design for recycling [circular], so that the product can be more easily separated or dismantled." *(Senior Manager, Chemical Company)* **Know-how, capabilities, resources chemical firms** "[K]nowledge is somehow captured along the supply chain. … [I]t is the chemical producer that know how to make chemicals." *(Secretary General)* **Development of renewable energies** "A very important driver, which has not been profoundly described in literature concerns (cost of) renewable energies." (*Managing Director, Consultancy*)